Parks & Recreation Commission

REGULAR MEETING AGENDA

Date: 1/25/2017
Time: 6:30 p.m.
Arrillaga Family Recreation Center
Cypress Room
700 Alma St., Menlo Park, CA 94025

A. Call To Order

B. Roll Call

C. Public Comment

Under "Public Comment," the public may address the Commission on any subject not listed on the agenda. Each speaker may address the Commission once under Public Comment for a limit of three minutes. Please clearly state your name and address or political jurisdiction in which you live. The Commission cannot act on items not listed on the agenda and, therefore, the Commission cannot respond to non-agenda issues brought up under Public Comment other than to provide general information.

D. Presentations and Proclamations

D1. Update on the Community Service Department Childcare Programs

E. Regular Business

E1. Accept Commission minutes for meeting on December 21, 2016 (attachment)

E2. Review and discuss City Community Funding Process and allocations for FY 2016-17 (attachment)

E3. Review and discuss City Council work plan and goal setting (Staff Report # 17-001-PRC)

F. Reports and Announcements

F1. Commissioner Report (Jennifer Baskin and Marianne Palefsky)

F2. Community Services Director's update and announcements (Staff Report # 17-002-PRC)

G. Informational Items

G1. Commissioner Attendance Report and Proposed Policy Revision (attachment)

G2. Update on Jack Lyle Restroom project (Staff Report # 17-003-PRC)

G3. Federal Research Action Plan on Recycled Tire Crumb Rubber on Playing Fields Update (attachment)

H. Adjournment

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At every Regular Meeting of the Commission, in addition to the Public Comment period where the public shall have the right to address the Commission on any matters of public interest not listed on the agenda, members of the public have the right to directly address the Commission on any item listed on the agenda at a time designated by the Chair, either before or during the Commission’s consideration of the item.

At every Special Meeting of the Commission, members of the public have the right to directly address the Commission on any item listed on the agenda at a time designated by the Chair, either before or during consideration of the item.

Any writing that is distributed to a majority of the Commission by any person in connection with an agenda item is a public record (subject to any exemption under the Public Records Act) and is available for inspection at the City Clerk’s Office, 701 Laurel St., Menlo Park, CA 94025 during regular business hours.

Persons with disabilities, who require auxiliary aids or services in attending or participating in Commission meetings, may call the City Clerk’s Office at 650-330-6620.

REGULAR MEETING MINUTES - DRAFT

Date: 12/21/2016
Time: 6:30 p.m.
Arrillaga Family Recreation Center
700 Alma St., Menlo Park, CA 94025

A. Vice Chair Stanwood called the meeting to order at 6:34 p.m.

B. Roll Call

Present: Vice Chair Stanwood, Commissioner Baskin, Commissioner Johnson, Commissioner Lane (arrived at 6:43 p.m.) and Commissioner Palefsky
Absent: Chair Harris
Staff: Derek Schweigart, Assistant Community Services Director

C. Public Comment

There was no Public Comment

D. Presentations and Proclamations

D1. Update on Community Special Events

Matt Milde, Recreation Coordinator, gave the Commission an update on the Community Special Events. He mentioned all the events the City organizes throughout the year, how successful each event is and their attendance.

E. Regular Business

E1. Accept Commission minutes for meetings of October 26, 2016 and November 16, 2016 (Attachment) (Attachment)

ACTION: Motion and Second (Palefsky/Baskin) to accept the Parks and Recreation Commission meeting minutes of October 26, 2016; passes 5-0-2 (Chair Harris absent, one Commission vacancy).

ACTION: Motion and Second (Palefsky/Johnson) to accept the Parks and Recreation Commission meeting minutes of November 16, 2016 with changes to the Public Comment of Harry Ackley; passes 5-0-2 (Chair Harris absent, one Commission vacancy).

E2. Review proposal by the Menlo Park Little League for Burgess Park field improvements and provide general direction to staff (Staff Report # 16-027-PRC)

Todd Zeo, Recreation Supervisor, gave the Commission a review of the proposal by the Menlo Park Little League (MALL) for field improvements at Burgess Park. Todd asked the Commission for feedback on the various aspects of the project including the dugout resurfacing; tarp covers, shade structures and batting cage. After discussion, the following action was taken:

ACTION: Motion and Second (Johnson/Lane) to accept phase 1 of the proposal by the Menlo Atherton Little League and bring phase 2 back to the Commission at a later meeting once there is more information; passes 5-0-2 (Chair Harris absent, one Commission Vacancy)

E3. Selection of commissioner to serve on Bedwell-Bayfront Park Master Plan consultant selection committee

ACTION: Motion and Second (Stanwood/Lane) to nominate Commissioner Palefsky to serve on the consultant selection committee for the Bedwell-Bayfront Park Master Plan; Commissioner Palefsky accepted the nomination; passes 5-0-2 (Chair Harris absent, one Commission vacancy).

F. Reports and Announcements

F1. Commissioner Report (Tucker Stanwood)

Vice Chair Stanwood gave a report on the State of the City. He mentioned the highlights of the speech, the construction projects that will be happening in 2017 and the major issues the City has in front of it.

Commissioner Johnson gave a report on the meeting she attended regarding the CIP project at Jack Lyle Park. She mentioned the highlights and comments from the meeting regarding the restrooms being built at the Jack Lyle Park.

F2. Community Services Director's update and announcements (Staff Report # 16-028-PRC)

Derek Schweigart gave the Commission the Community Services Director's update and announcements.

G. Informational Items

G1. Update on Parks Capital Improvement Projects (Staff Report # 16-029-PRC)

Derek Schweigart gave the Commission an update on the Parks Capital Improvement Projects.

J. Adjournment

The Parks and Recreation Commission Meeting adjourned at 8:44 p.m.

Minutes prepared by Linda Munguia, Senior Office Assistant

STAFF REPORT

City Council
Meeting Date: **12/6/2016**
Staff Report Number: **16-202-CC**

Consent Calendar: **Adopt a resolution approving the City Council Subcommittee recommendations regarding the 2016-17 Community Funding allocation**

Recommendation

The Council Community Funding Subcommittee recommends that the City Council adopt a resolution (Attachment A) approving the proposed 2016-17 Community Funding allocation in the amount of $202,140 and allocate an additional $27,140 to the Community Programs budget to cover the additional grants awarded.

Policy Issues

The Subcommittee's recommendation is consistent with the Council's current Community Funding Program Policy, and well within the allowance for allocation up to 1.7 percent of property tax revenue (roughly $275,000).

Subcommittee Members Mueller and Carlton both made known their affiliations with some of the applicant organizations as a part of the decision process, including Council Member Mueller serving on the board of InnVision(Lifemoves). Council Member Carlton serves on the Vista Center Board. Council members did not participate in decisions related to organizations they are affiliated with.

Background

The City of Menlo Park adopted a formal policy by which to allocate General Fund dollars to community organizations in 1996 (see "Community Funding Program Guidelines" Attachment B) to respond to community needs and leverage City funds in response to the human service needs of Menlo Park residents.

The policy guidelines stipulate that eligible programs must address a verified community need and have a significant Menlo Park client base. Priority service areas include emergency assistance for those who are homeless or low-income; assistance to the disabled; help for seniors to be independent; senior daycare support; youth services including recreational and summer academic support; crisis and family counseling; and substance abuse prevention. Applicants must maintain accounting records with an independent audit at least once every two years.

Each fiscal year, according to the policy, no more than 1.7 percent of General Fund property tax revenue may be allocated to the Community Funding Program. This ceiling would amount to slightly under $275,000 for the 2016-17 fiscal year. The General Fund budget for 2016-17 includes $175,000 for eligible community programs selected for funding, consistent with the amount awarded last year. In addition, the City has previously funded several non-profit housing programs each year that are now included in the community funding program budget.

Analysis

Council Members Mueller and Carlton were appointed as the Community Funding Subcommittee for fiscal year 2016-17 in December, 2015. The Subcommittee is charged with evaluating the funding requests and making recommendations to the full Council as to the allocation of the funds budgeted for the community funding program. This year, the City provided notice of the grant program to agencies that received funding in prior years as well as additional organizations referred by Council members and staff. Twenty agencies responded with requests totaling $330,940. Several new agencies submitted applications this year, as well as organizations that did not apply last year. The applicant agencies provide services such as counseling, crisis intervention, employment assistance, shelter, hospice services, community health, risk reduction education, youth and senior services.

The Subcommittee reviewed the weighted criteria established to assess the applications against factors such as: verified program results; impact on the Menlo Park community; percentage of total budget spent on administrative overhead; receipt of City funding in previous years; community need for the program; unduplicated service or, if duplicated, evidence of collaboration; and alignment with Council goals. Assessment criteria are included with the application packet each year in order to support more complete applications.

All agencies that applied for funding this year were allocated at least $1000 except three: My New Red Shoes was determined not to meet the Council Policy's funding targets; Adolescent Counseling Services was determined to be a duplicate request; and the Subcommittee felt that San Mateo County had adequate funding from other sources. The largest grants, for $37,440, were to Star Vista for youth counseling services at Menlo Atherton High School and to $25,000 to Peninsula Conflict Resolution Center for a youth restorative justice and leadership program in partnership with the Boys and Girls Club of the Peninsula.

In total, the Subcommittee is recommending $202,140 in funding awards for this year, given the outstanding needs in the community and the City's strong financial picture. The table below outlines funding allocations approved by Council in FY 2015-16, requests for fiscal year 2016-17, and the Subcommittee recommendation.

Item	2015-16 Allocation	2016-17 Request	2016-17 Subcommittee recommended
Adolescent Counseling Services	$0	$20,000	$0
Boys and Girls Club of the Peninsula	$16,500	$30,000	$20,000
Comm. Overcoming Relationship Abuse	$5,000	$5,000	$5,000
Center for Independence	$0	$25,000	$5,000
HIP Housing	$17,500	$17,500	$17,500
Inn Vision Shelter Network/Lifemoves	$17,500	$20,000	$17,500
Legal Aid San Mateo County	$3,500	$5,000	$5,000
Junior League of the Peninsula	$0	$15,000	$6,000

My New Red Shoes	$0	$2,500	$0
Nuestra Casa	$4,000	$6,000	$4,000
Ombudsman Services of San Mateo Co.	$750	$2,500	$1,200
Pathways Home Health / Hospice	$0	$10,000	$7,500
Peninsula Conflict Resolution Center	$25,000	$55,000	$25,000
Peninsula Volunteers, Inc	$18,000	$40,000	$22,000
Ravenswood Education Foundation	$9,000	$10,000	$10,000
San Mateo County Human Services	$0	$5,000	$0
Service League of San Mateo County	$3,000	$3,000	$3,000
Star Vista	$30,000	$37,440	$37,440
Vista Center for the Blind	$8,000	$10,000	$8,000
Youth Community Service	$7,000	$12,000	$8,000
Total	**$164,750**	**$330,940**	**$202,140**

Additional information about each organization's application is available in the Community Services Department.

Impact on City Resources

The FY 2016-17 adopted budget includes an appropriation of $175,000. Staff suggests the additional $27,140 be allocated from anticipated additional property tax revenues.

Environmental Review

The Community Funding Program is not subject to California Environmental Quality Act requirements.

Public Notice

Public Notification was achieved by posting the agenda, with the agenda items being listed, at least 72 hours prior to the meeting.

Attachments

A. Resolution
B. Council Policy on Community Funding

Report prepared by:
Cherise Brandell, Community Services Director

RESOLUTION NO. _____

RESOLUTION OF THE CITY COUNCIL OF THE CITY OF MENLO PARK APPROVING THE COUNCIL SUBCOMMITTEE RECOMMENDATIONS REGARDING ALLOCATION OF 2016-17 COMMUNITY FUNDING

The City of Menlo Park, acting by and through its City Council, having considered and been fully advised in the matter and good cause appearing therefore.

BE IT AND IT IS HEREBY RESOLVED by the City Council of the City of Menlo Park that the City Council does hereby approve the City Council Subcommittee recommendations regarding the allocation of 2016-17 community funding in the amount of $202,140, as more particularly set forth in the Staff Report presented to the City Council on December 6, 2016.

I, Pam Aguilar, City Clerk of the City of Menlo Park, do hereby certify that the foregoing resolution was approved at a regular meeting of the City Council held on the sixth day of December, 2016, and adopted by the following votes:

AYES:

NOES:

ABSENT:

ABSTAIN:

IN WITNESS WHEREOF, I have hereunto set my hand and affixed the Official Seal of said City on this sixth day of December, 2016.

____
Pam Aguilar, CMC
City Clerk

City of Menlo Park	COUNCIL POLICY	
Department **Finance** **Subject** **Community Funding Program Guidelines**	**Page 1 of 2** **Approved by:** **City Council On June 4, 1996**	**Effective Date: June 4, 1996** **Procedure #** **FIN-01-1996**

PURPOSE

To provide guidelines for the award of monetary support to local non-profit agencies whose programs respond to the human service needs of Menlo Park residents. This funding is not intended for use as the sole support of any agency. All recipients of financial assistance grants enter into a contractual agreement with the City detailing the specific objectives to be accomplished as a result of the grant.

POLICY

1. GOALS AND PHILOSOPHY

The City of Menlo Park recognizes that:

1.1 the availability of basic human service programs is a key determining factor in the overall quality of life of Menlo Park residents;

1.2 the most cost-effective and efficient manner to insure that these services are available to local residents is through the development of agreements with existing non-profit agencies;

1.3 contractual agreements with non-profit agencies allow the City to influence the human service programs offered to Menlo Park residents; and

1.4 financial assistance grants demonstrate the City's support of the activities of specific non-profits and make it possible for these agencies to leverage additional funds which will benefit local residents.

2. ELIGIBILITY

2.1 All applicants must be formally incorporated non-profit entities and must be tax exempt (under Section 501(c)(3) of the IRS Code, and Section 2370(d) of the California Revenue and Taxation Code).

2.2 All applicants must be agencies based in Menlo Park or agencies which provide services throughout the County of San Mateo who can demonstrate a significant Menlo Park client base.

2.3 All applications must provide a service that is not a duplication of an existing public sector program, OR if the service is duplicated, the applicant must show why it is not an unnecessary duplication of service.

2.4 All applicants shall maintain accounting records which are in accordance with generally accepted accounting practices. The agency must have an independent audit performed at least once every two years.

2.5 The agency must have bylaws which define the organization's purposes and functions, its organization and the duties, authority and responsibilities of its governing body and officers.

2.6 Governance of the agency should be vested in a responsible and active board which meets at least quarterly and establishes and enforces policies. The board should be large enough and so structured to be representative of the community it serves. It should have a specific written plan for rotation or other arrangements to provide for new members.

2.7 The agency must provide for adequate administration of the program to insure delivery of the services. The agency must provide that it has a written job description for each staff position and an organizational chart approved by the board. One individual should be designated as the full time director of the agency.

2.8 No less than 85% of City funds granted must be used for direct services as opposed to administrative costs.

2.9 City grants can represent no more that 20% of an applicant's total operating budget.

2.10 All recipients agree to actively participate in City efforts to coordinate and to improve human services within the City.

2.11 The program described must respond to a verified community need as defined by the City Council:

DISABLED emphasizes support of programs that will allow the disabled to actively participate in their community and maintain independence from institutional support.

EMERGENCY ASSISTANCE AND LOW INCOME SUPPORT emphasizes support of programs that can meet emergency needs for people in crisis such as victims of homelessness, rape, and domestic violence and the basic needs such as food, etc., for low income residents.

SENIORS emphasizes support of programs which serve predominantly low income, frail and minority seniors; and those programs which make it possible for seniors to continue to be independent and active community participants.

YOUTH emphasizes support of delinquency prevention services including recreation; crisis and family counseling; substance abuse prevention; child care and acculturation of ethnic minorities.

PROCEDURE

Any agency requesting financial assistance must complete the required application and submit it to the Finance Department. The City Council subcommittee is responsible for reviewing all proposals and submitting recommendations for funding to the City Council.

FUNDING

Grants are funded by the General Fund. Each fiscal year, no more than 1.7 % of general fund property tax will be allocated to the Community Funding Program.

STAFF REPORT

Parks and Recreation Commission
Meeting Date: **1/25/2017**
Staff Report Number: **17-001-PRC**

Regular Business: **Review and discuss City Council 2017 Work Plan and Goal Setting**

Recommendation

Staff recommends that the Commission review the current City Council work plan goals and provide feedback to staff which may be incorporated in the Council goal setting session for 2017.

Policy Issues

It has been the City Council's policy to adopt goals/work plan annually to provide staff with direction for budget development. Any policy issues that may arise from the implementation of individual goals will be considered at that time.

Background

The City Council adopts goals and/or a work plan at the beginning of the year. These items are not typically funded until the adoption of the budget later in June. At their meeting on January 24, 2017, the City Council will receive an update on the work plan items for 2016. Many of the items on the work planfor 2016 are ongoing. The adopted work plan identified resources and funding necessary for each of the items.

Analysis

The Council work plan for 2016 approved on February 9, 2016 includes 72 items, some of which include multiple components. Various work plan items, CIP projects, and other projects are included as a Draft Council work plan in Attachment A. The list has been grouped into themes to help categorize the items. The themes are as follows and are in no specific order:

- Responding to the development needs of private residential and commercial property owners
- Realizing Menlo Park's vision of environmental leadership and sustainability
- Attracting thoughtful and innovative private investment to Menlo Park
- **Providing high-quality resident enrichment, recreation, discovery and public safety services**
- Maintaining and enhancing Menlo Park's municipal infrastructure and facilities
- Furthering efficiency in city service delivery models
- Improving Menlo Park's multimodal transportation system to move people and goods through Menlo Park more efficiently

Items of particular interest to the Park and Recreation Commission include:
12 – Complete the Belle Haven Pool facility analysis for year-round operations
13 – Complete the Belle Haven Action Plan Phase III Implementation
14 – Enhance Community Special events
15 – Maintain City Council-approved cost recovery levels in all Community Services programs

16 – Undertake a community process to rank potential projects for Measure T funding, which is now referred as the Parks and Recreation Facilities Master Plan Update
17 – Develop a Bedwell-Bayfront Park operations / maintenance plan to enhance use, improve access and determine a sustainable funding source for ongoing maintenance
19 – Complete Belle Haven Youth Center Playground replacement
36 – Construct restroom at Jack Lyle Park
38 – Replace Nealon Park sports field sod and irrigations system
39 – Address Nealon Park dog park
40 – Replace Willow Oaks dog park and install restroom
51 – Implement recommendations from the department operational review
A – Develop and implement a Strategic Plan
B – Revise and update departmental policies
C – Improve cooperative relationships with community stakeholders

The Council work plan discussion for this year is scheduled for Friday, January 27, 2017. At this meeting, Council will consider the current work plan/project list included as Attachment A. The ongoing nature of many of the projects is important for Council to consider if these items are still a priority. Many of the projects listed above have either been completed or are scheduled to be completed during the current fiscal year. Two projects which the Community Services Department will be putting forth to Council as high priority goals will be completing the Bedwell-Bayfront Park Master Plan and the Parks and Recreation Facilities Master Plan Update . Both projects will require most of the 2017 calendar year to complete .
This process is building toward preparation of the budget for fiscal year 2017-18. In an effort to help guide the work plan discussion, the following process is recommended for Council to consider:

- Review the current work plan items
- Consider new initiatives/projects
- Evaluate interest among the Councilmembers in the new initiatives/projects
  Assess relative importance of any new ideas/projects, which the Council desires to pursue in place ofcurrent work plan items
- Determine the impact/reprioritization of other work plan items

Staff is requesting feedback from the Commission on the overall Council work plan in light of the Commission's work plan goals, particularly the work plan goal # 2:

> Study and evaluate, through such means as the Master Plan process, operational planning goals, utilization options, and guidelines for City Park and Community Services facilities resulting in facilities and equipment being properly maintained, upgraded and/or expanded to meet community needs.

The following are suggested questions to guide the Commission discussion on this topic:

1. After reviewing the 2016 Council Work Plan Draft, does the Commission have any questions or feedback regarding the current Council work plan items?
2. How would the Commission like to be involved in the work plan moving forward and in particular the Bedwell-Bayfront Park Master Plan and Parks and Recreation Facilities Master Plan Update?
3. Are there other areas of importance the Council should consider for future work plans?

Impact on City Resources

Items contained in the work plan are usually funded as part of the budget process later in June. Once the work plan is adopted, the funding sources for the various work plan items will be identified.

Environmental Review
Environmental review is not required.

Public Notice
Public Notification was achieved by posting the agenda, with the agenda items being listed, at least 72 hours prior to the meeting.

Attachments
A. 2016 City Council Work Plan Status Update Draft

Report prepared by:
Derek Schweigart
Assistant Community Services Director

ATTACHMENT A 2016 City Council Work Plan – Approved Feb. 9, 2016 - DRAFT Status update for Jan. 24, 2017

Responding to the development needs of private residential and commercial property owners

Number	Source	Description	Lead Department	Update
Extremely Important				
1	WP	Complete the General Plan Update	Community Development	The General Plan and Zoning Ordinance Updates were completed with Council final action on December 6, 2016. The new General Plan and O (Office), LS (Life Sciences) and RMU (Residential Mixed Use) zoning became effective on January 6, 2017.
2	WP	Process complex development projects	Community Development	All projects previously listed as in construction are now complete with the exception of Anton Menlo, which has an extended construction period. All projects identified as undergoing building permit review have been issued permits and are under construction, with one project being completed. Of the projects identified as being in the land use entitlement process, nine have completed the land use entitlements. Eight major projects remain at various stages of the land use entitlement process.
Very Important				
3	WP	Implement Downtown/El Camino Real Specific Plan biennial review	Community Development	City Council review is complete. Staff has developed a two-phase implementation plan and has contracted with a consultant to modify the text and graphics of the Specific Plan. Phase 1 work is expected to be reviewed by the Planning Commission and City Council in early 2017. Work on Phase 2 will follow.

Realizing Menlo Park's vision of environmental leadership and sustainability

Number	Source	Description	Lead Department	Update

Important				
4	CIP	Community Zero Waste Policy Draft	City Manager's Office	R3, Cascadia, and Ruth Abbe and Associates were selected as the consultants for this project. Community workshops were held on November 2nd at the Arrillaga Recreation Center and on December 5, 2016 at the Onetta Harris Senior Center. At these workshops, attendees were presented with information on the project, its goals and the initiatives that could be considered for the Zero Waste Plan. Attendees provided feedback and were also encouraged to fill out an online survey. Staff also met with the consultants to review the draft rate model, which is still in progress. Next Step: The consultants are scheduled to provide an in-person update and presentation to the Environmental Quality Commission (EQC) in February.
5	CIP WP	Install EV charging stations as part of the Climate Action Plan	City Manager's Office	Four chargers were installed at two locations in summer 2016. Locations include the Civic Center parking lot and a downtown parking plaza. Next Step: Staff will return to City Council in the future if consideration of charging fees is required.
6	WP	Update the Heritage Tree ordinance	City Manager's Office	Environmental staff provided the EQC with an update on the Request for Proposals (RFP) at the November 30th EQC meeting, The commissioners were pleased to see the project moving forward. Next Step(s): The Request for Proposals (RFP) was released on January 5, 2017 with a closing date of February 21, 2017. Staff is expected to select a consultant on March 7th.

Attracting thoughtful and innovative private investment to Menlo Park

Number	Source	Description	Lead Department	Update
Extremely Important				
7	WP	Implement Housing Element programs	City Manager's Office Community Development	Work on the programs is planned over the term of the Housing Element (2015-2023). Four programs were identified for 2015. One program has been completed (revisions to secondary dwelling unit ordinance) and others are in process (overnight parking restrictions in the R-4-S zoning district, 21 Elements Nexus Study and Modifications to BMR Program). Staff is researching answers to previously submitted questions.
Very Important				
8	WP	Expand downtown outdoor seating program	City Manager's Office	Santa Cruz Street Café are currently under construction
Important				
9	WP	Implement the Economic Development Plan	City Manager's Office	Ongoing
10	CIP WP	Implement Downtown/El Camino Real Specific Plan streetscape (paseo, parklets)	City Manager's Office Public Works	A new paseo location was piloted on Curtis Street this summer. Staff is reviewing the feedback received.

Providing high-quality resident enrichment, recreation, discovery and public safety services

Number	Source	Description	Lead Department	Update
Extremely Important				
11	WP	Create a community disaster preparedness partnership (MenloReady) with residents, businesses and schools utilizing the existing agreement with the Menlo Park Fire Protection District	Police	Continue to work with the fire district to address disaster preparedness and have completed the Local Hazard Mitigation Plan Annex (required for eligibility for State and Federal disaster relief funds) which was approved by City Council for Aug. 30. The plan will be in operation for five years.
12	WP	Complete the Belle Haven Pool facility analysis for year-round operations	Community Services	In process; final report expected in Spring 2017.
Very Important				
13	WP	Complete the Belle Haven Action Plan Phase III implementation	Community Services	Completed
14	WP	Enhance Community special events	Community Services	Plan for deploying shared Community Services/Library position is being finalized.
15	WP	Maintain City Council-approved cost recovery levels in all Community Services programs	Community Services	All programs at approved cost recovery level
16	CIP	Undertake a community process to rank potential projects for Measure T funding	Community Services	Now called Parks and Recreation Master Plan Update. RFQ to be distributed in February, 2017.
17	WP	Develop a Bedwell Bayfront Park operations / maintenance plan to enhance use, improve access and determine a sustainable funding source for ongoing maintenance	Community Services	Interviews with Consultants week of Jan. 9, contract expected to go to Council February 7.
Important				
18	WP	Develop an implementation plan for the Sister City program	City Manager's Office	The Sister City Committee has met and is developing its work plan.

Maintaining and enhancing Menlo Park's municipal infrastructure and facilities				
Number	**Source**	**Description**	**Lead Department**	**Update**
Extremely Important				
19	CIP	Complete Belle Haven Youth Center playground replacement	Community Services Public Works	Complete.
20	CIP WP	Install bicycle and pedestrian improvements on Chilco Street	Public Works	Ongoing; Phase 1 and Phase 2 improvements complete. Phase 3 is in design.
21	CIP	Maintain citywide sidewalk repair program	Public Works	Ongoing; FY 2016-17 saw cutting is complete and repair work is beginning
22	CIP	Maintain citywide street resurfacing program	Public Works	Ongoing; submitted updated pavement management report to MTC in April. Presently developing streets for 2017 Street Resurfacing Project
23	CIP WP	Improve Haven Avenue streetscape (bike lanes, complete sidewalk gaps, new pedestrian bridge over Atherton Channel) (grant funded)	Public Works	In design; completed review by Bicycle and Transportation commissions and City Council approved on-street parking removal. Completed environmental clearance and design. Submitted encroachment permit application to Caltrans. No parking signs in the City right of way have been installed.
24	CIP	Adopt Urban Water Management Plan update	Public Works	Complete; City Council approved May 24.
25	CIP WP	Complete sidewalks on Santa Cruz Avenue	Public Works	Construction contract was awarded and construction will begin upon completion of Cal Water's water main upgrade project.
26	CIP WP	Develop a water master plan	Public Works	Study is 60 percent complete
27		a. Add an additional emergency water well		Ongoing; City Council approved the environmental document June 7. The City has selected the firm to drill the well with construction targeted to start in February.
28		b. Develop a recycled water program		Ongoing as part of the water system master plan
29		c. Enter into an agreement with West Bay Sanitary District for the Sharon Heights Recycled Water Project		Complete; City Council approved May 3.

Very Important				
30	CIP	Repair and Upgrade the Bedwell Bayfront Park leachate collection system	Public Works	Project moved to 2017-18 following completion of Park Master Plan in 2016-17
31	CIP	Install Library landscaping	Public Works	Ongoing; design is underway. New bike racks and table installed.
32	CIP	Replace Police radio infrastructure	Public Works	Ongoing; Planning Commission completed review in June. Project went out to bid and no bids were received. Project was rebid and now targeting award of contract at the Dec. 6 City Council meeting.
33	CIP WP	Address downtown parking garage (prioritize location, develop design concepts, consider Oak Grove bike lanes)	Public Works	Study session held May 24. Staff to return with scope of work for a sources sought (solicitation of interest) for certain parking plazas downtown. Oak Grove Bike Lanes has been added as a separate project. City retained a consultant and is preparing a report regarding implementation targeted for Dec. 6.
34	CIP	Enter into an agreement with Redwood City and the Salt Pond Restoration Project for the Bayfront Canal Bypass Project	Public Works	On hold; City Council received a status report May 24.
35	CIP	Design Pope/Chaucer bridge improvements	Public Works	Ongoing; the SFCJPA issued a Notice of Preparation for the EIR for the Upstream of 101 Project. Scoping meetings scheduled for January.

Important				
36	CIP	Construct restroom at Jack Lyle Park	Public Works	Ongoing; met with Peninsula Volunteers and Rosener House regarding specific location. Held a public outreach meeting on Dec. 15. Plans are currently being prepared.
37	CIP	Replace Library interior wall fabric	Public Works	Project moved to 2017-18 following the completion of the Library Strategic Plan and Space Needs Study (#42).
38	CIP	Replace Nealon Park sports field sod and irrigation system	Public Works	City Council held a study session May 24. Focus now is on the installation of a booster pump to enhance the pressure of the irrigation system.

39	CIP	Address Nealon Park dog park	Public Works	City Council held a study session May 24. Focus now is on increasing the maintenance of the sports field to address any issues associated with the shared use with the dog park.
40	CIP	Replace Willow Oaks dog park and install restroom	Public Works	Ongoing; Council awarded consultant contract on November 29. Community outreach targeted for February 2017.
41	CIP	Initiate Downtown utility undergrounding	Public Works	On hold; this will be coordinated with downtown parking structures (#33)
42	CIP	Complete library space needs study	Public Works	Ongoing; City Council approved the consultant contract Aug. 30 and the study is being prepared.

Furthering efficiency in city service delivery models

Number	Source	Description	Lead Department	Update
		Extremely Important		
43	WP	Complete the classification and compensation study and work with labor units to address the study's findings	Administrative Services	Complete
44	CIP WP	Complete the information technology master plan and:	Administrative Services	Complete
45		a. Implement key best practices		Ongoing
46		b. Launch a selection process for replacement of mission critical systems including an enterprise resource planning (ERP) business management system for the city including administrative and land development operations		On hold pending City Council direction regarding the IT Master Plan recommendations. This item will continue into 2017.
47		c. Identify and implement interim upgrades to existing business systems as a bridge to their replacement		Alarm billing and online parking permits systems are complete. Ongoing: electronic timecard implementation is underway, testing scheduled to begin in January; interim online access to building permit applications implementation is underway; upgrades to the financial reporting system underway. This item will continue into 2017.
48	WP	Complete a fee study for solid waste services	Administrative Services City Manager's Office	Consultant is currently working with staff on the study. This item will continue into 2017.

49	CIP WP	Complete administration building space planning	Public Works	Ongoing; under construction. Phases 1 and 2 complete. Phase 3 is under construction. Completion of remaining phases targeted for Summer 2017.
Very Important				
50	WP	Complete an updated cost allocation plan, user fee study for non-utility operations, and cost recovery models for non-development related services	Administrative Services	Consultant selected and work is scheduled to begin in late January. This item will continue into 2017.
	WP	Implement recommendations from the department operational reviews:	Community Services Library	
51		Develop and implement strategic plans for the Library and Community Services departments		Both plans were completed and are being implemented.
52		Revise and update departmental policies and procedures in the Library and Community Services departments		Community Services policy updates complete. Library policy updates are ongoing.
53		Develop and improve cooperative relationships with community stakeholders (school districts, community groups, etc.)		Ongoing

Important				
54	WP	Analysis and prioritization of alternative service delivery model goals, what outcome is desired (financial, service changes, etc.) and what metrics determine success	City Manager's Office	Ongoing
55	WP	Assess current staffing levels in the Administrative Services department, realign existing resources, and add resources where necessary to support the organization's current and future needs for technology, financial and human resources support	Administrative Services	Ongoing; successfully completed recruitment for two management analysts (Human Resources and Finance), two additional analyst vacancies remain (Human Resources and Information Technology)
56	WP	Improve community communications	City Manager's Office	Ongoing; informational item presented to the City Council on Oct. 11.
57	WP	Initiate organizational study for development services utilizing industry best practices	City Manager's Office Community Development Public Works	Developing a scope of work for the study
58	WP	Initiate organizational study for Public Works maintenance services	City Manager's Office Public Works	Developing a scope of work for the study

Improving Menlo Park's multimodal transportation system to move people and goods through Menlo Park more efficiently				
Number	**Source**	**Description**	**Lead Department**	**Update**
Extremely Important				
59	WP	Develop and implement transit improvements (study transit options including enhancements to existing shuttles and transportation management associations, install new shuttle stop signs and amenities)	Public Works	Ongoing; were awarded funds from SMCTA and C/CAG for expanded shuttle service in 2016-17. Next steps are to finalize service enhancements and publicize route changes, expected in early 2017.
60	CIP WP	Study and prioritize Willow Road transportation improvement options	Public Works	Ongoing; conducted City Council study session Aug. 23 about desired improvements and Willow Road curb extensions on Oct. 25. Next step is to return to the Transportation Commission for review in early 2017.
61	CIP WP	Work with Caltrans and regional funding partners to design and begin construction on 101/Willow Road interchange	Public Works	Ongoing; design completed. Secured remaining funds to advance to construction. Caltrans in process of award construction contract. Coordinating with PG&E on gas and electric utility relocations.
62	CIP WP	Construct Citywide Bicycle and Pedestrian Visibility Project (add green colored pavement to existing high-use corridors at conflict points and downtown bike racks) (grant funded)	Public Works	Complete; Majority of installation completed in June 2016
63	CIP WP	Construct Menlo Park-Atherton Bike/Pedestrian Improvements Project (Valparaiso Avenue Safe Routes to School project) (grant funded)	Public Works	Complete, construction substantially complete in November 2016.
64	CIP WP	Construct Menlo Park-East Palo Alto Connectivity Project (add Class III bike routes and sharrows to connecting streets and fill sidewalk gaps on O'Connor Street and Menalto Avenue) (grant funded)	Public Works	Complete; construction substantially complete in October 2016.
65	CIP WP	Prepare Project Study Report for Ravenswood Avenue/Caltrain grade separation Project (grant funded)	Public Works	Ongoing; awarded consultant contract in March 2016. Held the first community workshop May 2 and second workshop Oct. 4. Commission presentations scheduled for Nov./Dec. 2016. Next step is to incorporate feedback into preliminary engineering work and present information to the City Council in February.

66	CIP WP	Explore Dumbarton Rail Corridor activation / reuse	Public Works	Ongoing; the City is coordinating through the SamTrans-led Dumbarton Corridor Study. The first community workshop held in Menlo Park May 12 and the second workshop was held in Redwood City Sept. 14. A presentation to the City Council occurred Nov. 15.
67		Install bus shelters at the Senior Center and on Willow Road between U.S. 101 and Bayfront Expressway	Public Works	Ongoing; Provided update to the City Council on Oct. 25. Council authorized the City Manager to enter into agreements with SamTrans for the installation of bus shelters. In process of negotiating agreement with SamTrans. Concrete pad for Shelter at Market Place Park was poured in December 2016.
Very Important				
68	CIP WP	Coordinate with regional agencies on High Speed Rail project, including environmental review	Public Works	Ongoing; the High Speed Rail Authority initiated environmental review in May 2016. The City prepared a comment letter on the Notice of Preparation in June 2016.
69	CIP WP	Begin design and implement El Camino Real Corridor Study	Public Works	Ongoing; City Council acted May 3 to advance design and construction of east-west crossings and further evaluation of Alternative 2. North-south corridor improvements on hold pending further City Council direction.
70	CIP	Design and construct Sand Hill Road signal modification project	Public Works	Majority of construction is complete.
71		Establish a crosswalk policy	Public Works	Complete; City Council approved the policy Sept. 13.
Important				
72	CIP WP	Work with Caltrain to complete Peninsula Corridor Electrification Project design review	Public Works	Ongoing; City Council authorized the City Manager to sign the agreement May 24.

CITY OF
MENLO PARK

STAFF REPORT

Parks and Recreation Commission
Meeting Date: 1/25/2017
Staff Report Number: 17-002-PRC
Informational Item: Community Services Director's update and announcements

Recommendation

Staff recommends that the Commission receive the Community Services Director's update and announcements.

Policy Issues

City policies are not affected.

Background

I. Recreation classes for winter session begin

The winter session for recreation classes started Jan. 9, 2017. The Onetta Harris Community Center has a variety of new classes, in addition to ongoing favorites. Classes offered include Tiny Ninjas martial arts (karate), Young Samurai martial arts (karate), Happy Hour yoga, resistance/weight training, adult kickboxing/self-defense, Zumba toning, Hip-hop Zumba. Registration is also open for the spring session which runs Monday, April 3, 2017, to Friday, June 9, 2017. Please contact Onetta Harris Community Center staff at 650-330-2250 for more details about the classes and other programs offered. Menlo Park Senior Center

II. Onetta Harris Community Center's Classroom Renovation Completed

Construction on the Onetta Harris Community Center's classroom project recently completed. The project began in December and included the conversion of two smaller rooms into one bigger room. The new flexibility created by this larger space allows for larger fitness classes and can accommodate meetings of up to 30 people. The timing is perfect for the start of the winter session that began Monday, Jan. 9, 2017. The room is also available for rentals. For more information about facility rentals or other programs, please contact the Onetta Harris Community Center at 650-330-2250.

III. Menlo Park Grant for the Arts

The Menlo Park Community Services Department released the next round of the Menlo Park Grant for the Arts (MPGA) for the 2017-18 year, which is for organizations looking to perform in a professional-grade theater in effort to support the Menlo Park artistic community. We are pleased to announce that these five (5) organizations will be awarded $500-$1,000 toward subsidizing the rental cost of the Menlo-Atherton Performing Arts Center (PAC) for performances from July 2017 to June 2018. This grant was created to increase the accessibility of the PAC by members of the community and to encourage the growth of local artistic groups by providing a high-quality venue at a subsidized cost. Past recipients have included: Menlo Park Chorus, West Bay Opera, Western Ballet, iSing Silicon Valley, Peninsula Arts & Letters, Menlowe Ballet, Circus Arts Menlo Park, Palo Alto Jazz Alliance, Master Sinfonia Chamber Orchestra, ALS Association, Palo Alto Chamber Orchestra, Peninsula Youth Orchestra, Magical Stings West and Ensemble Phoenix. MPGA online applications will be accepted through March 1st, 2017, or until funds are no longer available.

IV. Menlo Park Senior Center Events and Highlights

Menlo Park Senior Center's MLK Fish fry, now in its 18th year, was held on Friday, January 13, with over 70 people in attendance. The program this year was prepared with the help of volunteers and patrons who sang a song in honor of Dr. King, and excerpts from his famous "I Have a Dream" speech.

January 27 the Senior Center will be hosting its Chinese New Year celebration. A small group of our Chinese patrons will be planning the program for the event, which is slated to include a dance performance, authentic food, and red money bags for those in attendance.

Starting January 2, the Senior Center has expanded its hours and has been open M-F, from 8:30-3:30, to accommodate those who need to be at the facility sooner, and those who like to continue with game room activities. More organized programs and classes in later afternoon are being offered in spring as a part of the facility use expansion.

V. Status update on Jack Lyle and Willow Oaks Park CIP projects

A community meeting was held in December at the Rosener House on December 15 where City staff received public feedback on the project. The next steps include a footprint staging and renderings at project site to collect additional community feedback. Project updates will be included on the City website.

Community workshops for Willow Oaks Park Restroom and Dog Park Renovation are tentatively scheduled for Thursday, February 9, 4:00-6:00 p.m. and Saturday, February 11, 10:00 a.m.-12:00 p.m.

VI. City Council Update

The Council annual goal setting is scheduled for January 27 from noon – 5 at the Arrillaga Family Recreation Center. Staff will be proposing that the Park and Facilities Master Plan update and the Bedwell Bayfront Park Planning process are two of their priority items for the year.

Approval of the Bedwell-Bayfront Park Master Plan consultant contract is scheduled for the Council meeting on February 7, 2017.

Analysis

Analysis is not required.

Impact on City Resources

There is no impact on City resources.

Environmental Review

Environmental review is not required.

Public Notice

Public Notification was achieved by posting the agenda, with the agenda items being listed, at least 72 hours prior to the meeting.

Attachments

None

Report prepared by:
Derek Schweigart
Assistant Community Services Director

2016 COMMISSION ATTENDANCE REPORT

PARKS & RECREATION Meets monthly Name	January 1/27/2016	February 2/24/2016	March 3/23/2016	April 4/27/2016	May 5/25/2016	June 6/22/2016	July 7/27/2016	August N/A	September 9/7/2016	September 9/28/2016	October 10/26/2016	November 11/16/2016	December 12/21/2016
James Cebrian	Present	Present	Present	ABSENT	ABSENT	ABSENT	ABSENT	Canceled for summer break	ABSENT	Present	Present	Present	N/A
Kristin Cox	Present	ABSENT	Present	ABSENT	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A
Christopher Harris	Present	Present	Present	Present	Present	Present	ABSENT		Present	Present	ABSENT	Present	ABSENT
Laura Lane	Present	Present	Present	Present	Present	ABSENT	Present		Present	Present	ABSENT	Present	Present
Marianne Palefsky	Present	Present	Present	Present	ABSENT	Present	Present		Present	ABSENT	Present	Present	Present
Thomas Stanwood	Present	Present	Present	Present	Present	Present	Present		Present	Present	Present	Present	Present
Jennifer Baskin	N/A	N/A	N/A	N/A	Present	ABSENT	Present		Present	Present	Present	ABSENT	Present
Jennifer Johnson	N/A	N/A	N/A	N/A	N/A	Present	ABSENT		Present	ABSENT	Present	Present	Present

last updated 12/2016

City of Menlo Park

City Council Policy

Department City Council	Page 1 of 1	Effective Date January 1, 1991
Subject Board and Commission Attendance Policy	**Approved by** Resolution 2801 - 05/27/1985 Revised Resolution 4242 - 12/04/1990	**Procedure #** CC-91-0001

PURPOSE:

This policy is adopted in order to encourage attendance at Board and Commission scheduled meetings and to replace members who are unable to attend on a consistent basis.

BACKGROUND:

A policy of attendance at Board and Commission scheduled meetings has not been uniform throughout the City. Many commissions have their own policies which they implement on an informal basis. Some commission scheduled meetings have been cancelled due to the lack of a quorum, a number of Commissions have members who miss a majority of their scheduled meetings and the issue of attendance at scheduled meetings is of concern. Some Commission chairpersons have previously expressed a need for an attendance policy which would be consistent for all boards and commissions and which would dictate the removal of a board or Commission member who has missed a certain number of scheduled meetings in the calendar year.

There are, often times, excellent reasons why a Board or Commission member might not be able to attend a scheduled meeting: illness, business or home commitments. The policy should be flexible enough so that a reasonable number of absences are allowed. Extensive absences on the part of a Board or Commission member do restrict the ability of a Board or Commission to complete its work and an attendance policy is meant to discourage such behavior.

POLICY:

1) A compilation of attendance will be submitted to the Council annually in January listing absences for all Board and Commission members.

2) Absences, which result in attendance at less than two-thirds of Board and Commission scheduled meetings for any reason during the calendar year, will be reported to the City Council and may result in replacement of the Board or Commission member by the Council.

3) Any Board or Commission member who feels that unique circumstances have led to numerous absences, can appeal directly to the City Council for a waiver of this policy or a leave of absence.

4) When an absence by a commissioner occurs after the posting of the agenda, which results in a lack of a quorum and therefore cancellation of the commission meeting, the attendance of the commission for the noticed meeting will be recorded on the commission attendance report.

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CITY OF MENLO PARK

STAFF REPORT

Parks and Recreation Commission
Meeting Date: **1/25/2017**
Staff Report Number: **17-003-PRC**

Informational Item: **Update on the status and design guidelines for the Jack Lyle Park Restroom project**

Recommendation

This is an informational item and does not require City Council action

Policy Issues

The City Council previously approved a project to construct a restroom at Jack Lyle Park as part of the FY 2015-16 Capital Improvement Program (CIP) and authorized additional funding for the project in FY 2016-17.

Background

On November 10, 2015 a public meeting was held on potential locations and restroom designs, including a pre-fabricated structure. Attendees from the public provided feedback and voiced their support for a pre-fabricated structure adjacent to the Rosener House.

Subsequent to that meeting the City met with Rosener House officials and board members from the Peninsula Volunteers. They were receptive to the project and approved the restroom location adjacent to the Rosener House.

A preliminary design for the restroom has been developed by the City's consultants (SSA Landscape Architects) and was presented at a community workshop at the Rosener House on December 15, 2016. Overall the feedback received from the community review of the design was positive. The location next to the Rosener House, as well as matching the architectural style of the Rosener House to make the restroom "blend-in" was preferred. Designing the facility for two, family-style restrooms also received positive feedback.

Analysis

In order to further develop the design parameters, staff reviewed the Planning and Building code requirements as well as opportunities to incorporate sustainable design concepts. Since the park is zoned PF (Public Facility) and all uses for government purposes by the City are considered permitted uses, the project does not require any further review regarding land use. The only development standard is a maximum floor area ratio of 30%, which the park is substantially below.

The Planning Division also stated that the restroom does not require architectural control approval. Section 16.68.020 of the Municipal Code discusses architectural control approval and when it is required. The section explicitly exempts accessory buildings. The question is whether restrooms are defined as accessory buildings. In the most recent case involving the restroom at Kelly Park, Planning defined the restroom as an accessory building. To be consistent with the last determination and because Planning believes they are accessory to the park use, their determination is that the restrooms do not need architectural control.

Although this is a pre-manufactured building the Building Division will review the design for conformance with the latest building and seismic codes. Given the proposed size of the building of approximately 180 square feet, CalGreen building requirements do not apply.

Although not specifically required, green building design standards will be considered on this project. There are sustainable components inherent in the design, including recycled materials (doors, block walls, roof); low energy fixtures (LED lights, metered water closets / faucets). The building also uses sustainable materials that are mostly local, with minimized carbon footprints. Since this is a pre-fabricated building, it should have a smaller carbon footprint than a site-built structure because of the nature of mass-production.

Although this is a new building many of the opportunities for sustainable design are negated by the location of the building adjacent to the existing Rosener House. Designing the roofline to allow in winter sun, and block out summer sun is not really an option because of the building orientation. Incorporating solar panels would also require the re-orientation of the building. Sky lights could be added but they do not necessarily offset energy costs when using LED light fixtures. On-site waste-water treatment is not an option given the small size of the building. The idea of allowing natural light in to warm the floor, etc. is a great concept, but typically achieved using a lot of glass, which is not an option when privacy, venting, and maintenance are primary goals of a restroom.

Impact on City Resources

The Jack Lyle Park Restroom project budget is $350,000. Sources of funds include Rec-in-Lieu Fees and from the annual transfer of General Fund dollars.

Environmental Review

The project is categorically exempt under Class 3 (Section 15303, “New Construction or Conversion of Small Structures”) of the current California Environmental Quality Act (CEQA) Guidelines.

Public Notice

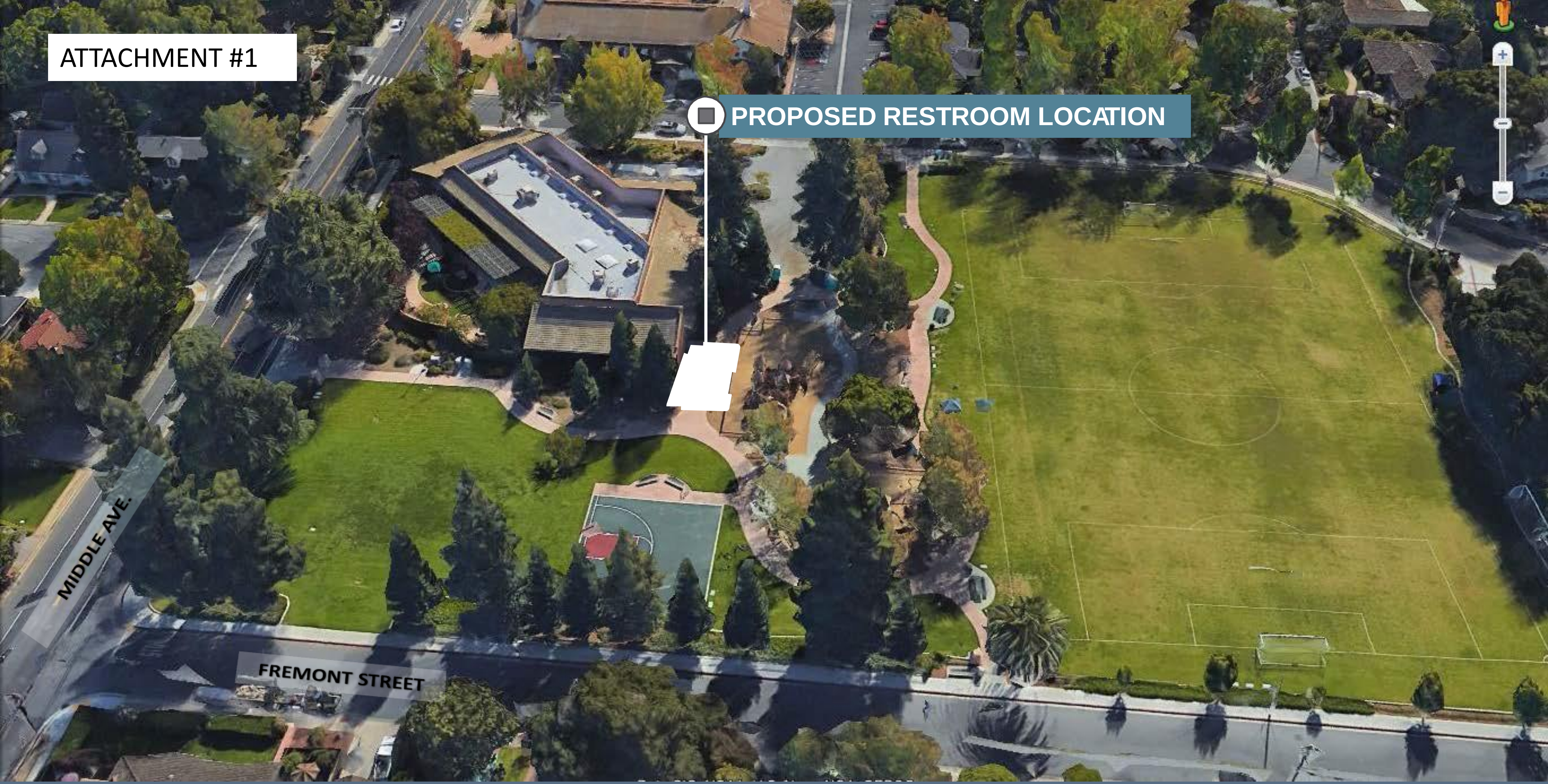
Public Notification was achieved by posting the agenda, with the agenda items being listed, at least 72 hours prior to the meeting.

Attachments

Attachment #1: Site Plan
Attachment #2: Artist Rendering of Proposed Restroom

Report prepared by:
Michael Zimmermann, Senior Civil Engineer

Reviewed by:
Justin Murphy, Public Works Director



JACK LYLE PARK RESTROOM – Site Plan

ATTACHMENT #2

JACK LYLE PARK RESTROOM / PHOTO-SIMULATION

EPA
United States
Environmental Protection
Agency

EPA/600/R-16/364 | December 2016 | www.epa.gov

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds

STATUS REPORT

National Exposure Research Laboratory
Office of Research and Development

Prepared By:

U.S. Environmental Protection Agency (EPA)[1]

Centers for Disease Control and Prevention / Agency for Toxic Substances and Disease Registry (CDC/ATSDR)[2]

U.S. Consumer Product Safety Commission (CPSC)/ Directorate for Health Sciences[3]

Disclaimer:

This document has been reviewed by the U.S. Environmental Protection Agency, the Agency for Toxic Substances and Disease Registry, and the Consumer Product Safety Commission and approved for release.

Any mention of trade names, products, or services does not imply an endorsement by the US Government.

[1] US EPA Contact: Monica Linnenbrink – tirecrumbs@epa.gov
[2] CDC/ATSDR Contact: 1-800-CDC-INFO (1-800-232-4636) or visit CDC-INFO website at https://wwwn.cdc.gov/dcs/ContactUs/Form. Reference Tire Crumb Research Status Report or visit the ATSDR webpage titled: Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds at https://www.atsdr.cdc.gov/frap/index.html.
[3] CPSC Contact: Eric Hooker - EHooker@cpsc.gov

Table of Contents

I. Executive Summary

Over the past several years, parents, athletes, schools, and communities have raised concerns about the safety of recycled tire crumb rubber used as infill for playing fields and playgrounds in the United States. The public has expressed concerns that the use of these fields could potentially be related to certain health effects. Studies to date have not shown an elevated health risk from playing on fields with tire crumb rubber, but these studies have limitations and do not comprehensively evaluate the concerns about health risks from exposure to tire crumb rubber.

Synthetic turf field systems were initially introduced in the 1960s. Currently, there are between 12,000 and 13,000 synthetic turf recreational fields in the United States, with 1,200 – 1,500 new installations each year (STC et al., 2016). Synthetic turf fields are installed at municipal and county parks; schools, colleges and universities; professional team stadiums and practice fields; and military installations. Potentially millions of people are estimated to use these fields, including professional and college athletes, youth athletes in school or other athletic organizations, coaches, team and facility staff, referees, fans, bystanders and local communities.

On February 12, 2016, the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry (CDC/ATSDR) and the U.S. Environmental Protection Agency (EPA)[4], in collaboration with the Consumer Product Safety Commission (CPSC)[5], released a *Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds* (FRAP)[6]. The purpose of the FRAP is to study key questions concerning the potential for human exposure resulting from the use of tire crumb rubber in playing fields and playgrounds. This kind of information is important for any follow up evaluation of risk that might be performed.

The FRAP includes outreach to key stakeholders to obtain information to fill important data gaps, research to characterize constituents of tire crumb made from recycled tire rubber, studies to identify ways in which people may be exposed to tire crumb rubber based on their activities on the fields, and an analysis of existing scientific literature on the topic.

Prior to initiating the study, federal researchers developed a research protocol, *Collections Related to Synthetic Turf Fields with Crumb Rubber Infill*[7], which describes the study's objectives, research design, methods, data analysis techniques, and quality assurance/quality control measures in place to ensure the integrity of the following components of the research:

- literature review and data gaps analysis;
- tire crumb rubber characterization research;
- human exposure characterization research.

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[4] The specific roles of EPA and CDC/ATSDR are provided in the FRAP

[5] This report includes contributions written by the CPSC staff and has not been reviewed and/or approved by, and may not necessarily reflect the views of, the Commission.

[6] The FRAP is available through the Tire Crumb website: www.epa.gov/tirecrumb

[7] The research protocol is available through the Tire Crumb website: www.epa.gov/tirecrumb

The study protocol was reviewed by independent external peer reviewers, CDC's Institutional Review Board (IRB) and EPA's Human Subjects Research Review Official. The data collection components of the study went through the Office of Management and Budget's (OMB) Information Collection Request (ICR) review process. The OMB ICR process included a public comment period[8]. On August 5, 2016, EPA, CDC/ATSDR and CPSC received final approval from OMB to begin the research.

This status report provides a summary of the agencies' activities to-date, including:

- stakeholder outreach;
- tire and tire crumb rubber manufacturing process;
- final peer-reviewed Literature Review/Gaps Analysis;
- Tire Crumb Rubber Characterization and Exposure Characterization research;
- use of recycled rubber tires on playgrounds;
- next steps and a timeline.

Since research is currently ongoing, the status report does not include any preliminary findings of the research. The results of the research on synthetic turf fields will be available later in 2017.

> The purpose of the FRAP is to study key questions concerning the potential for human exposure resulting from the use of tire crumb rubber in playing fields and playgrounds.

Summary of Stakeholder Outreach

EPA, CDC/ATSDR, and CPSC teams have engaged in a number of outreach activities, listed below, to inform the public, research organizations, industry, government organizations and non-profit organizations about the FRAP and to gather and share information that may be used to inform the research. Section III and Appendix A provide additional information on stakeholder outreach covering the following areas:

- Solicited public comment on components of the study, including collection of tire crumb rubber samples and information from field users;
- Regularly updated the Tire Crumb Study website (www.epa.gov/tirecrumb), with links to the FRAP and the research protocol, Tire Crumb Questions and Answers, government websites that provide recommendations for recreation on fields with tire crumb, and other information;
- Hosted a public webinar to provide an overview of the FRAP;
- Distributed study updates to an e-mail list of about 800 stakeholders.

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[8] Public and peer review comments and the agencies' responses are available on the OMB's website – http://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201607-0923-001.

The agencies also reached out to other federal, state, and international government organizations involved in planning or conducting tire crumb research. These included California's Office of Environmental Health Hazard Assessment, Washington State Department of Health, the National Toxicology Program at the National Institute of Environmental Health Sciences, the European Chemicals Agency, and the Netherlands National Institute for Public Health and the Environment.

Industry Overview

Agency researchers gathered information from industry, non-governmental organizations, and others to inform the design and implementation of the research on synthetic turf fields containing rubber infill. This included collecting information on how tires and tire crumb rubber are manufactured, and on how synthetic turf fields are constructed, installed, and maintained.

From February to September 2016, the study team held meetings with five industry trade associations, three synthetic turf field companies, two synthetic turf field maintenance professionals, one academic institution, and five non-profit organizations. EPA, CDC/ATSDR, and CPSC scientists toured a total of five tire recycling facilities in the south, west, and northeast regions of the United States, where they observed different types of tire crumb rubber processing technologies. The facilities ranged in size from small to large operations with varying degrees of mechanized technologies to process the tires. The tire crumb rubber infilling process was observed on two field installations in the Washington, D.C. metropolitan area. Through these tours, the team gathered information on a number of topics, including:

- The state of tire manufacturing and scrap-tire collection and recycling;
- The nature and varieties of processes and machinery used in the processing of scrap tires into tire crumb rubber;
- Tire-manufacturing standards;
- Tire recycling process standards and tire crumb rubber product standards;
- Tire crumb rubber infill product types;
- Storage, packaging and transportation of tire crumb rubber to fields;
- The number and distribution of synthetic turf fields;
- Synthetic turf field construction, installation and maintenance practices.

Peer-Reviewed Literature Review/Gaps Analysis

The overall goals of the LRGA were to inform the interagency research study and to identify potential areas for future research.

The research team conducted a Literature Review/Gaps Analysis (LRGA, included in this status report) that provides a current summary of the available literature and captures the data gaps as characterized in those publications. The overall goals of the LRGA were to inform the interagency research study and to identify potential areas for future research. The LRGA does not include critical reviews of the strengths and weaknesses of each study, but does provide the authors' conclusions regarding their research, where applicable. The LRGA also does not make any conclusions or recommendations regarding the safety of recycled tire crumb rubber used in synthetic turf fields and playgrounds.

The LRGA identified 88 references from data sources, including PubMed, Medline (OVID), Embase (OVID), Scopus, Primo (Stephen B. Thacker CDC Library), ProQuest Environmental Science Collection, Web of Science, ScienceDirect, and Google Scholar. Each reference reviewed was categorized according to 20 general information categories (e.g., study topic, geographic location, sample type, conditions, and populations studied) and more than 100 subcategories (e.g., for study topic: site characterization, production process, leaching, off-gassing, microbial analysis, and human risk). The research in the FRAP addresses many of the gaps identified in the LRGA, particularly with respect to tire crumb rubber characterization and exposure characterization. A summary of the results of the data gaps component of the LRGA is provided Section IV B. The final peer-reviewed document is included in Appendix B.

Data Collection for Tire Crumb Rubber Characterization

EPA and CDC/ATSDR are conducting a characterization of the components of tire crumb rubber, which is critical to understanding the potential for exposure. As part of the tire crumb rubber characterization study, researchers collected tire crumb rubber samples from nine tire recycling plants and 40 synthetic turf fields (both indoor and outdoor) from the four U.S. census regions. Laboratory analyses are in progress, including measurements of the amounts of volatile organic chemicals (VOCs) and semi-volatile organic chemicals (SVOCs) emitted from the tire crumb rubber under different temperature conditions. Bioaccessibility measurements for metals and SVOCs are being conducted to better understand how much of the chemicals present in tire crumb rubber can be absorbed in the body. In addition to quantitative target chemical analyses, samples will be assessed to determine whether there may be VOCs and SVOCs in tire crumb rubber that have not been previously reported. In addition to the potential for chemical exposures at synthetic turf fields, concerns have been raised about the potential for exposure to microbial pathogens. The microbial populations associated with the tire crumb rubber infill collected from synthetic turf fields are also being characterized.

Data Collection for Exposure Characterization

Characterizing exposure of individuals to constituents in tire crumb rubber is another important consideration for understanding potential health risk. The exposure characterization study is a pilot-scale effort to: (a) collect information on human activity parameters (such as frequency and duration of field use and contact rates with field materials for different activities) that affect potential exposures of synthetic turf field users to tire crumb rubber; and (b) conduct a human exposure measurement study to develop and assess methods for measuring exposures and to generate data for improved exposure characterization. The field recruitment process has begun; however, field collection has not yet started because fields with active sports seasons are not currently available. The agencies are continuing their efforts to identify fields that meet the study criteria.

Recycled Tire Materials Used in Playgrounds

CPSC's role in the FRAP is to assess the potential risks to consumers associated with the use of recycled tire crumb rubber in playground surfaces. CPSC staff identified five general types of playground surfaces that are made with recycled tire materials: (1) loose-fill rubber, (2) rubber tiles, (3) poured-in-place rubber, (4) bonded rubber, and (5) synthetic turf. Limited information is available about the chemical safety of recycled tire materials in playground surfaces. CPSC is using a combination of field observations, focus groups, and a national survey of parents and child care providers to collect information on children's behaviors on playgrounds and to identify exposure factors. Specific risk assessment strategies will be determined based on review of the new data, including the tire crumb rubber characterization and bioavailability studies currently being performed by EPA and CDC/ATSDR, and likely will focus on the substances of highest concern.

Next Steps and Timeline

Analysis of the tire crumb samples collected from fields and recycling facilities, and the exposure characterization component of the study, will continue in 2017. Parts of the exposure study may be conducted during the hotter months of 2017. The results of the research on synthetic turf fields are anticipated to be available in 2017. The CPSC playground study also will continue in 2017.

The agencies will continue to share information with other government agencies that have ongoing or planned tire crumb rubber. As it is available, updated information will be posted to EPA's tire crumb rubber website (www.epa.gov/tirecrumb) and stakeholder groups will be notified of these updates.

The status report does not include any preliminary findings of the research.

The results of the synthetic turf fields research will be available later in 2017.

II. Introduction

Concerns have been raised by the public about the safety of recycled tire crumb rubber used in playing fields and playgrounds. Studies to date have not shown an elevated health risk from playing on fields with tire crumb rubber, but these studies have limitations and do not comprehensively evaluate the concerns about health risks from exposure to tire crumb rubber.

On February 12, 2016, the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry (CDC/ATSDR) and the U.S. Environmental Protection Agency (EPA), in collaboration with the Consumer Product Safety Commission (CPSC), launched a multi-agency effort called the *Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds* (FRAP). The purpose of the FRAP is to study key questions concerning the potential for human exposure resulting from the use of tire crumb rubber in playing fields and playgrounds.

To support the goals of the FRAP, federal researchers developed the research protocol titled *Collections Related to Synthetic Turf Fields with Crumb Rubber Infill*. The research protocol describes the following components of the research study:

- Literature Review/Gaps Analysis;
- tire crumb rubber characterization research;
- human exposure characterization research.

The review of the literature and data gaps analysis involved an examination of information available for tire crumb rubber used for synthetic turf infill, in addition to playgrounds. The tire crumb rubber characterization research focused on samples collected from tire crumb rubber manufacturing facilities and indoor and outdoor synthetic turf fields across the country. Exposure characterization research outlined in the protocol focuses on synthetic turf fields. The CPSC team is developing research plans for playgrounds.

This status report provides a summary of activities to date, including: (1) stakeholder outreach, (2) the tire crumb rubber manufacturing industry, (3) the final peer-reviewed Literature Review/Gaps Analysis (LRGA), (4) progress on the research activities, and (5) next steps and a timeline for completion of the final report. The research updates included in this document are:

- characterization of the chemicals and materials found in tire crumb rubber,
- characterization of the exposure scenarios for athletes and others using turf fields containing tire crumb rubber,
- a study to better understand how children use playgrounds containing tire crumb rubber.

III. Stakeholder Outreach

Completed Activities

EPA, CDC/ATSDR, and CPSC engaged in a number of outreach activities to support the FRAP. These activities focused on three areas:

1. Informing the public about the FRAP and encouraging them to provide feedback through a public comment process. This was accomplished by sharing information through EPA's public website and e-mail updates, public webinars, and providing opportunities for public comment.

2. Sharing information with other government organizations that are planning or conducting research on this topic. EPA, CDC/ATSDR, and CPSC engaged U.S. and international organizations through regular conference calls, webinars, and other mechanisms for sharing expertise and information.

3. Contacting organizations to obtain information to inform the FRAP. A brief summary of these efforts is described below. Discussions were held with government organizations, industry, and other groups to better understand how tires and tire crumb rubber are manufactured, and how synthetic turf fields are constructed, installed, and maintained; as well as to obtain other studies or information that could be used for the study.

Future Activities

EPA, CDC/ATSDR, and CPSC will continue the outreach activities described above. As the exposure characterization portion of the research is implemented, additional outreach will be undertaken to gather information from field users. The CPSC team will be engaging parents and child caregivers in focus groups to gather information about how children use playgrounds.

See Appendix A for more detailed descriptions of the outreach activities to support the FRAP.

IV. Status of Activities

A. Industry Overview

The agencies used outreach efforts and publicly available information to gain a better understanding of the synthetic turf industry, tire manufacturing process, processes for creating tire crumb rubber, and procedures for synthetic turf field installation and maintenance. This section provides information related to these topics.

Figure 1: A synthetic turf field under construction (USEPA, 2016a)

Waste Tire Generation and Recovery Estimates

A large volume of used automobile and truck tires enters the waste stream in the United States each year. An estimated 4.77 million tons of waste tires were generated in 2013, and 40.5 percent, or 1.93 million tons, were recovered through recycling and production of retreaded tires (U.S. EPA, 2015). Much of the waste tire material is used in fuel markets, including cement kilns, utility boilers, industrial boilers, pulp and paper mills, and dedicated scrap tire-to-energy facilities (RMA, 2016a). In 2013, approximately 172,000 tons of scrap tires were converted to tire shreds for use in road and landfill construction, septic tank leach fields, and other construction applications (RMA, 2016a). Approximately 975,000 tons of scrap tires (i.e., approximately 59.5 million tires) were used in the ground rubber applications market, which includes the manufacture of new rubber products, rubber-modified asphalt, and playground and sports surfacing (RMA, 2014 and 2016a). The Rubber Manufacturers Association (RMA) estimated that in 2013, 33 percent of these scrap tires were used in molded/extruded products, 31 percent in playground mulch, 17 percent in sports surfaces, 7 percent in asphalt, 6 percent in automotive products, and 6 percent were exported (RMA, 2014). Recycled rubber from tires is used in several types of recreational venues, including use as infill material in synthetic turf fields, on playgrounds either as loose rubber mulch or rubber mats, for running surfaces, and in equestrian arenas. Recycled tire material may also be used in other applications, such as tire-derived rubber flooring materials (CalRecycle, 2010).

Synthetic Turf Fields

Synthetic turf field systems initially were introduced in the 1960s. Currently, there are between 12,000 and 13,000 synthetic turf sports fields in the United States, with approximately 1,200 to 1,500 new installations each year (See Figure 1) (STC et al., 2016a). Synthetic turf fields are installed at municipal and county parks; schools and colleges; professional team stadiums and practice fields; and military installations. Users include professional and college athletes, youth athletes in school and/or other athletic organizations, adult and youth recreational users, coaches, team and facility staff, referees, and fans and bystanders of all ages. No data were identified to estimate the number of individuals using synthetic turf fields in the United States; however, given the large number of installed fields it can be reasonably anticipated that the number of users nationwide is in the millions.

Tire Manufacturing Process

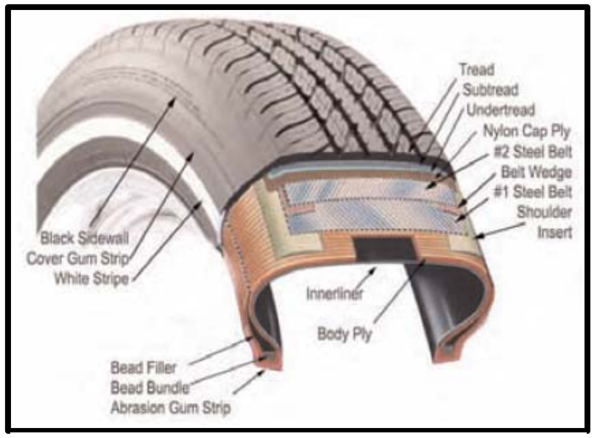

Figure 2: Cross Section of a Tire (NHTSA, 2016)

The five main components of tires are tread, sidewall, steel belts, body plies, and bead (ChemRisk, 2008). Tires are manufactured with a range of materials, including natural and synthetic rubber and elastomers; reinforcement filler material; curatives including vulcanizing agents, activators, accelerators, antioxidants, antiozonants, inhibitors, and retarders; extender oils and softeners; phenolic resins and plasticizers; metal wire; polyester or nylon fabrics; and bonding agents (Dick and Rader, 2014; Cheng et al., 2014; ChemRisk, 2008; NHTSA, 2006). In tire manufacturing, the natural and synthetic ingredients are mixed together under heat and high pressure and rolled into rubber sheets. These rubber sheets either can be calendared with textile sheets or extruded together and forced through a die. A tire is built by applying layers of rubber, rubber-encased materials, steel belts, and tread rubber. The built tire then is cured at a temperature between 150° and 180°C (300° and 360°F) (Chemrisk, 2008). This tire-curing process is referred to as vulcanization, and it involves the formation of crosslinks between polymer chains in rubber. Figure 2 displays a cross-section of a tire.

Chemicals of Interest or Concern in Tires

Many of the concerns that have been raised by the public are about the potential exposure to chemicals in tire crumb rubber infill used in synthetic turf fields. Chemicals of interest or concern used in tire manufacturing range from polyaromatic hydrocarbons (PAHs) in carbon black to zinc oxide (ZnO), which is used as a vulcanizing agent and could contain trace amounts of lead and cadmium oxides. Chemicals in many other classes could be used in tire manufacturing, including sulphenamides, guanidines, thiazoles, thiuams, dithiocarbamates, sulfur donors, phenolics, phenylenediamines, and others (ChemRisk, 2008). There is limited information to assess whether some of these chemicals might carry impurities or byproducts. During vulcanization, the rubber is heated with vulcanizing agents under pressure, which causes profound chemical changes at the molecular level, altering the initial composition of the tire and giving it its elasticity (Coran, 1994).

There is uncertainty about whether rubber material in vulcanized tires might undergo chemical transformation over time. The rubber could serve as a sorbent for chemicals in the air and in dust that falls onto the field. One laboratory reported irreversible adsorption of volatile organic compounds (VOCs) and semivolatile organic compound (SVOC) analytes spiked onto tire crumb rubber (NYDEC, 2009).

Tire Manufacturing Standards

The National Highway Traffic Safety Administration conducts research and mandates certain requirements for passenger-car tires to ensure crash avoidance and fuel efficiency (NHTSA, n.d.). The reason NHTSA was established was to implement the provisions of the Congressional Safety Act of 1966. For example, 49 CFR 571.109 (Standard Number 109: New Pneumatic and Certain Specialty Tires) requires testing of tires for physical properties and provides standards for tire labeling and serial numbers. Industry associations, such as the Tire and Rim Association, also establish engineering standards for tires, rims, and allied parts (NHTSA, 2006).

Tires introduced on the European tire market are also subject to the European Union's Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) regulation that restricts the use of high-aromatic oils in tires produced after January 2010 (Eur-Lex-32005L0069-EN, n.d.). Tires or parts of tires must not contain more than 1 mg/kg of benzo[*a*]pyrene, or more than 10 mg/kg of the sum of benzo[*a*]pyrene, benzo[*e*]pyrene, benzo[*a*]anthracene, chrysene, benzo[*b*]fluoranthene, benzo[*j*]fluoranthene, benzo[*k*]fluoranthene and dibenzo[*a,h*]anthracene (Eur-Lex-32005L0069-EN, n.d.).

Tire Crumb Rubber Manufacturing Process

In the United States, tires typically are collected at tire dealerships and automobile service stations and shipped to tire recyclers. Tires of different types (e.g., passenger cars, trucks) and from different manufacturers are mixed together at tire collection stations and tire recycling plants. According to the Synthetic Turf Council (STC)[9], there are nine tire crumb rubber producers in the United States produce approximately 95 percent of the recycled rubber used as infill in synthetic turf field applications (STC et al., 2016a).

Tire Types

The STC's guidelines state that tire crumb rubber is derived from scrap car and truck tires that are ground up and recycled (STC, 2011) to a certain size for use in synthetic turf fields. The exact proportion of each tire type in the infill product is unclear and appears to vary depending on the tire crumb rubber producer.

The use of off-the-road (OTR) tires to produce tire crumb rubber infill may be more limited. An article in the newsletter published by the Institute of Scrap Recycling Industries, Inc. (ISRI) discusses the many challenges and considerations associated with the sourcing, transportation, and processing of OTR tires, including the needs for downsizing larger tires before feeding them into primary shredders and for removing bead bundles to reduce the wear on the shredders

[9] The Synthetic Turf Council is a non-profit trade association whose objective is to encourage, promote, and facilitate better understanding among all parties involved in the manufacture, selection, delivery, and use of today's synthetic turf systems (STC, n.d.-c).

(Mota, 2013). The logistics, cost, and additional processing required to use OTR tires limits their use as feedstock for producing tire crumb rubber infill (Sikora, 2016).

Ambient and Cryogenic Processes

Two tire recycling processes, (1) ambient and (2) cryogenic, are used to create tire crumb rubber in the 10- to 20-mesh (0.84- to 2.0-mm) size, which is generally the size used in synthetic turf infill. ASTM International a not-for-profit organization that develops and publishes international voluntary consensus standards[10] for materials, products, systems and services (ASTM, n.d.), developed Method ASTM D5644[11], which can be used to determine the average particle size distribution of recycled vulcanizate particulate (ASTM, 2013a). The number of tire recycling facilities using the ambient process is greater than the number of facilities using the cryogenic process (STC et al., 2016a).

The ambient process uses granulation or cracker mills to produce tire crumb rubber at room temperature (Scrap Tire News, 2016). Cracker mills use revolving rollers with serrations in them to size-reduce the tires. Once the granules are produced, they are fed through screens and sorted to the appropriate size (Scrap Tire News, 2016). The cryogenic process uses liquid nitrogen to freeze partially shredded tires, which then are fed into a hammer mill to create tire crumb rubber.

Fabric (i.e., polyester, nylon, or other fibers) and steel belt components of the scrap tire are separated in both processes (Scrap Tire News, 2016). Fabric is removed from the rubber using air classifiers or vacuums, while the steel is removed using magnetic separators. Gravity separators also can be used to remove contaminant particles, such as rocks, and can aid in the sorting process. Likewise, water can be used for pre-washing to remove gravel and dirt and cooling during the ambient process; otherwise no chemicals are added to the original rubber composition during either process. Following processing, tire crumb rubber typically is placed into one-ton sacks and distributed to fields for spreading.

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[10] The ASTM standards can be incorporated into contracts; used in laboratories and offices; referenced in codes, regulations, and laws; or referred to for guidance. Although ASTM standards are voluntary, in cases in which an ASTM standard is referenced in a law, regulation, or code, compliance with the ASTM standard could be required (ASTM, n.d.).

[11] All ASTM standards can be found at https://www.astm.org/.

Synthetic Turf Fields

Synthetic turf fields are installed for various activities played at both the recreational and professional level, including football, soccer, and lacrosse. There are approximately eight major synthetic field installers in the United States with the largest four being national in scope, installing coast to coast (Sprinturf, 2016). An estimated 95 percent of the existing fields in North America use recycled rubber infill exclusively or in a mixture with sand or alternative infills; the remaining five percent contain only alternative infills (STC et al., 2016a). STC also reports that the use of exclusively alternative infills in new installations increased in 2016 (STC et al, 2016b). Outdoor synthetic turf fields are more common than indoor fields (FieldTurf, 2016a), with some sources indicating that indoor fields constitute approximately five to 15 percent of the market (Sprinturf, 2016). The differences in the construction between outdoor and indoor fields are the use of a more durable fiber in indoor fields (Sprinturf, 2016) and the use of adhesives to glue down the fiber carpet to the floor of indoor facilities (FieldTurf, 2016b).

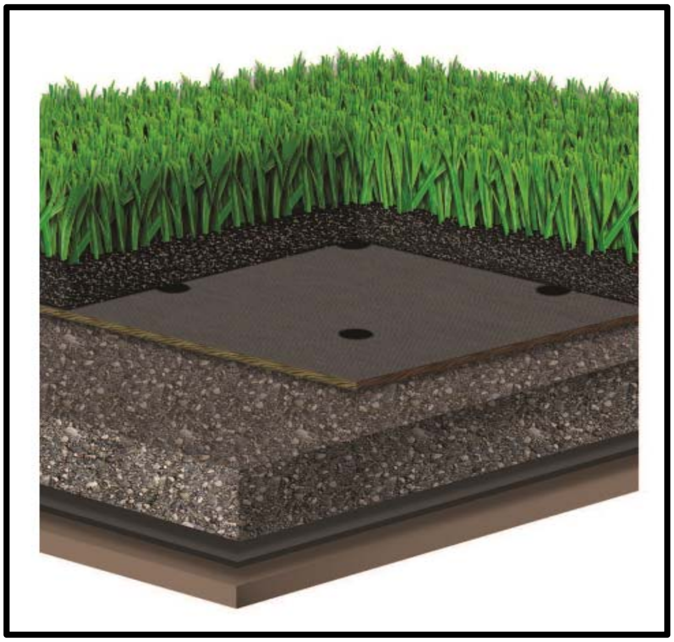

Figure 3: A cross-section of the layers of a typical synthetic turf field (STC, n.d.-b)

Current generation synthetic turf fields are typically constructed with a bottom gravel/stone base layer to allow for drainage (STC, 2011). On top of the drainage layer lies the turf component, which is composed of multi-layered polypropylene and urethane backing material with polyethylene fiber blades. Sometimes a pad can be used for additional cushioning on a field (STC, 2011). Figure 3 displays a cross-section of a typical turf field and Figure 4 shows materials for a synthetic turf field before installation..

Figure 4: Sand and packaged crumb rubber awaiting field installation (USEPA, 2016b)

The colored lines, hash marks, numbers, and logos on a field are created either as part of the turf during the manufacturing process, or at the job site by cutting the original backing material from the field and gluing or sewing the colored pieces onto the backing material (STC, n.d.-c). Lines also can be temporarily painted on the field.

Figure 5: Tire crumb rubber is placed on a field in layers during installation (USEPA, 2016c)

Fields can be infilled with material in a few different ways. Sand is often used as a lower layer infill material to act as a ballast for the turf component. On top of this lower layer either will be tire crumb rubber or a sand/tire crumb rubber mix, topped by additional tire crumb rubber. Other fields can use an infill exclusively comprised of tire crumb rubber. On a small number of fields, tire crumb rubber could be coated with paint, typically green, either for aesthetic purposes or heat control (FieldTurf, n.d.-d; Sprinturf, n.d.). To a much lesser extent, natural materials (e.g., ground coconut husk), ethylene propylene diene monomer (EPDM), or thermoplastic elastomers (TPE) granules are used as the complete infill. These materials also can be used as the uppermost layer of infill (STC et al., 2016a). Infill material typically is spread using small utility vehicles that make multiple passes across entire fields, laying the material down in thin layers that are placed one on top of the other until the appropriate height is reached (Figure 5). Additional machinery can be used to drag or brush the blades upright to allow the material to fall between the blades (STC, 2011).

Synthetic Turf Field Standards

The *Standard Test Methods for Comprehensive Characterization of Synthetic Turf Playing Surfaces and Materials* (ASTM, 2009) can be used to identify the physical properties and compare the performance of synthetic turf systems and components of the system. The standard presents a list of test methods that can be used to test components of the field, including turf blades, carpet backing material, shock absorbing pads, and infill material.

The *Standard Specification for Extractable Hazardous Metals in Synthetic Turf Infill Materials* (ASTM, 2016a) specifies a test method to determine the amount of hazardous metals that have the potential to be extracted from synthetic turf infill materials, if ingested. The standard adopts both the specified test method and the limits on the extractable amounts of heavy metals from the *Consumer Safety Specification for Toy Safety* (ASTM 2016b). It also applies to any infill material used in synthetic turf, irrespective of whether it is synthetic or natural. On November 30, 2016, recycled rubber and synthetic turf industry groups announced that leading members of the Recycled Rubber Council, Safe Fields Alliance, and STC are voluntarily moving to ensure all synthetic turf infill products created and used by their organizations will comply with ASTM F3188-16 (BusinessWire, 2016).

Synthetic Turf Field Maintenance

As is the case with natural fields, synthetic turf fields, too need to be maintained through a set of routine maintenance practices (STC, 2015). Routine synthetic turf field maintenance is conducted to maintain a safe playing surface, improve its appearance, and extend the life of the field (STC, 2015). Recommended maintenance practices include brushing the field for infill redistribution, raking to rejuvenate the fibers and to relevel the top portion of the infill, and sweeping for debris removal (STC et al., 2016a; FieldTurf, n.d.-b). It is recommended that some of these practices be performed more frequently than others, depending on the frequency with which the field is used and specific guidelines for the sport played on the field. There are also guidelines that recommend using surfactants, such as liquid laundry fabric softener or static conditioner, to help reduce static electricity that builds up during maintenance (STC, 2015; FieldTurf, n.d.-b). Water also is used to reduce the static electricity in synthetic turf fields (Daily, 2016).

It is important to maintain an appropriate amount of infill in the field for proper cushioning and firmness. Tire crumb rubber can be lost for a number of reasons, such as migration in the shoes and clothing of athletes, in weather events such as rain or snow, and through routine maintenance practices (Pennsylvania State University Center for Sports Surface Research, 2016). Because of tire crumb rubber migration, new infill material sometimes is added to existing fields to refresh or replace the tire crumb rubber that is lost over time. Infill material also can be added to modify the sponginess of a field, which, as in the case of the National Football League (NFL), is required to maintain a certain field firmness level (NFL, 2014). Certain high-use locations on a field might require replacement material more often than others (STC, 2015). Prior to every game, the NFL field testing program requires surface hardness to be measured in multiple field locations using the Clegg Impact Tester device (NFL, 2014) which can determine the surface hardness of a field by measuring how quickly a weight stops upon impact to that field (NFL, 2014). Through the use of the Clegg Impact Tester, a Gmax[12] score can be determined, quantifying field firmness. Outside the NFL testing program, the *Standard Specification for Impact Attenuation of Turf Playing Systems as Measured in the Field* (ASTM F1936) also can be used to determine the field surface firmness (Sports Turf Managers Association, n.d.). This standard establishes its own test method (ASTM F355) to determine surface firmness, suggests test point locations and specifies an upper limit of surface hardness when using another testing device (ASTM, 2015).

Maintenance practices can vary based on the budget for field maintenance and employee knowledge of these practices (Pennsylvania State University Center for Sports Surface Research, 2016). Synthetic turf fields typically last about eight years before replacement, but can last longer, depending on the frequency of their use and level of maintenance (STC, 2016).

[12] Surface hardness is measured in Gmax, which is the ratio of maximum negative acceleration on impact in units of gravities to the acceleration due to gravity (McNitt & Petrunak, 2013). The higher the Gmax value, the harder the surface. A Gmax value should be related to the device that is measuring hardness. For instance, a 100 Gmax with the Clegg Impact Tester is not the same as a 100 Gmax with the F355 device (NFL, 2014).

B. Literature Review/Gaps Analysis Overview

To comprehensively understand the current state-of-the science and data gaps associated with the toxicity of and human exposure to constituents in tire crumb rubber, CDC/ATSDR, EPA and CPSC undertook a collaborative effort to review the scientific literature and analyze data gaps (See Appendix B). The first objective of the Literature Review/Gaps Analysis (LRGA) collaboration was to identify the existing body of literature related specifically to human exposure to tire crumb rubber through the use of synthetic turf athletic fields and playgrounds. The second objective was to characterize and summarize the relevant data from the scientific literature. The final objective was to review the summary information and identify data gaps to build on the current understanding of the state-of-the-science and inform the development of specific research efforts that would be most impactful in the near-term.

Federal researchers examined a wide variety of information sources to build a list of relevant citations. The literature search included the following databases: PubMed Medline (OVID); Embase (OVID); Scopus; Primo (Stephen B. Thacker CDC Library); ProQuest Environmental Science Collection; Web of Science; ScienceDirect and Google Scholar. The LRGA focused on scientific publications that addressed tire crumb rubber use, physical characteristics and chemical composition, potential pathways of exposures, bioavailability, and component toxicity and risk assessment. It included studies that examined occupational exposures at tire recycling plants, human exposures related to field and playground installations, and subsequent exposures involved with use of synthetic turf and playground facilities. It did not include studies on automotive tire manufacturing processes and related exposures and risks. In determining whether or not to include a publication found in the course of the literature search, a set of relevance criteria was developed. A Quality Assurance Project Plan was also developed to guide data collection, organization and analysis. A number of other steps were taken to ensure quality in data entry and analysis.

The LRGA identified 88 relevant references. Each reference that was reviewed was categorized according to 20 general information categories (e.g., study topic, geographic location, sample type, conditions, populations studied) and more than 100 sub-categories (e.g., for the study topic sub-categories included: site characterization, production process, leaching, off-gassing, microbial analysis, and human risk). As part of the effort, greater than 350 discrete chemical compounds also were identified in the literature collected for this effort and a list of potential chemical constituents was compiled to inform further research efforts.

The studies that were identified covered a wide range of topics and locations, but some topic areas received greater coverage than others. For example, information on chemical leaching and offgassing and volatilizing from tire crumb rubber was found in 36 and 25 studies, respectively, but less information was available on microbiological, bioavailability, and biomonitoring aspects of tire crumb rubber exposures (i.e., seven, five, and three studies, respectively). No epidemiological studies were identified in the literature search. Data gaps could be more pronounced for locations such as playgrounds and indoor fields, and for studies that examine environmental background levels of tire crumb rubber constituents. Studies on occupational exposures from turf and playground installations were also limited. Metal constituents of tire crumb rubber, such as lead and zinc, have been frequently identified in the literature as a constituents of concern, but research on exposures to these metals by field and playground users is limited. While a number of volatile and semivolatile organic chemicals (especially polycyclic aromatic hydrocarbons) have been measured in some studies, research on other organic chemical constituents identified by the LRGA is more limited.

Other important data gaps include the lack of more in-depth characterizing of dermal and ingestion exposure pathways, identifying constituents and scenarios resulting in the highest exposures, developing and applying biomonitoring for constituents of concern, and assessing the feasibility and approaches for epidemiological investigations. Several important data gaps for assessing exposures and risks of tire crumb rubber at synthetic fields and playgrounds are summarized in Table 1.

The LRGA does not include critical reviews of the strengths and weaknesses of each study but does provide the author's conclusions regarding their research, where applicable. The LRGA does not make any conclusions or recommendations regarding the safety of the use of recycled tire crumb rubber in synthetic turf fields and playgrounds. The review provides information useful for guiding and designing future research efforts needed to further address questions regarding exposures and risks for tire crumb rubber used in synthetic turf fields and playgrounds.

See Appendix B for the full State-of-the-Science LRGA.

Table 1. Data Gaps for Research on Tire Crumb Rubber in Synthetic Fields and Playgrounds

	Research Area	Data Gaps
Tire Crumb Rubber Characterization	Chemical Characterization	• Studies that have measured metal, volatile organic chemicals (VOCs), and semi-volatile organic chemicals (SVOCs) (e.g., polycyclic aromatic hydrocarbons [PAHs] and benzothiazole) were usually based on small numbers of tire crumb rubber samples. The wide range of organic chemicals potentially used in tire manufacture, or their degradates, have not been analyzed systematically across a large range of tire crumb rubber samples from synthetic fields and playgrounds in the United States. • Limited information is available on chemical constituents in molded rubber products made with tire crumb rubber used in some playground settings.
	Emissions Assessments	• Few laboratory-based studies have investigated VOC and SVOC emissions from synthetic fields and playgrounds under different temperature conditions. Measurements using dynamic emission chamber measurements have been reported, but the number and types of measured chemical emissions have been limited.
	Microbial Assessments	• Microbiological assessments for synthetic turf fields and playgrounds have been limited and have been based on traditional culture methods. The use of molecular methods has not been applied in studies of tire crumb rubber.
	Bioaccessibility	• Several studies have examined potential bioaccessibility of metals and PAHs. However, studies that systematically measure a wider range of metal and organic chemical constituents, using multiple simulated biological fluids, and across a large range of tire crumb rubber samples are lacking.
	Variability	• Most studies characterizing tire crumb rubber from synthetic fields and playgrounds in the United States have been relatively small, and restricted to a few fields or playgrounds. Measurements for samples collected from a wider range of tire recycling plants, synthetic fields, and playgrounds across the United States is lacking. Also, information is limited on the range of chemical, microbiological, and physical characteristics and factors related to variability in tire crumb rubber and potential exposures.

Table 1 (continued). Data Gaps for Research on Tire Crumb Rubber in Synthetic Fields and Playgrounds

	Research Area	Data Gaps
Exposure/Risk Characterization	Exposure Factors	• Exposure and risk assessments have typically relied on generic exposure factors. Information specific to the frequency and duration of synthetic field and playground uses, physical activities, contact rates, and hygiene are limited. • Exposure factor data are not available either across the wide variety of sports and recreational users of synthetic turf fields and playgrounds with tire crumb rubber, or for occupational exposures.
	Dermal/Ingestion Exposures	• While multiple studies have attempted to characterize potential inhalation exposures to tire crumb rubber chemical constituents, more limited information is available for understanding dermal and ingestion exposures.
	Broken Skin/Ocular Exposures	• Little information is available on the potential for increased exposures via broken skin (i.e., due to cuts and scrapes) and through ocular fluids.
	Particle Exposures	• There is limited information on exposure to tire crumb particles and their constituents through inhalation, dermal, and ingestion. Information on the exposure potential as synthetic fields and playgrounds age and weather, and for various uses and activities on synthetic fields and playgrounds is limited.
	Variability	• Few studies have evaluated the variability of exposures to tire crumb rubber constituents by activity type, exposure scenario, age, material type and condition, facility type and condition, and ambient conditions such as temperature and wind or ventilation. Limited information is available on the variability of exposures and related factors across a wide range of user groups and scenarios. • A few studies suggest that inhalation exposures at indoor facilities are higher compared to those at outdoor facilities, but the available information is limited.
	Biomonitoring	• Only a few biomonitoring studies have been performed. Only hydroxypyrene has been measured as a biomarker in athletes and workers. • Additional tire rubber-specific biomarker measurements have not been reported for synthetic field and playground users and biomarker analysis methods might be lacking for some chemicals. • Large scale biomonitoring studies of populations exposed and not-exposed to synthetic turf fields and playgrounds with tire crumb rubber have not been reported.
	Cumulative/Aggregate Assessments	• Exposures to multiple tire crumb constituents are likely to occur via multiple pathways (e.g., inhalation, ingestion, and dermal contact). However, studies that evaluated cumulative and aggregate exposure and risks are limited.
	Epidemiology Studies	• No epidemiological investigations for synthetic turf field or playground users were identified in the literature review. • Survey and biomonitoring tools for accurate assessment of relative exposures for synthetic field and playground users in an epidemiological study are lacking.
Alternative Assessments	Alternative Infills/Materials	• Most research to date has focused on characterizing tire crumb rubber infill. Similar research on other infill materials, including natural materials, ethylene propylene diene monomer (EPDM), thermoplastic elastomers (TPE), and recycled shoe rubber are either lacking or limited.
	Natural Grass Fields	• Few studies have been performed to assess potential chemical exposures from natural grass playing fields.
	Other Exposure Sources	• Only a few comparative assessments have been performed on relative exposures to chemicals associated with tire crumb rubber from other sources.

C. Data Collection for Synthetic Turf Fields/Summary of Activity to Date

This section provides updates on the tire crumb rubber characterization and human exposure characterization research components of the FRAP.

The tire crumb rubber characterization study is an evaluation of tire crumb rubber samples collected from tire crumb rubber manufacturing plants and from indoor and outdoor synthetic turf fields in the four U.S. census regions. The human exposure characterization study is a pilot-scale exposure study to gather activity data and exposure measurements from people who regularly perform athletic activities on synthetic turf fields.

Prior to initiating the study, federal researchers developed the research protocol titled *Collections Related to Synthetic Turf Fields with Crumb Rubber Infill*. The research protocol describes the following specific elements of the FRAP:

- literature review and data gaps analysis;
- tire crumb rubber characterization research;
- human exposure characterization research.

The study protocol was reviewed by independent external peer reviewers, CDC's Institutional Review Board (IRB) and EPA's Human Subjects Research Review Official. The data collection components of the study went through the Office of Management and Budget (OMB) Information Collection Request (ICR) review process. The OMB ICR process included a public comment period[13]. On August 5, 2016, EPA, CDC/ATSDR and CPSC received final approval to begin the research.

Field collections started in mid-August. Collection of samples for the tire crumb rubber characterization component of the study is now complete, and analyses of the samples are in progress. Recruitment of fields and participants for the exposure characterization work is also underway.

A summary of these activities is provided in this section with more details provided in Appendix C.

[13] Public and peer review comments and the agencies' responses are available on the OMB's website – http://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201607-0923-001.

Tire Crumb Rubber Characterization Study

The tire crumb rubber characterization study involved the collection of crumb rubber material from tire recycling plants and synthetic turf fields from the four U.S. census regions, with laboratory analysis for a wide range of metals, VOCs, SVOCs, particle characteristics, and microbes.

Figure 6 summarizes the sampling and proposed analyses under the research protocol. The sampling of nine recycling plants and 40 indoor and outdoor synthetic turf fields, as proposed, has been completed. The numbers and types of samples collected from synthetic turf fields are shown in Table 2. Samples were collected from three lots or storage containers at the nine recycling plants, giving a total of 27 samples each for metals analyses, SVOC analyses, and particle characterization.

Table 2. Samples Collected for Analyses at Synthetic Turf Fields

Region	Individual Location Samples Collected Across 40 Fields[a]				Total Composite Samples Prepared[c]
	For Organic Chemical Analysis	For Metals Analysis	For Particle Characterization	For Microbial Analysis	
Northeast	63	63	63	63	18
Midwest	56	56	56	56	16
South	91	91	91	91	26
West	70	70	69[b]	70	20
Total	280	280	279	280	80

[a]At each field, samples were collected from seven individual locations.
[b]The cap came off of one sample collection container during transport.
[c]For each synthetic turf field, one composite sample was prepared in the laboratory from the seven individual location samples for organic chemical analyses and one composite sample was prepared for metals analyses.

Laboratory analyses are in progress including analysis of metals and SVOCs in the tire crumb rubber, particle characterization, dynamic emission chamber measurements for VOCs and SVOCs under different temperature conditions, and bioaccessibility measurements for metals and SVOCs. The emissions and bioaccessibility experiments will provide important information about the types and amounts of chemical constituents in the tire crumb rubber material available for human exposure through inhalation, dermal, and ingestion pathways.

In addition to quantitative target chemical analyses, suspect screening and non-targeted analysis methods are being applied for VOCs and SVOCs to determine whether there could be potential chemicals of interest that have not been identified or reported in previous research. In addition to the potential for chemical exposures at synthetic turf fields, concerns have been raised about the potential for exposure to microbial pathogens. The study also involved the collection of tire crumb rubber infill from synthetic turf fields to assess microbial populations. The status of the ongoing tire crumb rubber sample analyses is shown in Table 3.

Table 3. Status of Laboratory Analyses for Tire Crumb Rubber Characterization

Sample Type	Status
Direct Constituent Analysis	
Metals constituent ICP/MS analyses	In Progress
Metals constituent XRF analyses	In Progress
SVOC constituent LC/MS analyses	In Preparation
SVOC constituent GC/MS analyses	In Preparation
Dynamic Chamber Emissions Experiments	
Chamber experiments for VOCs in TC at 25°C	Completed
Chamber experiments for VOCs in TC at 60°C	Completed
Chamber experiments for SVOCs in TC at 25°C	Completed
Chamber experiments for SVOCs in TC at 60°C	Completed
Emissions Sample Analyses	
VOC emissions analyses	In Progress
Formaldehyde emissions analyses	In Progress
SVOC emissions LC/MS analyses	In Progress
SVOC emissions GC/MS analyses	In Progress
Particle Characterization Analysis	
Particle size characteristics	In Progress
Scanning electron microscopy	In Preparation
Microbial Sample Analysis	
Microbial analyses – targeted	In Progress
Microbial analyses – non-targeted	In Progress
Bioaccessibility Analysis	
Metals bioaccessibility analyses	In Preparation
SVOC bioaccessibility analyses	In Preparation

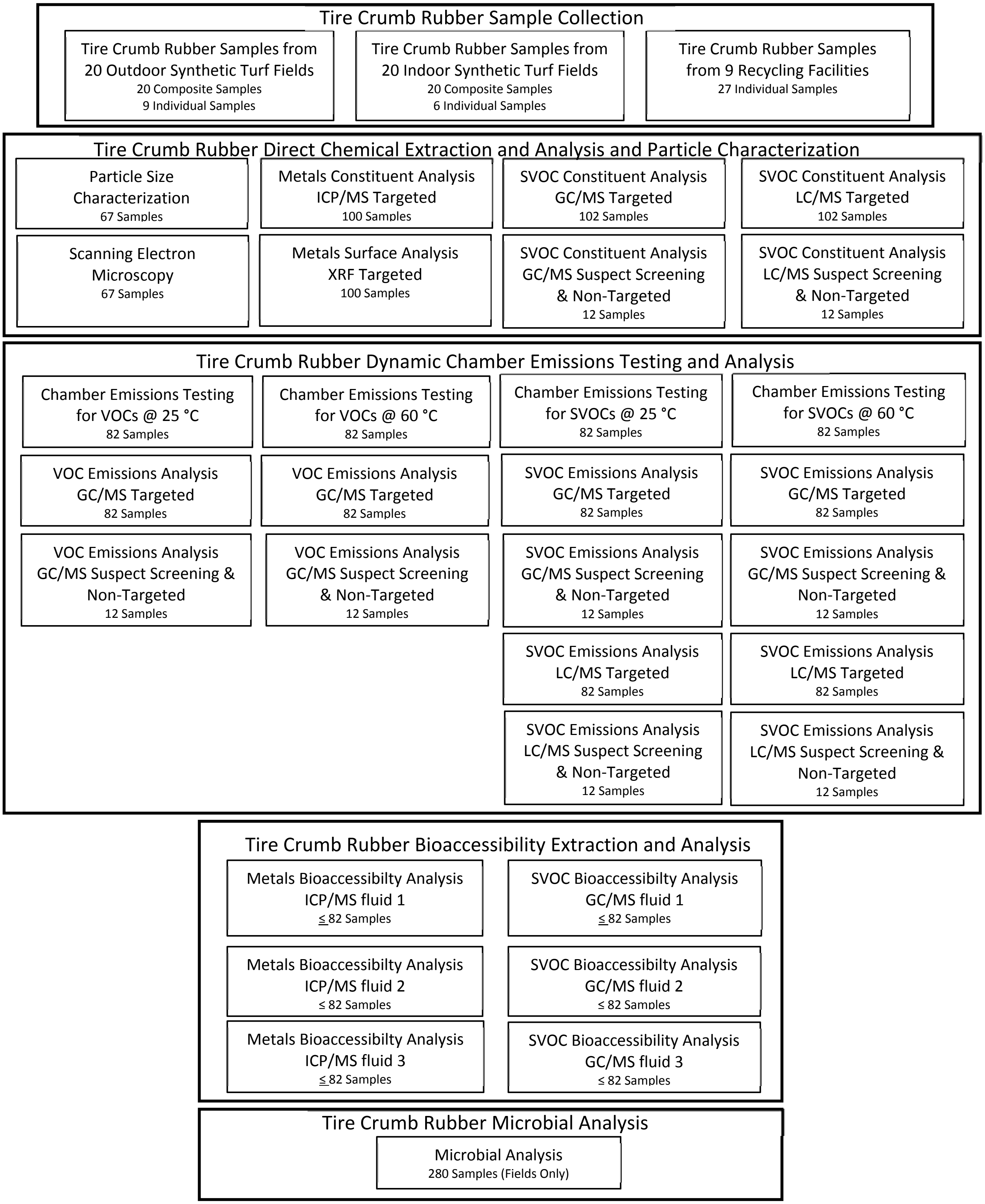

Figure 6. Proposed Tire Crumb Rubber Characterization

Exposure Characterization Study

The exposure characterization study is a pilot-scale effort to: (a) collect information on human activity parameters for synthetic turf field users that affect potential exposures to tire crumb rubber constituents; and (b) conduct a human exposure measurement study to further develop and deploy appropriate sample collection methods to generate data for improved exposure characterization.

While the field recruitment process has begun, field collection has not yet commenced because fields with active sports seasons are not currently available. The agencies are continuing their efforts to identify fields that meet the study criteria. The following discussion and Figure 7 provide a summary of the proposed research. Appendix C provides additional details.

The agencies will survey and observe adults and youth (or the parents of children) who use synthetic turf fields with tire crumb rubber infill. Information will be collected to provide data about relevant parameters (such as frequency and duration of field use and contact rates with field materials for different activities) for characterizing and modeling exposures associated with the use of synthetic turf fields. For a subset of participants, the agencies will video tape the participants while they are participating in a physical activity on a synthetic turf field. In addition, publicly available videography of users engaged in activities on synthetic fields will be acquired. The videos will be used to provide information to characterize types of contact and contact rates that are difficult to capture consistently using surveys. A subset of participants providing survey responses also will be asked to participate in an exposure measurement study. A set of personal, biological, and field environment samples will be collected around a sport or training activity performed on a synthetic turf field. Personal and environmental samples will be analyzed for metal, VOC, and SVOC analytes, and a subset of VOC and SVOC samples will undergo suspect screening and non-targeted analysis. Biological samples will be held in a biorepository for future analysis once potential biomarker chemicals of interest are identified based on the tire crumb rubber and exposure characterization studies.

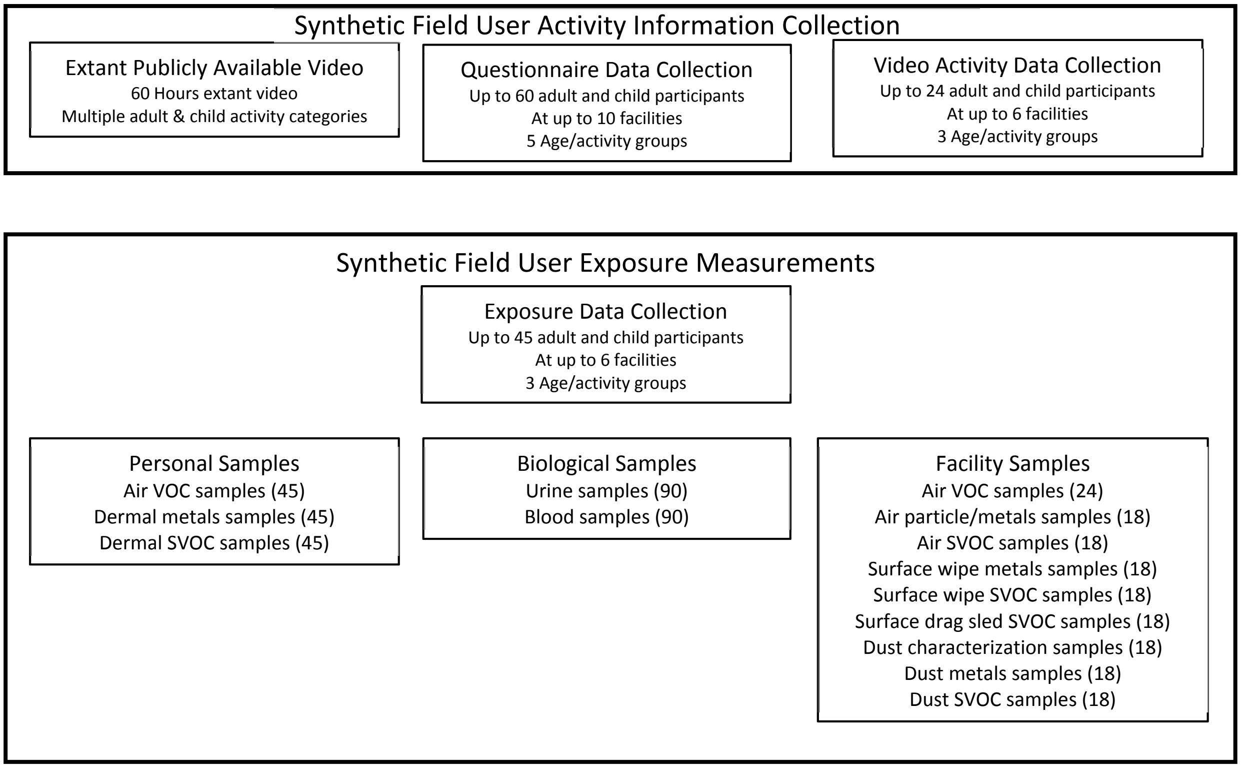

Figure 7. Summary of Proposed Exposure Characterization

D. Recycled Tire Materials in Playground Surfaces

Playground Surfaces

The role of CPSC in the FRAP is to identify and assess the risks associated with the use of recycled tire crumb rubber in playground surfaces. Shock-absorbing playground surfaces are designed to reduce the severity of injury and risk of death from vertical falls from playground equipment, compared to harder surfaces. The *Public Playground Safety Handbook*[14] from CPSC is a guide to promote safety awareness to those who purchase, install, and maintain public playground equipment used by children ages 6 months through 12 years (CPSC, 2010). This handbook includes guidelines on playground surfacing including those made with recycled tires. The staff of CPSC identified five general types of playground surfaces that are made with recycled tire materials: (1) loose-fill rubber, (2) rubber tiles, (3) poured-in-place rubber, (4) bonded rubber, and (5) synthetic turf. The *Public Playground Safety Handbook* provides some guidance on these surfacing types, and all playground surfacing should comply with the impact attenuation standards per ASTM F1292-13, *Standard Specification for Impact Attenuation of Surfacing Materials Within the Use Zone of Playground Equipment* (CPSC, 2010; ASTM, 2013b). Additional ASTM standards are available for specific surfacing types. See Appendix D for descriptions and standards applicable to each surface type.

Literature Review

The LRGA (Appendix B) notes that data gaps were more pronounced for recycled tire crumb rubber on playgrounds and indoor fields than for outdoor synthetic turf fields. The LRGA team and CPSC staff identified the limited scientific literature that examined the chemical safety of recycled tires in playground surfacing. Laboratory studies reported no evidence of genetic toxicity and skin sensitization potential associated with recycled tire playground surfacing (Birkholz, et al., 2003; OEHHA, 2007). Five reports of laboratory analyses identified extractable organic compounds and metals from recycled rubber playground surfacing, including PAHs, phthalates, and benzothiazole (Llompart, et al., 2013; Celeiro, et al., 2014; Highsmith, et al., 2009). California's Office of Environmental Health Hazard Assessment used exposure models of hand-to-mouth contact and direct ingestion of pieces of tire rubber and found minimal risk of cancer and non-cancer health effects to children (OEHHA, 2007).

Six literature reviews and other assessments of the health and ecological risks associated with the use of recycled tire rubber on playgrounds either support the relative safety of tire crumb rubber playground surfaces (Simon, 2010; Cardno Chem Risk, 2013; LeDoux, 2007; Anderson et al., 2006) or expressed concerns about hazards to children's health (Sullivan, 2006; Environmental and Human Health, Inc., 2007). The authors of these reviews discussed the limitations of the available data and concluded that additional studies are needed to support the safety of recycled tire rubber in playground surfacing.

[14] *Public Playground Safety Handbook* is available at: https://www.cpsc.gov/s3fs-public/325.pdf.

CPSC Activities

To support the understanding of exposure at playgrounds, CPSC is planning a survey of parents to get first-hand perspectives on potential exposures from playground surface materials. A survey of parents could provide valuable information on the behavioral factors that will be specific to scenarios of children interacting with recycled tire materials in playground surface. In late 2016, CPSC staff initiated preliminary data collection activities that will inform development of the national survey. These include field observations of children at public playgrounds and focus groups of people who visit and work at playgrounds.

In the field, CPSC staff observed children playing on playgrounds at public parks in a limited region of Maryland. After gaining permission from playground owners, CPSC staff observed children on playgrounds with loose-fill and unitary surfaces. Observation sessions were for 20-minute periods and occurred during approximately two weeks in October 2016. Observers recorded the incidences of ten behaviors of children interacting with playground surfacing during the observation session. Subjects were children who appeared to be six months to five years old. Observers did not interact with the children, parents, or anyone else at the playgrounds, and no identifying information about the children was collected. Each of the surface-interaction behaviors of interest was observed at least once for unitary and for loose-fill surfaces. This observational activity was very limited in scope and not intended to produce statistically representative data; however, the behaviors observed will be considered while developing the national survey.

Staff of CPSC engaged with a contractor with experience in conducting behavioral research for government agencies to perform focus groups as a method for collecting information to support development of the national survey of parents. A focus group is a collection of people assembled for a "carefully planned series of discussions designed to obtain perceptions on a defined area of interest in a permissive, nonthreatening environment" (Krueger & Casey, 2015). The focus groups will include three sets of participants: (1) parents of children between 1 and 3 years of age, (2) childcare providers of children between one and three years of age, and (3) playground inspectors. Participants will be recruited in the Washington, D.C. metropolitan area. The focus group moderator will lead an informal, but structured, discussion within each group to address a list of questions regarding playground visitation habits, children's activities and behaviors observed on playgrounds, clothing worn by children on playgrounds, snacks and refreshments consumed at playgrounds, hand-washing habits, and other similar topics. Visual aids will be provided to clarify understanding of the different types of playground surfaces. Participants will be compensated financially for their time. No recruitment of survey participants will begin until approvals are obtained from a human subjects IRB and OMB.

The staff of CPSC will work with the contractor to develop a national survey that will be distributed to parents and child caregivers in various regions of the United States. The survey questions will be developed based on information collected in the focus groups, playground field observations, and other research studies. The contractor will develop and propose sampling and data collection plan options necessary to obtain a nationally representative sample of households with children aged five and under. The timing of performance of the survey will depend on the preceding steps required before recruitment of participants can begin (i.e., OMB and IRB approval). Findings of the national survey will be used to inform development of exposure scenarios and exposure factors that can be used to estimate children's exposure to substances of concern in playground surfaces made with recycled tires.

Specific risk assessment strategies will be determined based on review of the new data, including the tire crumb rubber characterization and bioavailability studies currently being performed by EPA and ATSDR. The CPSC team will use exposure modeling to determine whether any of the bioavailable substances in recycled tires could pose a health hazard to children using playgrounds. Oral, dermal, and inhalation routes of exposure will be considered individually and in combination. The CPSC team might explore collection of samples at playgrounds with recycled tire surfaces for chemical analysis and bioavailability characterization; however, this plan comes with practical challenges.

More details on CPSC's review of the use of recycled tire materials in playground surfacing, literature review, and the ongoing data collection efforts can be found in Appendix D.

V. Next Steps and Timeline

Analysis of the tire crumb samples collected from fields and recycling facilities, and the exposure characterization component of the study, will continue in 2017. Parts of the exposure study may be conducted during the hotter months of 2017. The results of the research on synthetic turf fields are anticipated to be available in 2017. The CPSC playground study also will continue in 2017.

The agencies will continue to share information with other government agencies that have ongoing or planned tire crumb rubber. As it is available, updated information will be posted to EPA's tire crumb rubber website (www.epa.gov/tirecrumb) and stakeholder groups will be notified of these updates.

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Appendices

Appendix A – Stakeholder Outreach
Appendix B – State-of-Science Literature Review/Gaps Analysis
Appendix C – Data Collection for Synthetic Turf Fields/Summary of Activity to Date
Appendix D – Playground Surfaces with Recycled Tire Materials

Appendix A – Stakeholder Outreach

The EPA, CDC/ATSDR, and CPSC teams have engaged in a number of outreach activities to inform interested stakeholders about the Federal Research Action Plan (FRAP) and to gather and share information that may be used to inform the research. These outreach activities focused on three areas: 1) informing the public about the FRAP and encouraging them to provide feedback through a public comment process, 2) sharing information with government organizations that have planned and/or ongoing research efforts on this topic, and 3) conducting targeted outreach with organizations to gather additional information to help inform the implementation of the FRAP. These stakeholder outreach activities are further described below.

Informing the Public

Website

The FRAP was released on February 12, 2016. EPA, ATSDR, and CPSC developed a website (http://www.epa.gov/tirecrumb) describing the action plan and notified interested groups when the plan was announced. This website has been updated regularly throughout the research process in an effort to keep all stakeholders informed on the progress of the study. The website includes:

- An overview of the research;
- Frequently asked questions with answers;
- A fact sheet about the FRAP;
- Links to other available tire crumb rubber informational materials;
- A link to the Federal Register (FR) Notice, link to public comments and the agencies responses to public comments, and other information.

Using the website, interested individuals can sign-up to receive study updates via e-mail. To-date, more than 800 stakeholders have requested to receive updates about the study.

Webinar

The agencies published a FR Notice on February 18, 2016 requesting public comment on the data collection components of the FRAP (tire crumb rubber sample collection and collections related to the development of exposure scenarios). The data collection components were required to go through an Information Collection Request (https://www.epa.gov/icr) review conducted by Office of Management and Budget (OMB).

To encourage the general public to provide comments on the Federal Register Notice, the agencies hosted a webinar on April 14, 2016 describing the research study for anyone that was interested. This webinar was promoted on EPA's tire crumb rubber webpage, through the tire crumb rubber stakeholder e-mail list, and through EPA social media. The EPA, CDC/ATSDR, and CSPC research teams were available throughout the webinar to answer questions and provide extra detail where needed. More than 150 people participated in the webinar. The webinar was recorded and can be accessed through the FRAP website (http://www.epa.gov/tirecrumb).

Public Comment Period

The plans for the agencies to collect information (i.e. tire crumb sample collection and exposure information collection from field users) that are a part of the FRAP were available for public comment through a FR Notice. The agencies published the 60-day FR Notice on February 18, 2016 and extended the comment period at the public's request for two additional weeks to May 2, 2016. Once the FR Notice was posted, public comments were solicited by promoting the FR Notice on EPA's tire crumb rubber webpage, through the tire crumb rubber stakeholder e-mail list and through EPA social media. Members of the public submitted over 80 comments; these were addressed. The Notice, public comments, and responses to public comments are publicly available on OMB's website (http://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201607-0923-001).

Sharing Information with Other Government Agencies

The EPA, CDC/ATSDR, and CSPC teams engaged in outreach activities to share information with government organizations that have planned or ongoing research efforts. These outreach activities facilitated the sharing of expertise and information to help inform the implementation of the FRAP. Specific outreach activities included in-person meetings and conference calls. Examples of government organizations sharing expertise and information through these outreach activities are included below.

Regular Conference Calls with States

CDC/ATSDR hosts monthly calls with state public health agencies to discuss the FRAP. These calls were held to share information and updates on the on-going research and to answer questions. These calls typically have between 10 and15 state public agencies participating. EPA also kept the Association of State and Territorial Solid Waste Management Officials (ASTSWMO) and interested state solid waste agencies informed through periodic conference calls and updates at meetings throughout 2016.

Webinar

The EPA team hosted a webinar on April 12, 2016 for state and local government organizations describing the FRAP and the FR Notice. The EPA, CDC/ATSDR, and CSPC research teams were available throughout the webinar to answer questions and provide extra detail where needed. About 100 state and local groups participated in the webinar. The webinar was recorded and shared with states to distribute to others within their organizations who might be interested in the topic.

Government Agencies Sharing Expertise and Information

Other government agencies that are sharing information and have ongoing or planned tire crumb rubber research include California's Office of Environmental Health Hazard Assessment, the U.S. National Toxicology Program (NTP), headquartered at the National Institute of Environmental Health Sciences, the European Chemicals Agency, and the Netherlands National Institute for Public health and the Environment. The EPA, CDC/ATSDR, and CPSC teams have been meeting regularly with these organizations through conference calls and in-person meetings.

- ***California.*** As mentioned above, the state of California's Office of Environmental Health Hazard Assessment has an in-depth tire crumb rubber study underway. This study includes a series of scientific studies to determine if chemicals in tire crumb rubber and synthetic turf field materials can potentially be released under various environmental conditions and what, if any, exposures or health risks these potential releases may pose to players who frequently play on artificial fields constructed with tire crumb rubber. The evaluation includes expert solicitation and stakeholder participation to help guide the design. EPA, CDC/ATSDR and CPSC have shared information about methodology being used for the studies. The research plan includes animal toxicity studies, which are being conducted by NTP/NIEHS.
- ***International Agencies.*** Once the FRAP was announced, the European Chemicals Agency (ECHA) contacted EPA expressing their interest. ECHA is an agency of the European Union that implements chemical legislation for the protection of human health and the environment. This interest has resulted in regular calls with ECHA and an in-person meeting. During these meetings, information related to research efforts are shared. In addition, the Netherlands and France are also interested in studying tire crumb rubber exposure and characterization and communications with these organizations are on-going.

Conducting Targeted Outreach to Gather Additional Information

The purpose of conducting targeted outreach was to request informational resources from industry and non-profit organization/interest groups to inform the implementation of the FRAP. The EPA team held discussions with stakeholder groups, toured recycling facilities and observed field installations. Specifically, EPA, CDC/ATSDR, and CPSC requested information and existing studies about how tires and tire crumb rubber are manufactured; how synthetic turf fields are constructed, installed, and maintained; and other studies or information that could be used for the study

The objective was to enhance the agencies' understanding of how tires and tire crumb rubber are manufactured; and how synthetic turf fields are constructed, installed, and maintained, in order to identify potential variabilities in the tire crumb rubber product that is produced and installed in synthetic turf fields across the country.

Approach

The Paperwork Reduction Act (PRA) limited the number of entities that could be engaged by EPA to fewer than nine within a stakeholder group. In meetings that involved several different stakeholders, EPA was not seeking group consensus, input, or advice. Between February and September of 2016, EPA met or held conference calls with: five industry trade associations, three synthetic turf field companies, two synthetic turf field maintenance professionals, one academic institution, and five non-profit organizations. The EPA team also toured a total of five tire recycling facilities located in the south, west, and northeast regions of the United States., where both the ambient and cryogenic tire processing technologies were observed. The facilities ranged in size from small to large operations with varying degrees of mechanized technologies to process the tires. EPA observed the tire crumb rubber infilling process on two field installations in the Washington, D.C. metropolitan area. Study team members from CDC and CPSC also participated in several of the recycling facility and field installation observations. Collectively, presentations and information exchanges spanned a number of topics, including:

- The state of tire manufacturing and scrap-tire collection and recycling;
- The nature and varieties of processes and machinery used in the processing of scrap tires into tire crumb rubber;
- Tire-manufacturing standards;
- Tire recycling processing standards and/or tire crumb rubber product standards;
- Tire crumb rubber infill product types; storage, packaging, and transportation of tire crumb rubber to fields;
- The number and distribution of synthetic turf fields;
- Synthetic turf field construction, installation, and maintenance practices.

Participants often recommended resources the study team could consult for more information.

Use of Information Obtained

As previously stated, the purpose of the outreach effort was to help inform the study design and implementation of the FRAP. The information was also used to develop a preliminary summary of the tire and tire crumb rubber manufacturing process, as well as the process by which synthetic turf fields are constructed, installed and maintained. Over the next several months, EPA will continue to review, analyze, and supplement the information included in this status report and will provide an updated summary in the study's final report.

Appendix B – State-of-the-Science Literature Review/Gaps Analysis

Tire Crumb Research Study

State-of-the-Science Literature Review/Gaps Analysis

White Paper Summary of Results

December, 2016

Prepared By

U.S. Environmental Protection Agency / Office of Research and Development

Centers for Disease Control and Prevention / Agency for Toxic Substances and Disease Registry

U.S. Consumer Product Safety Commission / Directorate for Health Sciences

Disclaimer

This document has been reviewed by the U.S. Environmental Protection Agency, Office of Research and Development, the Agency for Toxic Substances and Disease Registry, and the Consumer Product Safety Commission and approved for release. In accordance with guidance in the US EPA's Peer Review Handbook, the document was sent out for an independent, external peer review to three subject matter experts with expertise in analytical chemistry, human exposure assessment, and human exposure modeling. The document was revised based on reviewer recommendations.

Any mention of trade names, products, or services does not imply an endorsement by the US Government.

I. Executive Summary

Concerns have been raised by the public about the safety of recycled tire crumb rubber used in synthetic turf fields and playgrounds in the United States. Recycled tire materials used for synthetic turf infill and playground surface applications may lead to human exposures to chemical constituents in tire material. Human exposures to tire crumb rubber vary with time and activity associated with use of synthetic fields and playgrounds. Limited studies have not shown an elevated health risk from playing on fields with tire crumb, but the existing studies have not comprehensively evaluated the concerns about health risks from exposure to tire crumb rubber and important data gaps exist (U.S. EPA, 2016).

Because of the need for additional information, the U.S. Environmental Protection Agency (EPA), the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry (ATSDR), and the U.S. Consumer Product Safety Commission (CPSC) launched a multi-agency action plan to study key environmental human health questions. The Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds (referred to hereafter as the Federal Research Action Plan) includes numerous activities, including research studies (U.S. EPA, 2016). The Federal Research Action Plan includes numerous activities related to the design and implementation of a tire crumb research study. An important component of the Action Plan is to identify key knowledge gaps to inform the conduct of other elements of the Federal Research Action Plan.

To comprehensively understand the current state-of-the science and data gaps associated with the toxicity of and human exposure to constituents in tire crumb rubber, CDC/ATSDR, EPA and CPSC undertook a collaborative effort to review the scientific literature and analyze data gaps (See Appendix B). The first objective of the Literature Review/Gaps Analysis (LRGA) collaboration was to identify the existing body of literature related specifically to human exposure to tire crumb rubber through the use of synthetic turf athletic fields and playgrounds. The second objective was to characterize and summarize the relevant data from the scientific literature. The final objective was to review the summary information and identify data gaps to build on the current understanding of the state-of-the-science and inform the development of specific research efforts that would be most impactful in the near-term.

Federal researchers examined a wide variety of information sources to build a list of relevant citations. The LRGA focused on scientific publications that addressed tire crumb rubber use, physical characteristics and chemical composition, potential pathways of exposures, bioavailability, and component toxicity and risk assessment. It included studies that examined occupational exposures at tire recycling plants, human exposures related to field and playground installations, and subsequent exposures involved with use of synthetic turf and playground facilities. It did not include studies on automotive tire manufacturing processes and related exposures and risks. In determining whether or not to include a publication found in the course of the literature search, a set of relevance criteria was developed. A Quality Assurance Project

Plan was also developed to guide data collection, organization and analysis. A number of other steps were taken to ensure quality in data entry and analysis.

The LRGA identified 88 relevant references. Each reference that was reviewed was categorized according to 20 general information categories (e.g., study topic, geographic location, sample type, conditions, populations studied) and more than 100 sub-categories (e.g., study topic sub-categories: site characterization, production process, leaching, off-gassing, microbial analysis, and human risk). As part of the effort, greater than 350 discrete chemical compounds also were identified in the literature collected for this effort and a list of potential chemical constituents was compiled to inform further research efforts.

The studies that were identified covered a wide range of topics and locations, but some topic areas received greater coverage than others. For example, information on chemical leaching and offgassing and volatilizing from tire crumb rubber was found in 36 and 25 studies, respectively, but less information was available on microbiological, bioavailability, and biomonitoring aspects of tire crumb rubber exposures (i.e., seven, five, and three studies, respectively). No epidemiological studies were identified in the literature search. Data gaps could be more pronounced for locations such as playgrounds and indoor fields, and for studies that examine environmental background levels of tire crumb rubber constituents. Studies on occupational exposures from turf and playground installations were also limited. Metal constituents of tire crumb rubber, such as lead and zinc, have been frequently identified in the literature as a constituents of concern, but research on exposures to these metals by field and playground users is limited. While a number of volatile and semivolatile organic chemicals (especially polycyclic aromatic hydrocarbons) have been measured in some studies, research on other organic chemical constituents identified by the LRGA is more limited.

Other important data gaps include the lack of more in-depth characterizing of dermal and ingestion exposure pathways, identifying constituents and scenarios resulting in the highest exposures, developing and applying biomonitoring for constituents of concern, and assessing the feasibility and approaches for epidemiological investigations. Several important data gaps for assessing exposures and risks of tire crumb rubber at synthetic fields and playgrounds are summarized in Table B-1.

The LRGA does not include critical reviews of the strengths and weaknesses of each study but does provide the author's conclusions regarding their research, where applicable. The LRGA does not make any conclusions or recommendations regarding the safety of the use of recycled tire crumb rubber in synthetic turf fields and playgrounds. The review provides information useful for guiding and designing future research efforts needed to further address questions regarding exposures and risks for tire crumb rubber used in synthetic turf fields and playgrounds.

Table B-1. Data Gaps for Research on Tire Crumb Rubber in Synthetic Fields and Playgrounds

	Research Area	Data Gaps
Tire Crumb Rubber Characterization	Chemical Characterization	• Studies that have measured metal, volatile organic chemicals (VOCs), and semi-volatile organic chemicals (SVOCs) (e.g., polycyclic aromatic hydrocarbons [PAHs] and benzothiazole) were usually based on small numbers of tire crumb rubber samples. The wide range of organic chemicals potentially used in tire manufacture, or their degradates, have not been analyzed systematically across a large range of tire crumb rubber samples from synthetic fields and playgrounds in the United States. • Limited information is available on chemical constituents in molded rubber products made with tire crumb rubber used in some playground settings.
	Emissions Assessments	• Few laboratory-based studies have investigated VOC and SVOC emissions from synthetic fields and playgrounds under different temperature conditions. Measurements using dynamic emission chamber measurements have been reported, but the number and types of measured chemical emissions have been limited.
	Microbial Assessments	• Microbiological assessments for synthetic turf fields and playgrounds have been limited and have been based on traditional culture methods. The use of molecular methods has not been applied in studies of tire crumb rubber.
	Bioaccessibility	• Several studies have examined potential bioaccessibility of metals and PAHs. However, studies that systematically measure a wider range of metal and organic chemical constituents, using multiple simulated biological fluids, and across a large range of tire crumb rubber samples are lacking.
	Variability	• Most studies characterizing tire crumb rubber from synthetic fields and playgrounds in the United States have been relatively small, and restricted to a few fields or playgrounds. Measurements for samples collected from a wider range of tire recycling plants, synthetic fields, and playgrounds across the United States is lacking. Also, information is limited on the range of chemical, microbiological, and physical characteristics and factors related to variability in tire crumb rubber and potential exposures.

Table B-1 (continued). Data Gaps for Research on Tire Crumb Rubber in Synthetic Fields and Playgrounds

	Research Area	Data Gaps
Exposure/Risk Characterization	Exposure Factors	• Exposure and risk assessments have typically relied on generic exposure factors. Information specific to the frequency and duration of synthetic field and playground uses, physical activities, contact rates, and hygiene are limited. • Exposure factor data are not available either across the wide variety of sports and recreational users of synthetic turf fields and playgrounds with tire crumb rubber, or for occupational exposures.
	Dermal/Ingestion Exposures	• While multiple studies have attempted to characterize potential inhalation exposures to tire crumb rubber chemical constituents, more limited information is available for understanding dermal and ingestion exposures.
	Broken Skin/Ocular Exposures	• Little information is available on the potential for increased exposures via broken skin (i.e., due to cuts and scrapes) and through ocular fluids.
	Particle Exposures	• There is limited information on exposure to tire crumb particles and their constituents through inhalation, dermal, and ingestion. Information on the exposure potential as synthetic fields and playgrounds age and weather, and for various uses and activities on synthetic fields and playgrounds is limited.
	Variability	• Few studies have evaluated the variability of exposures to tire crumb rubber constituents by activity type, exposure scenario, age, material type and condition, facility type and condition, and ambient conditions such as temperature and wind or ventilation. Limited information is available on the variability of exposures and related factors across a wide range of user groups and scenarios. • A few studies suggest that inhalation exposures at indoor facilities are higher compared to those at outdoor facilities, but the available information is limited.
	Biomonitoring	• Only a few biomonitoring studies have been performed. Only hydroxypyrene has been measured as a biomarker in athletes and workers. • Additional tire rubber-specific biomarker measurements have not been reported for synthetic field and playground users and biomarker analysis methods might be lacking for some chemicals. • Large scale biomonitoring studies of populations exposed and not-exposed to synthetic turf fields and playgrounds with tire crumb rubber have not been reported.
	Cumulative/Aggregate Assessments	• Exposures to multiple tire crumb constituents are likely to occur via multiple pathways (e.g., inhalation, ingestion, and dermal contact). However, studies that evaluated cumulative and aggregate exposure and risks are limited.
	Epidemiology Studies	• No epidemiological investigations for synthetic turf field or playground users were identified in the literature review. • Survey and biomonitoring tools for accurate assessment of relative exposures for synthetic field and playground users in an epidemiological study are lacking.
Alternative Assessments	Alternative Infills/Materials	• Most research to date has focused on characterizing tire crumb rubber infill. Similar research on other infill materials, including natural materials, ethylene propylene diene monomer (EPDM), thermoplastic elastomers (TPE), and recycled shoe rubber are either lacking or limited.
	Natural Grass Fields	• Few studies have been performed to assess potential chemical exposures from natural grass playing fields.
	Other Exposure Sources	• Only a few comparative assessments have been performed on relative exposures to chemicals associated with tire crumb rubber from other sources.

II. Table of Contents

III. Background

a. Problem Statement

Synthetic turf installations for athletic fields and other applications in the United States began to rise in popularity in the mid twentieth century. Modern synthetic turf products are typically composed of three layers – fiber material used to simulate grass blades, infill material for cushioning and stability, and backing material (Cheng et al., 2014). A common material used for infill is granulated crumb rubber from recycled tires.

One method of producing crumb rubber involves grinding used tires, removing steel and fiber tire components and sorting the rubber pellets by size. Pellet sizes can range from about one-sixteenth to one-quarter inch in diameter and are typically applied at a rate of two to three pounds per square foot of field surface (NYDOH, 2008). The Rubber Manufacturer's Association (2014) estimates that 24.4 percent of used scrap tires in the U.S. were recycled into crumb rubber. A major focus of the LRGA effort was to provide additional information on potential exposures at synthetic turf fields and playgrounds. Of the total tires recycled into crumb rubber in 2013, 31 percent was used in playground mulch and 17 percent was used in sports surfacing.

Given the widespread use of recycled tire rubber in synthetic turf and playground mulch applications, concerns about the toxicity of the recycled materials have arisen. Human exposures to the tire crumb rubber vary with time and activity associated with use of synthetic fields and playgrounds. Limited studies have not shown an elevated health risk from playing on fields with tire crumb rubber, but the existing studies do not comprehensively evaluate the concerns about health risks from exposure to tire crumb rubber (U.S. EPA, 2016).

Because of the need for additional information, the U.S. Environmental Protection Agency (EPA), the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry (ATSDR), and the U.S. Consumer Product Safety Commission (CPSC) launched a multi-agency action plan to study key environmental human health questions. The Federal Research Action Plan includes numerous activities, including a literature search and data gap analysis (LRGA) as well as various other research efforts (U.S. EPA, 2016). A key objective of the Action Plan is to identify key knowledge gaps.

b. Objectives of Literature Review/Gaps Analysis

In order to more fully understand data gaps associated with human exposure to tire crumb rubber and their toxicity, ATSDR, CPSC and EPA undertook a collaborative effort in the form of a scientific literature review and subsequent gaps analysis. The first objective of the collaboration was to identify the existing body of literature related specifically to human exposure to tire crumb rubber through the use of synthetic turf athletic fields and playgrounds. The second objective was to characterize and summarize the relevant data from the scientific literature. The final objective was to review the summary information and identify data gaps to help inform the development of specific research efforts.

c. Scope of Effort

The ultimate objective of the Literature Review and Gap Analysis (LRGA) effort was to inform the design of a Tire Crumb Research Study (TCRS) (EPA, 2016). Therefore, the scope of the LRGA was focused on the needs of the scientists designing the TCRS. The LRGA focused on identification of scientific publications that studied tire crumb rubber use, physical characteristics and chemical composition, potential pathways of exposures, bioavailability, and component toxicity. The LRGA did not include studies related to human or ecological exposures in automotive tire manufacturing processes. The LRGA focused only on the life cycle of tires that reach the facilities where they are converted to crumb rubber. Studies that examine occupational exposures at "tire to crumb rubber" generation facilities, human exposures related to field / playground installations, and subsequent exposures involved with use of synthetic turf / playground facilities were considered as part of the scope for this effort. Where literature existed in these areas of study, it was included in the LRGA analysis.

IV. Methodology

a. Data Sources

Research and commentary on tire crumb rubber is represented in a diverse set of publications. The LRGA effort explored a wide variety of information sources to build a list of relevant citations for this effort. Initial searches for relevant material began with the preliminary list of reports and bibliographic lists below. Additional literature relevant to this effort was identified by reviewing the references listed in the preliminary lists. Material collection for this document was completed in late May 2016, with sources ranging in release dates from 1991 to 2015. Literature sources released after May 2016 have not been included in the LRGA.

Preliminary Lists used to Identify Relevant Literature

- A Scoping-Level Field Monitoring Study of Synthetic Turf Fields and Playgrounds (U.S. EPA, 2009)
- Tire Crumb and Synthetic Turf Field Literature and Report List as of Nov. 2015 (U.S. EPA, 2015)
- CDC Review of Published Literature and Select Federal Studies on Crumb Rubber and Synthetic Turf (see Appendix A)
- Literature review of microbial work done on tire crumb rubber artificial fields (See Appendix B)
- EPA-NCEA Summary of Available Exposure and Health Risk Assessment Studies on Artificial Turf, Playgrounds and Tire Crumbs (See Appendix C)

The sources listed in Appendices A, B and C provided an initial starting point for identifying relevant publications for the LRGA. The scientists working on the LRGA conducted a literature search using the following databases: PubMed, Medline (OVID), Embase (OVID), Scopus, Primo (Stephen B. Thacker CDC Library), ProQuest Environmental Science Collection, Web of Science, ScienceDirect, and Google Scholar. The Key Terms used in these searches included the following terms: Artificial Turf, Synthetic Turf, Crumb Rubber, Tire Crumb Rubber, Sports Field, Turf, Exposure, Analytes, Chemicals, Elements, Human Health Effects, Adverse Health Effects, Environmental Exposure, Health Risk, Health Impact, Toxicity, Toxic, Carcinogen, Emission, Off-gas, Routes of Exposure, Infill, Risk.

A separate, independent literature search was performed by the EPA library in Durham, NC. The goal of this search was to identify any relevant tire crumb rubber exposure publications and sources that were not identified in the initial search conducted by the LRGA scientists. The following terms were used for both searches:

- Tire Crumb
- Artificial Turf
- Synthetic Turf
- Toxicity
- Health Risks
- Eco Risks
- Leaching
- Human Exposure
- Benzothiazole (BHT)
- Lead
- PAHs

The EPA library literature search can be found in Appendix D.

Based on these information sources, the LRGA team identified relevant literature from the following areas: (1) Journal publications, (2) Reports, white papers, fact sheets, and similar publications developed by federal and state agencies (3) Reports on industry-sponsored research, including white papers, fact sheets, and similar publications and (4) Symposium/conference proceedings. The list of relevant publications is provided in Appendix E.

The references were stored in an Excel spreadsheet that was also used to synthesize the information from the studies. A Microsoft SharePoint site was created as a central repository of all the information relevant to the LRGA, including the literature, spreadsheet, and other materials.

b. Factors & Criteria for Literature Source Inclusion

Factors outlined by the EPA Science Policy Council in “A Summary of General Assessment Factors for Evaluating the Quality of Scientific and Technical Information” were considered in the identification of literature for this project (U.S. EPA, 2003). These are (1) Applicability and

Utility; (2) Evaluation and Review; (3) Soundness; (4) Clarity and Completeness; and (5) Uncertainty and Variability.

The objective of the LRGA team was to cite literature that conformed to these five factors. However, several of the studies did not fully conform to some aspect of the outlined criteria. For instance, there were several white papers and reports in relevant technical areas that were not independently peer-reviewed or peer review was not documented. Although these and other references did not fully conform to one or more of the criteria, they were included in the LRGA because they provided useful information in better understanding risks from tire crumb rubber.

In determining whether or not to include a publication in the LRGA, a set of relevance criteria were developed. An iterative approach was used to address the relevancy of the publications. First, the title of the publication was reviewed to see if it included one or more of the criteria terms below. If it was unclear whether the publication was relevant based upon the title, the publication abstract was reviewed for relevance. If it was unclear whether the publication was relevant based upon the abstract, parts or all of the body of the publication was reviewed. If the information was found to be applicable, the publication was included in the LRGA.

<u>Relevance Criteria</u>
Tire Crumb
Artificial Turf
Synthetic Turf
Tire Crumb Toxicity
Tire Crumb Health Risks
Tire Crumb Ecological Risks
Synthetic Turf Leaching
Human Exposure to Tire Crumb

c. Quality Assurance & Assumptions

A Quality Assurance Project Plan (QAPP) was developed as part of this effort to guide data collection, organization and analysis. EPA policy (U.S. EPA, 2008) is based on the national consensus standard ANSI/ASQ E4-2004 Quality Systems for Environmental Data and Technology Programs: Requirements with Guidance for Use. This standard recommends a tiered approach that includes the development and use of Quality Management Plans (QMPs). The organizational units in EPA that generate and/or use environmental data are required to have Agency-approved QMPs. A programmatic QMP was developed for the overall TCRS. The TCRS QMP is supported by project-specific QA project plans (QAPPs). A QAPP was prepared and included the technical details and associated QA/QC procedures for the LRGA components.

Due primarily to time constraints, a number of assumptions were made in the conduct of the literature review and subsequent analysis of data gaps. For example, while the LRGA team performed extensive searches to find relevant literature for analysis it is possible that other sources exist which were inaccessible, unavailable or not found during the literature search.

Because publications were typically “screened” for relevance based upon their title and/or abstract, but not always the entire publication, it is possible that relevant information may have been overlooked. Finally, as indicated in Section IV B., it was assumed that most, if not all, journal articles from the scientific literature had been peer reviewed. However, peer review status was not always used as a deciding factor whether to include a source in the LRGA (see Section IV B).

d. Literature Review and Data Extraction

All relevant studies were reviewed and characterized according to the information categories and sub-categories shown in Table B-2 The information was extracted from the papers and reports and entered into an Excel spreadsheet that allowed the data to be sorted according to the various topic areas. The results were filtered according to the various categories and subcategories to assess the frequency that the various topic categories were represented by the universe of literature reviewed. A brief description of the results and conclusions from each study was also provided in the spreadsheet. A screenshot of a portion of the LRGA spreadsheet is provided in Figure B-1. The entire LRGA spreadsheet can be viewed on the EPA’s Federal Research Action Plan on Recycled Tire Crumb Status Report website.

Table B-2. Information Categories and Subcategories Used in LRGA Spreadsheet		
Categories	**Subcategories**	
1. Reference Type	Journal Article Report Report of Peer Review Abstract	1. Reference Type
2. Study Topic(s)	Literature Review Data Gaps Site Characterization Production Process Constituent Characterization Leaching Stormwater Runoff Site Monitoring Headspace/de-gassing-Bulk Off-gassing/volatilizing Human Exposure	2. Study Topic(s)
3. Geographic Location	See spreadsheet: Status Report website	
4. Study/sample Location	Laboratory Indoor Field Outdoor Field Natural Grass Field	4. Study/sample Location
5. Sample Type	Bulk Crumb Rubber Bulk Grass Blades or Fibers Alternative Fill Type Leachate Urine	5. Sample Type
6. Conditions Studies	Age or Weathering Meteorological Geographical Indoor vs Outdoor Synthetic vs Natural	6. Conditions Studies
7. Populations Studied	Children/Teens Adults Athletes	7. Populations Studied
8. Constituents Evaluated	VOCs SVOCs Inorganics Lead	8. Constituents Evaluated
9. Specific Constituents Studies	See Appendix F and Status Report website	
10. Constituents of Highest Concern	See Status Report website	
11. Number of Observations/Samples	See Status Report website	
12. Human Exposure Route	Ingestion Inhalation Dermal	
13. Exposure Factors Used to Assess Exposure	Body Weight Inhalation Rate Ingestion Rate Skin Surface Area Adherence Bioavailability Fraction Absorption Fraction	13. Exposure Factors Used to Assess Exposure
14. Risk Assessment	Cancer Non-cancer Screening	14. Risk Assessment
15. Toxicity or Regulatory Data Used	See Status Report website	
16. Risk Characterization	See Status Report website	
17. Risk of Highest Concern	See Status Report website	
18. Brief Description of Results	See Section VI, and Status Report website	
19. Additional Information or Comments	See Status Report website	
20. Related References	See Status Report website	

Literature Review and Data Gap Analysis Spreadsheet						Reference Type								Study Topic(s)															
Study #	Have study?	Reviewed?	See Constituent Tab	See Related References	References - Scientific Literature	Journal Article	Report	Report of Peer Review	Abstract	Manuscript	Summary Only	Website	Memo	Literature Review	Data Gaps	Site Characterization	Production Process	Constituent Charac.	Leaching	Stormwater runoff	Site Monitoring	Head Space/de-gassing-Bulk	Off-gassing/volatilizing	Human Exposure	Human Risk	Microbial	Epidemiologic	Biomonitoring	Bioavailability
1	y	y	n	n	Anderson, ME; Kirkland, KH; Guidotti, TL, Rose, C. (2006). A Case Study of Tire Crumb Use on Playgrounds: Risk Analysis and Communication When Major Clinical Knowledge Gaps Exist. Environ Health Perspect. 114(1):1-3.	x								x	x														
2	y	y	y	n	Anthony, D.H.J. and Latawiec, A. (1993). A preliminary chemical examination of hydrophobic tire leachate components. National Water Research Institute, Burlington, Ontario, Canada, Report No. 93-78. Part III. Parts I and II not reviewed: not relevant (see comments).		x												x										
3	y	y	n	n	Bass, JJ; Hintze, DW. (2013). Determination of Microbial Populations in a Synthetic Turf System. Skyline-The Big Sky Undergraduate Journal 1(1):1.	x																			x	x			
4	y	y	n	n	Beausoleil, M; Price, K; Muller, C. (2009). Chemicals in outdoor artificial turf: a health risk for users? Public Health Branch, Montreal Health and Social Services Agency. http://www.nccoh.ca/sites/		x							x	x									x	x				

Figure B-1. Screenshot of a portion of the LRGA spreadsheet (see full spreadsheet on the Status Report website).

A list of potential chemical constituents was also developed based on chemicals identified in the various studies. The list included the name of the chemical, CAS number, synonyms, and concentrations observed in the various studies. EPA's National Center for Computational Toxicology assisted by providing CAS numbers and synonyms for constituents for which this type of information was not provided in the study. The constituents list is provided in Appendix F. A screenshot of a portion of the chemical constituents' spreadsheet is provided in Figure B-2.

Analyte	Synonym(s)	CAS#	12. Cheng and Reinhard 2014; Potential Contaminants that can Leach from Tires	15. CDPH 2010; Maximum Detected			
				4 Outdoor Fields		1 Indoor Field	
				ug/m^3	Monitor type	ug/m^3	Monitor typ
Carbon Tetrachloride		56-23-5					
Chlorobenzene		108-90-7					
Chloroform	Trichloromethane	67-66-3					
Chloromethane	Methyl chloride	74-87-3		1.7	Personal	1.57	Personal
Chrysene		218-01-9	x	3.40E-04	Stationary		
Coronene		191-07-1	x				
o-Cyanobenzoic acid	2-Cyanobenzoic acid	3839-22-3					
Cyclohexanamine	Cyclohexylamine	108-91-8					
Cyclohexanamine, N-cyclohexyl-	Dicyclohexylamine	101-83-7					
Cyclohexanamine, N-cyclohexyl-N-methyl-	N-Cyclohexyl-N-methylcyclohexanamine	7560-83-0					
Cyclohexane		110-82-7		17.5	Personal	10.3	Personal
Cyclohexane, isocyanato	Isocyanatocyclohexane	3173-53-3					
Cyclohexane, isothiocyanato-		1122-82-3					
Cyclohexanone		108-94-1					
N-Cyclohexyl-2-benzothiazolesulfenamide (CBS)	N-Cyclohexyl-2-benzothiazolesulfenamide	95-33-0					
n-Cyclohexyl-formamide	N-Cyclohexylformamide; Formamide, N-cyclohexyl	766-93-8					
Cycloninasiloxane, octadecamethyl-	Octadecamethylcyclononasiloxane	556-71-8					
Cyclopenta[cd]pyrene		27208-37-3	x				
4H-cyclopenta[def]phenanthren-4-one	4H-Cyclopenta(def)phenanthren-4-one	5737-13-3	x				
4H-cyclopenta[def]-phenanthrene	4-H-Cyclopenta(d,e,f)phenanthrene	203-64-5	x				

Figure B-2. Screenshot of a portion of the constituent spreadsheet (see Appendix F for the list of constituents; the full spreadsheet is available on the Status Report website).

V. Results

a. Summary Statistics

A total of 97 studies were identified by the methods described in Section IV. Seven were reviewed, but not included in the LRGA analysis because were found to be outside the scope of the project, and two were found to be duplicates of studies already included in the LRGA (see the full literature review spreadsheet for additional details on the Status Report website). The final number of studies evaluated was 88. More than 350 potential chemical constituents were identified in the resources reviewed for the LRGA (see Appendix F for additional details).

Table B-3. Summary Statistics	
References Identified for Consideration in the LRGA	97
References Not Included in LRGA Analysis Due to Irrelevance, etc.	7
Duplicate references	2
TOTAL NUMBER OF REFERENCES INCLUDED IN LRGA	**88**
Discrete Chemical Compounds Identified in Constituent Analysis	>350
LRGA References Included in Constituents List	38

b. Reference Types

Reference Type refers to the nature of the document reviewed. Journal articles are publications in the scientific literature that are typically peer reviewed. Reports represent documents prepared by government, contractor, university, industry or other entities. Reports of peer reviews are typically summaries of comments by reviewers of reviewed documents. Abstracts include short descriptions of documents which may precede a more detailed discussion on the relevant topic. Additional reference types included summaries only, website text, and memos which are self-explanatory.

The Literature Review/Gaps Analysis (LRGA) team examined all of the above reference types in the course of the effort. The majority of sources identified were either Journal Articles (43) or Reports (40). Of the other reference types included in the analysis (i.e., Report of Peer Review, Abstract, Summary Only, Website, and Memo), only one citation was identified for each reference type. This demonstrated the extent to which the literature search was oriented toward Journal Articles and Reports, which typically provided the most relevant, comprehensive information on tire crumb rubber.

c. Study Topics

The LRGA team identified 20 different Study Topics across the literature reviewed. An "other" category was also included to capture additional topics not covered by the 20 main categories. "Study Topic" refers to the focus of the document. In some cases, documents included information on one topic (e.g., a literature review). In other cases, documents addressed more than one topic. For example, a document may include both a review of the existing scientific literature, but also include the results of novel research aimed at addressing specific questions (e.g., leaching of chemicals from tire crumb rubber, or site monitoring to assess human health risk from exposure to tire crumb rubber). Table B-4 provides a summary of the number of studies that addressed each of the various topic areas.

Table B-4. Number of Studies that Addressed Various Topic Areas	
Leaching	36
Human Risk	32
Human Exposure	27
Eco Exposure/Risk	26
Literature Review	24
Toxicity Assessment	19
Constituent Characterization	16
Headspace/de-gassing-Bulk (lab)	13
Off-gassing/volatilizing (field)	12
Site Monitoring	12
Data Gaps	11
Stormwater Runoff	7
Microbial	7
Production Process	6
Bioavailability	5
Modeling	5
Site Characterization	4
Biomonitoring	3
Risk Communication	2
Epidemiologic	0
Other	31

The bulk of the Study Topics identified in the LRGA addressed leaching of tire crumb rubber constituents, exposures to humans and ecosystems from tire crumb rubber and subsequent risks from those exposures, and previous literature reviews intended to better understand tire crumb rubber constituents, exposures or toxicity. Toxicity assessment, characterization of constituents found in tire crumb rubber and site monitoring, and volatilizing of constituents from crumb material in either the lab or field were also frequently recorded Study Topics. Studies that were categorized in the 'Other' topic category included topics such as gastric digestion simulations, skin abrasion, assessments of study protocols, mutagenicity assessments, etc. A full list of the "Other" types can be found in the Literature Review Spreadsheet on the Status Report website. Lack of information in Study Topic areas may be an early indicator of data gaps which may require more research.

d. Geographic Locations

Information related to geographic location was collected as part of the LRGA effort in order to provide spatial context for the data. The level of geographic information was typically recorded at the state or country scale. Geographic location was recorded for more than 50 of the studies included in the LRGA. Thirteen U.S. states were represented by one or more studies (i.e., California, Colorado, Connecticut, Florida, Maine, Nevada, New Jersey, New York, Ohio, Pennsylvania, Utah, Virginia, and Washington). Other countries identified in the analysis included nations such as Canada, Denmark, France, Italy, Japan, Korea, Norway, Spain, Sweden, Taiwan and The Netherlands. There were a total of 30 sources for which no locational information was provided or was non-applicable.

e. Study/Sample Locations

The Study/Sample Location category differs from the Geographic Location category. It refers to the type(s) of site(s) where samples were collected or analyzed. For example, a study to identify the constituents in tire crumb rubber may have been conducted entirely in the laboratory using manufactured tire crumb rubber. Alternatively, tire crumb rubber samples may have been collected from an indoor or outdoor field. Samples may also have been collected from both synthetic turf and natural fields or background locations, or from playgrounds or other locations where tire crumb rubber may be used.

The subset of Study/Sample Locations included Scientific Laboratories, Indoor Fields, Outdoor Fields, Natural Grass Fields, Synthetic Grass Fields, Playgrounds and Other types. For the purpose of the LRGA, "Scientific Laboratories" were defined as indoor facilities with controlled environments and specific quality assurance procedures. "Indoor Fields" were located inside enclosed facilities with climate control, and "Outdoor Fields" were in open or partially contained facilities with some open air access. "Synthetic Grass Fields" included a variety of designs, but were typically composed of an underlay material, tire crumb rubber infill and synthetic blades. "Natural Grass Fields" were surfaces with specifically real grass plants with natural soil material. A variety of "Playgrounds" were included which generally refer to an area with recreational equipment anchored in the ground with surrounding tire crumb rubber used for cushioning surface. An eighth type of Study/Sample Location was identified as "Background" which refers to analyses conducted to determine background levels of tire crumb rubber constituents.

Of the sources included in the LRGA, most (42) involved analysis in a scientific laboratory (Table B-5). The analysis also showed that 35 literature sources included analysis conducted on or in the area of a synthetic turf field; 20 of these involved outdoor fields and 8 involved indoor fields, and others did not specify. There were 8 studies that addressed natural grass fields and 8 that addressed background locations. Nine sources examined playground environments, however because Kim et al. (2012b) uses the term "playgrounds" to mean facilities traditionally defined as athletic fields, this number was adjusted to eight sources. The 13 "Other" locations included roadbeds, parking lots, new/commercial products, test plots, mulch, green roofs, and rubber running tracks. A full list of the "Other" types can be found in the Literature Review Spreadsheet on the Status Report website.

The focus of the LRGA was synthetic athletic field and playground environments. Artificial turf marketed for private residential homes may also provide an additional exposure pathway, and may contribute to cumulative exposures to a variety of materials found in tire crumb rubber. However, publications pertaining to residential use were not included in the LRGA.

Table B-5. Number of Studies in Each Study/Sample Site Category	
Laboratory	42
Synthetic Grass Field	35
Outdoor Field	20
Playground	8
Indoor Field	8
Natural Grass Field	8
Background	8
Other	13

f. Sample Types

The Sample Type category refers to the nature of the sample(s) collected. For example, samples of bulk tire crumb rubber or artificial grass blades/fibers may have been collected for the purpose of leaching studies, or air samples may have been collected by stationary area samplers or by personal breathing zone samplers. Other examples include wipe samples from fields or tire crumb rubber for assessing dermal exposure, or urine samples from biomonitoring studies.

The term "Alternative Infill Type" was used to designate sources that examined infill materials other than tire crumb rubber (e.g., sand). Another sample type identified as "Leachate" generally refers to sources that studied samples of liquid or solid material that had been removed from the immediate area of the tire crumb rubber via normal maintenance, meteorological or hydrogeologic processes.

The majority of the literature sources (44) provided information of the analysis of bulk crumb rubber (Table B-6). Leachate samples were studied in 22 sources, while stationary air samples were evaluated in another 20 sources. The 20 "Other" sample types included materials such as elastic compounds, dust, glue, bio-fluid extracts, rubber pavers natural grass and soil from test plots, and other materials. A full list of the "Other" types can be found in the Literature Review Spreadsheet on the Status Report website.

Table B-6. Number of Studies Addressing Sample Type Category	
Bulk Crumb Rubber	44
Leachate	22
Stationary Air Samples	20
Bulk Grass Blades or Fibers	13
Personal Exposure (air)	9
Wipe Samples	5
Alternative Fill Type	4
Urine	3
Other	20

g. Conditions Studied

The Conditions Studied category refers to analyses that may have been done to identify differences in constituent concentrations or exposures based on age or weathering of the artificial turf, or the effects of meteorological conditions or geography. This study element also refers to analyses that evaluate for differences between indoor and outdoor environments, synthetic and natural turf, site and background conditions, differences based on active or inactive play, or other activity related conditions.

The LRGA team identified 20 literature sources that examined exposures based upon age or weathering of the artificial turf, while 10 other sources analyzed the effect of meteorological conditions on artificial turf and tire crumb rubber (Table B-7). Nine of the literature sources examined levels of constituents found in tire crumb rubber in relation to background levels of the same constituents at the study sites. There were 12 "Other" conditions studied types, which included temperature, coated vs non-coated crumb rubber, tire crumb rubber chip size, and pH. A full list of the "Other" types can be found in the Literature Review Spreadsheet on the Status Report website.

Table B-7. Number of Studies by Conditions Studied	
Age or Weathering	20
Meteorological	10
Site vs Background	9
Synthetic vs Natural	6
Indoor vs Outdoor	5
Activity Related	5
Active vs Inactive Play	4
Other Sources	3
Geographical	1
Other	12

h. Populations Studied

Populations Studied are those populations that were considered in an exposure or human health assessment (e.g., children/teens, adults, workers, athletes). Fourteen literature sources examined children/teen exposures, while 13 sources studies adults and 10 studied athletes (Table B-8). Four sources included in the LRGA looked at worker exposures to tire crumb rubber installations / maintenance. "Other" types of populations identified in the analysis include athletic coaches, spectators, gardeners, and microbial populations. A full list of the "Other" types can be found in the Literature Review Spreadsheet on the Status Report website.

The age groups identified in the various studies differed for non-adult individuals. Thus, for the purpose of categorizing the studies based on age, children and teens were combined in one category and adults were categorized separately. Activities based on the ages of the populations studied may be different due to differing behavior patterns. Likewise, other exposure factors (e.g., inhalation rates, skin surface area, body weight) may differ based on age, and can affect exposure levels.

Table B-8. Number of Studies by Populations Studied	
Children/Teens	14
Adults	13
Athletes	10
Workers	4
Other	6

i. Constituents Evaluated

The Constituents Evaluated results capture the general category of contaminants that were addressed in the study (e.g., volatile organic compounds (VOCs), semi volatile organic compounds (SVOCs), inorganics, microbes, particulate matter). Polycyclic aromatic hydrocarbons (PAHS) are also included as a broad category because they are frequently included in the literature sources. Likewise, lead and benzothiazole are included because they are frequently included in the sources. A separate column in the spreadsheet (found on the Status Report website) is included to capture information on the Specific Constituents Studied. A separate Constituents Tab in the spreadsheet provides additional information on the constituents studied (e.g., concentration data) (see Appendix F for a list of constituents with more details available on the spreadsheet found on the Status Report website).

Forty-nine of the literature sources included in the LRGA evaluated inorganic compounds related to rubber exposures (Table B-9). The next most prevalent constituents identified in the literature review were PAHs, identified in 41 sources, followed by VOCs (38 sources), SVOCs (31 sources) and lead (Pb) by 29 sources. Particulate matter, Benzothiazole and Microbes were constituents studied to a lesser extent. “Other” types of constituents identified included ‘extractable substances,’ dissolved organic carbon, and ‘organics.’ A full list of the “Other” types can be found in the Literature Review Spreadsheet on the Status Report website. Specific references were made to zinc and a variety of metals, phthalates, benzene, nitrosamines, a variety of complex organic compounds, and others. Zinc and other metals were identified most often as the constituents of highest concern in the literature sources.

Table B-9. Number of Studies by Chemical Constituents Studied

Inorganics	49
PAHs	41
VOCs	38
SVOCs	31
Lead	29
Benzothiazole	20
Particulate Matter	18
Microbes	6
Other	6

j. Number of Samples or Number of Observations

The number of observations or number of samples collected in each of the studies reviewed for the LRGA varied according to the study purpose and scope. These data were included in the spreadsheet when they were available in the publication reviewed. For detailed information on the numbers of observations or number of samples collected, see the LRGA spreadsheet on the Status Report website.

k. Human Exposure Routes

Human Exposure Route identifies whether ingestion, inhalation, or dermal exposures were evaluated in a human exposure/risk assessment. Some studies evaluated more than one route of exposure. Twenty-two of the LRGA literature sources investigated inhalation exposures. Another 16 sources considered ingestion exposures, while 12 sources reviewed dermal exposure scenarios. Secondary exposures (e.g., from residual tire crumb rubber contacted through activities such as washing clothes) is also possible, but were not considered in the literature reviewed.

l. Exposure Factors

The Exposure Factors category provides specific information on the exposure factors used studies that estimated human exposure/risk. The U.S. EPA generally defines exposure factors as factors related to human behavior and characteristics that help determine an individual's exposure to an agent. The LRGA identified 14 unique exposure factors, as well as an "other" group. The 14 unique factors included: Body Weight, Inhalation Rate, Ingestion Rate, Skin Surface Area, Surface Area to Body Weight ratio (SA/BW), Adherence, Bioavailability fraction, Absorption fraction, Hand-to-mouth contacts/hr, Hand-to-surface contacts/hr, Hand-to-mouth transfer fraction, Exposure Duration, Exposure Frequency, and Exposure Time.

Fourteen literature sources in the LRGA provided information on the use of one or more exposure factors. The exposure factors that were reportedly used are summarized in Table B-10. Exposure frequency (d/yr or d/week) (n=13) and exposure time (hr/day) (n=11) were the exposure factors that were most often reported, followed by exposure duration (years) (n=10), body weight (kg) (n=9), and inhalation rate (m^3/hr or m^3/day) (n=9). Ingestion rate (g/day) was reported in 8 studies and skin surface area (cm^2) was reported in 6 studies. The other factors were reported by three or fewer LRGA literature sources (for additional details see the spreadsheet on the Status Report website).

Table B-10. Exposure Factors Used by LRGA References

Factor	N	Value(s)
Exposure Frequency (d/yr or d/wk)	13	24-365 d/yr; 4-7 d/wk[a]
Exposure Time (hr/day)	11	0.54-10[a]
Exposure Duration (yrs)	10	1-50[a,b]
Body Weight (kg)	9	15-70[b]
Inhalation Rate (m^3/hr or m^3/day))	9	1.9-6 m^3/hr; 17.0-22.4 m^3/day[a,b]
Ingestion Rate (g/day)	8	0.02-10[a]
Skin Surface Area (cm^2)	6	20-17,084[a,b]
Adherence Factor (mg/cm^2)	2	0.04-1
Bioavailability	2	0.04-1
Absorption Fraction	2	7
Hand-to-mouth Contacts/hr	1	0.01-0.1
Surface Area to BW Ratio (cm^2/kg)	1	246-352[b]
Hand to Surface Contacts/hr	1	23

[a] Varies depending on scenario evaluated.
[b] Varies by age.

m. Risk Assessment

The Risk Assessment category refers to the type of endpoints evaluated and the type of assessment conducted. Five endpoints / assessment types were identified. Fifteen quantitative assessments were identified, in addition to 14 qualitative assessments, and nine screening level assessments. The LRGA also identified fourteen literature sources with cancer endpoints and 13 sources with non-cancer endpoints. Eight "other" types of assessments were also noted including ecological risk, aquatic or cell toxicity, worst-case, margin of safety, microbial risks, and growth inhibition. A full list of the "Other" types can be found in the Literature Review Spreadsheet on the Status Report website.

Table B-11. Number of Studies by Type of Risk Assessment	
Quantitative	15
Qualitative	14
Cancer	14
Non-cancer	13
Screening	9
Other	8

n. Toxicity or Regulatory Data Used to Assess Risk

A variety of data sources were used to evaluate risks in the literature sources evaluated in the LRGA, including reference doses (RfDs) and cancer slope factors (CSFs) from EPA's integrated Risk Information System (IRIS), Health Effects Assessment Summary Tables (HEAST), National Ambient Air Quality Standards (NAAQS) and drinking water standards. Other data sources included the Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Levels (MRLs), Consumer Product Safety Commission (CPSC) guidance, American Council of Government Industrial Hygienists (ACGIH) threshold limit values (TLVs), and state and regional guidance. Some studies used World Health Organization (WHO) drinking water standards, European acceptable daily intakes (ADIs), or other country-specific national targets, limits, or regulatory values. In some cases, no observable effects concentrations (NOECs) or no observable effects limits (NOELs) were used. The Ames test, AhR-based bioassays, and toxicity characteristic leaching procedures (TCLPs) were used by others (for details see the spreadsheet on the Status Report website).

VI. General Conclusions as Stated in the Literature

Brief summaries of results, conclusions, and recommendations from the LRGA studies are provided below. They are provided in chronological order according to eight broad topic areas: (1) exposure and human health risks to children and athletes, (2) occupational risks, (3) ecological risks, (4) leaching, (5) air concentrations, volatilization, and particulate matter, (6) microbial populations, (7) weathering/aging, and (8) data gaps and recommendations for further study. Although some LRGA studies covered more than one topic area, summaries of their conclusions are provided primarily under a single topic area. In most cases, the conclusions are provided exactly as written by the author(s). These summaries are intended to provide the reader with a general sense of the conclusions of the studies, as provided by the authors. For additional details on these studies, see the LRGA spreadsheet on the Status Report website, or refer to the individual studies which provide the reader with a sense of the distribution of results when utilizing the LRGA.

Exposure, Toxicity, and Human Health Risk to Children and Athletes from Chemical Constituents in Tire Crumb Rubber

Several of the LRGA studies provided conclusions with regard to the human health risks associated with the use of tire crumb rubber in artificial turf fields or other applications. Some of these conclusions were based on reviews of existing literature. Others were based on data collection and analysis. Examples of the conclusions are provided below. While many of the studies indicated that risks to human were minimal, others suggested that potential risks exist and should be further explored.

> Birkholz et al. (2003) *"designed a comprehensive hazard assessment to evaluate and address potential human health and environmental concerns associated with the use of tire crumb in playgrounds. Human health concerns were addressed using conventional hazard analyses, mutagenicity assays, and aquatic toxicity tests of extracted tire crumb. Hazard to children appears to be minimal. Toxicity to all aquatic organisms (bacteria, invertebrates, fish, and green algae) was observed; however, this activity disappeared with aging of the tire crumb for three months in place in the playground. We conclude that the use of tire crumb in playgrounds results in minimal hazard to children and the receiving environment."*
>
> Sullivan (2006) conducted an assessment of environmental toxicity and potential contamination from artificial turf using shredded or crumb rubber and concluded that *"The impacts on human health of crumb rubber used in artificial turf are not known at this time. However, there is some evidence that tire rubber can be harmful either from direct contact or from associated dust. The most common detrimental health effect resulting from direct exposure to tire rubber is allergic or toxic dermatitis. Inhalation of components of tire rubber or dust particles from tire rubber can be irritating to the respiratory system and can exacerbate asthma. It is not clear whether dermal or inhalation exposure to tire rubber can lead to sufficient absorption of chemicals to cause mutagenic or carcinogenic effects. The degree of direct contact between the rubber used in artificial turf is not well enough known at this time to determine whether the level of the potential for harm to humans playing on artificial turf containing crumb rubber."*
>
> The Norwegian Institute of Public Health and the Radium Hospital (2006) conducted an assessment of the risks to football players on indoor artificial turf fields, and concluded that *"the use of artificial turf halls does not cause any elevated health risk. This applies to children, older children, juniors and adults."*
>
> In 2006, KEMI, the Swedish Chemicals Inspectorate, published a status report on synthetic turf from a chemical perspective. The conclusions were that *"Measurement of*

indoor air and exposure calculations have shown that there is probably a small health risk associated with simply being on or playing on synthetic turf surfaces that use rubber from recycled tyres. The exposure levels and any allergic reactions, however, have been poorly studied"(KEMI, 2006).

California's Office of Environmental Health Hazard Assessment evaluated the health effects of recycled waste tires in playground and track products, and stated *"Overall, we consider it unlikely that a onetime ingestion of tire shreds would produce adverse health effects." "Only exposure to zinc exceeded its health-based screening value"* (OEHHA, 2007).

Hofstra (2007a) stated that *"Based on the available literature on exposure to rubber crumb by swallowing, inhalation and skin contact and our experimental investigations on skin contact we conclude, that there is not a significant health risk due to the presence of rubber infill for football players an artificial turf pitch with rubber infill from used car tyres."*

Based on a study involving leaching of lead from turf glades blades, the U.S. Consumer Product Safety Commission (CPSC, 2008) reported that *"The results…for this set of tested synthetic turf fields show no case in which the estimated exposure for children playing on the field would exceed 15 ug lead/day."*

Johns (2008) conducted an initial evaluation of potential human health risks associated with playing on synthetic turf fields on Bainbridge Island, Washington using the highest chemical concentrations obtained from Norwegian Institute of Public Health and Radium Hospital (2006), Plesser and Lund (2004), and California OHHEA (2007). Health risks were evaluated for children (8-10 yrs old) and teenagers (11-18 years old) participating in team sports. Johns (2008) concluded that *"Overall, the balance of the studies reviewed indicate that human health risks from playing on synthetic turf fields is minimal, even though low concentrations of some chemicals have been demonstrated to leach from the tire crumb, or volatilize as vapor."*

Based on a literature review and the results of the 2007 CalEPA study, Denly et al. (2008) concluded that *"Based on the information reviewed none of the risk assessments showed concentrations of contaminants that would be at a level of concern, even under conservative assumptions and thus it does not appear that the ingestion of tire crumb would pose a significant health risk for children or adults."*

Based on a Danish study conducted by Nilsson et al., (2008), "*Four representative substances were selected for the health assessment: benzothiazole, dicyclohexylamine, cyclohexanamine and dibutyl phthalate. These substances are present in high concentrations in contact water from the leaching tests and are representative of the harmful substances emitted from the products." Nilsson et al. (2008)* reported that *"there* *are no health effects associated with exposure to the four substances tested, with the exception of a potential risk for developing allergy in particularly sensitive individuals (benzothiazole and the two amines).”*

Beausoleil et al. (2009) concluded that *“the health risks for players who use artificial turf are not significant and that it is completely safe to engage in sports activities on this type of outdoor field” b*ased on literature reviews and qualitative reviews of the data.

The New York Department of Environmental Conservation (NYDEC, 2009) conducted a public health evaluation *“on the results from the ambient air sampling and concluded that the measured levels of chemicals in air at the Thomas Jefferson and John Mullaly Fields do not raise a concern for non-cancer or cancer health effects for people who use or visit the fields...the findings do not indicate that these fields are a significant source of exposure to respirable particulate matter."*

A human health risk assessment of five artificial turf fields in Connecticut indicated that *“cancer risks were only slightly above de minimis levels for all scenarios evaluated including children playing at the indoor facility, the scenario with the highest exposure” (CDPH, 2010).* The Connecticut Academy of Science and Engineering (CASE) (2010) 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.”*

Based on a literature review, Van Ulirsch et al. (2010) concluded that *"Data collected from recreational fields and child care centers indicate lead in synthetic turf fibers and dust at concentrations exceeding the Consumer Product Safety Improvement Act of 2008 statutory lead limit of 300 mg/kg for consumer products intended for use by children, and the U.S. Environmental Protection Agency’s lead-dust hazard standard of 40* $\mu g/ft^2$ *for floors.....Synthetic turf can deteriorate to form dust containing lead at levels that may pose a risk to children."*

Simon (2010) stated that *"A review of existing literature points to the relative safety of crumb rubber fill playground and athletic field surfaces. Generally, these surfaces, though containing numerous elements potentially toxic to humans, do not provide the opportunity in ordinary circumstances for exposure at levels that are actually dangerous.”*

Van Rooij and Jongeneelen (2010) monitored football players in The Netherlands before and after playing on artificial turf fields. Only 1 of the 7 participants showed an increase in post-exposure urine concentration over pre-exposure concentrations. Van Rooij and Jongeneelen (2010) concluded that there is *"evidence that uptake of PAH by football players active on artificial grounds with rubber crumb infill is minimal. If there is any* *exposure, then the uptake is very limited and within the range of uptake of PAH from environmental sources and/or diet."*

Shalat (2011) conducted an evaluation of potential exposures to lead and other metals as the result of aerosolized particulate matter from artificial turf playing fields in New Jersey, and concluded that *"there is a potential for inhalable lead to be present on turf fields that have significant amounts of lead present as detectable by surface wipes. It also would appear likely from this sample that if the lead is present to any appreciable extent in the wipes it will likely be present in the breathing zone of players who are active on these fields, and that furthermore, these levels potentially exceed ambient EPA standards. Given that these are only occasional exposures this tends to reduce the risk of adverse health effects."*

Likewise, Lioy and Weisel (2011) concluded that *"Overall the metals, PAHs and semi-volatile compounds found all classes of materials to be at very low concentrations. Thus, for the metals and compounds identified there would be de minimus exposures and risk among anyone using fields with the exception of lead in a single new turf material. It is therefore prudent to reemphasize the need to avoid lead-based pigments in these materials as coloring agents."*

Ginsberg et al. (2011) conducted a human health risk assessment of synthetic turf fields based upon investigation of five fields in Connecticut. The results indicated that *"Cancer and noncancer risk levels were at or below de minimis levels of concern. The scenario with the highest exposure was children playing on the indoor field. The acute hazard index (HI) for this scenario approached unity, suggesting a potential concern, although there was great uncertainty with this estimate. The main contributor was benzothiazole, a rubber-related semivolatile organic chemical (SVOC) that was 14-fold higher indoors than outdoors. Based upon these findings, outdoor and indoor synthetic turf fields are not associated with elevated adverse health risks."*

Menichini et al. (2011) concluded that *"Compared with the Italian limits for "green area" soils, high contents of Zn and PAHs were found in the granulates present in playing fields, whatever the origin of the rubber. Zn and BaP concentrations largely exceeded such limits by up to two orders of magnitude...PCBs and PCDDs+PCDFs were found in a recycled tyre granulate, at levels in the order of magnitude of the mentioned limits."*

In a Korean study, Kim et al. (2012a) calculated the risk of ingestion exposure of lead by particle sizes of crumb rubber in artificial turf filling material with consideration of bioavailability. The range of bioavailability depended on the particle size and the type of extraction used. The < 250 um and acid extraction had the highest bioavailability. *"Results of this study confirm that the exposure of lead ingestion and risk level increases as the particle size of crumb rubber"* (Kim et al., 2012a). Average lead exposure ranged from 1.7 x 10-5 mg/kg-day to 4.1x 10-4 mg/kg-day with the highest exposure value for children 7-9 years old with the acid extraction method and the lowest exposure to children 13-18 years in both the acid and digestion extraction. Mean hazard quotients were <1.

Kim et al. (2012b) conducted a health risk assessment for artificial turf playgrounds in school athletic facilities in Korea and concluded that *"On the basis of the knowledge that is currently available concerning health effects and exposure linked to the use of artificial turf playgrounds, we did not find a direct health risk for users, except for children with pica."* The LRGA team noted that this publication uses the term "playgrounds" to mean facilities traditionally defined as athletic fields in US installations

Cardno Chem Risk (2013) concluded that *"adverse health effects are not likely for children or athletes exposed to recycled tire materials found at playgrounds or athletic fields...similarly, no adverse ecological or environmental outcomes from field leachate are likely."*

Pavilonis et al. (2014) conducted a study in New Jersey to assess the bioaccessibility and risk of exposure to metals and SVOCs in artificial turf field fill materials and fibers. *"Artificial biofluids were hypothesized to yield a more representative estimation of dose than the levels obtained from total extraction methods. PAHs were routinely below the limit of detection across all three biofluids precluding completion of a meaningful risk assessment. No SVOCs were identified at quantifiable levels in any extracts based on a match of their mass spectrum to compounds that are regulated in soil. The metals were measurable but at concentrations for which human health risk was estimated to be low. The study demonstrated that for the products and fields we tested, exposure to infill and artificial turf was generally considered de minimus, with the possible exception of lead for some fields and materials"* (Pavilonis et al., 2014).

Ruffino et al. (2013) conducted a risk assessment for synthetic turf fields in Italy, including the following exposure pathways: *"direct dermal contact (DDC)), dermal contact with the rainwater soaking the infill (rain water contact (RWC)) and inhalation of dusts and gases from the fields (dust and gas inhalation (DGI)."* Based on a variety of inorganic and organic chemicals, *"the cumulative carcinogenic risk proved to be lower than 10−6 and the cumulative noncarcinogenic risk lower than 1. The outdoor inhalation of dusts and gases was the main route of exposure for both carcinogenic and non-carcinogenic substances....the inhalation of atmospheric dusts and gases from vehicular traffic gave risk values of one order of magnitude higher than those due to playing soccer on an artificial field"* (Ruffino et al., 2013).

Llompart et al. (2013) analyzed rubber recycled tire playgrounds and pavers. *"The analysis confirmed the presence of a large number of hazardous substances including PAHs, phthalates, antioxidants (e.g. BHT, phenols), benzothiazole and derivatives,* *among other chemicals. The study evidences the high content of toxic chemicals in these recycled materials. The concentration of PAHs in the commercial pavers was extremely high, reaching values up to 1%"* (Llompart et al., 2013).

Marsili et al. (2014) conducted a preliminary hazard assessment for athletes based on the release of polycyclic aromatic hydrocarbons and heavy metals from rubber crumb in synthetic turf fields in Italy. *"The results of the present study demonstrate that PAHs are continuously released from rubber crumb through evaporation. Athletes frequenting grounds with synthetic turf are therefore exposed to chronic toxicity from PAHs. The main conclusion we can draw from this preliminary study, which will be validated by further field and laboratory research, is that although synthetic turf offers various advantages over natural grass, the quantity of toxic substances it releases when heated does not make it safe for public health"* (Marsili et al., 2014).

The health impact assessment of the use of artificial turf in Toronto, Canada concluded that, *"Available evidence indicates that under ordinary circumstances, adverse health effects among adults and children are unlikely to occur as a result of exposure to artificial turf infilled with crumb rubber in both outdoor and indoor settings."* The assessment elaborated further by stating, *"Based upon a review of the available evidence, third generation artificial turf is not expected to result in exposure to toxic substances at levels that pose a significant risk to human health provided it is properly installed and maintained and users follow good hygienic practices (for example washing hands, avoiding eating on artificial turf and supervision of young children to ensure they do not eat the infill material)"* (Toronto Public Health, 2015).

Analytical results of lead in crumb rubber from 113 athletic fields In New York City was provided online by the New York City Department of Parks and Recreation: Synthetic Turf Lead Results (http://www.dec.ny.gov/docs/materials_minerals_pdf/crumbrubfr.pdf) *"Aside from Thomas Jefferson Park, the test results for the remaining 112 fields and play areas were below the acceptable EPA lead level for soil (400 parts per million), the best standard available, and no potential lead hazards were found. Lead levels for the 112 fields ranged from 'not detected' to 240 ppm and 96% of the results were less than 100 ppm. Thomas Jefferson Park was the only field with an elevated lead level above the EPA standard."*

Occupational Exposure and Risk

A limited number of studies evaluated in the LRGA addressed occupational risks. Workers included coaches and those working in tire crumb rubber production facilities. These studies provide insight on potential human health risks for potentially exposed populations other than children and athletes. Examples of conclusions from those studies are provided below.

Chien et al. (2003) evaluated occupational health hazards in scrap tire shredding facilities in Taiwan and observed that *"Levels of volatile organics were not significant, but a few mutagens/carcinogens, such as styrene, benzothiazole, phthalate ester and naphthalene were identified. Total particulate levels ranged from 0.43 to 6.54 mg/m^3, while respirable particulates were in the range 0.23–1.25 mg/m3. Ames testing revealed indirect mutagenicity on strain TA98, indicating possible effects of frame-shift type mutagens. Chemical analysis of airborne particulates confirmed the presence of amines, aniline, quinoline, amides and benzothiazole, which are potentially convertible to frame-shift type mutagenic nitrosoamines."* Chien et al. (2003) concluded that *"particulate generated from scrap-tire shredding may pose a health threat to workers, and should not be regulated as 'nuisance'."*

Castellano et al. (2008) conducted a study of coaches working in areas where artificial turf pitches were used in Italy and concluded that *"there was no occupational exposure nor any additional exposure to the substances of interest other than an environmental exposure in urban areas."*

Savary and Vincent (2011) assessed exposure in four facilities in France where used tires are turned into rubber granulates. *"The results of this study indicate significant exposure to complex mixtures of rubber dust… exposure levels measured in these four facilities were between 0.31 and 41.00 mg/m^3; the ambient concentrations were between 0.17 and 6.23 mg/m^3." "VOC levels >1 ppm were not detected."*

Ecological Toxicity and Risk

While the primary focus of the LRGA was on human health risks, several of the papers reviewed provided information relevant to ecological risks. Examples of conclusions from these studies is provided below.

Kallqvist (2005) conducted an environmental risk assessment of artificial turf systems in Norway and concluded that *"The risk assessment shows that the concentration of zinc poses a significant local risk of environmental effects in surface water which receives run-off from artificial turf pitches. In addition, it is predicted that concentrations of alkylphenols and octylphenol in particular exceed the limits for environmental effects in the scenario which was used (dilution of run-off by a factor of ten in a recipient). The leaching of chemicals from the materials in the artificial turf system is expected to decrease only slowly, so that environmental effects could occur over many years. The total quantities of pollution components which are leached out into water from a normal artificial turf pitch are however relatively small, so that only local effects can be anticipated."*

Sullivan (2006) conducted an assessment of environmental toxicity and potential contamination from artificial turf using shredded or crumb rubber and concluded that

“The impacts on the environment of using crumb rubber in artificial turf also are not known at the present time...Zinc is the predominant toxicant to plants...The aquatic toxicity issue is not very clear cut."

In 2006, KEMI, the Swedish Chemicals Inspectorate, published a status report on synthetic turf from a chemical perspective. The conclusions were that *"Current knowledge allows the conclusion to be drawn that synthetic turf that contains rubber from recycled tyres may give rise to local environmental risks. Investigations have shown that zinc and phenols can leach from the rubber granulate, and these substances can affect aquatic and sediment dwelling organisms, if they reach neighbouring water courses"* (KEMI, 2006).

Based on an environmental and health evaluation of the use of elastomer granulates used as filling in artificial turf in France, Moretto (2007) concluded that *"From an ecotoxological point of view, the nature of the percolates having passed through a 3rd generation artificial pitch are proven to be without impact on the environment, irrespective of the type of filling granulates."*

California’s Office of Environmental Health Hazard Assessment (OEHHA) (2007) evaluated the effects of recycled waste tires in playground and track products, and stated *"...ecological effects from contaminated soil cannot be ruled out…the selenium level in the soil was only marginally higher than the PRG and the zinc levels were close to the normal background levels."*

Johns and Goodlin (2008) found that *"Toxicity tests on storm water collected from installed fields, or in laboratory tests using simulated precipitation events, indicate that water the percolates through turf fields with tire crumb is not toxic in tests that cover a wide range of aquatic plants and animals, including algae, bacteria, crustaceans, and fish."*

Milone and McBroom (2008) reported that *"An analysis of the concentration of metals in the actual drainage water indicates that metals do not leach in amounts that would be considered a risk to aquatic life as compared to existing water quality standards."*

The New York Department of Environmental Conservation (NYDEC, 2009) conducted a risk assessment for aquatic life protection and *found that "...crumb rubber may be used as an infill without significant impact on groundwater quality...Analysis of crumb rubber samples digested in acid revealed that the lead concentration in the crumb rubber samples were well below the federal hazard standard for lead in soil...A risk assessment for aquatic life protection...found that crumb rubber derived entirely from truck tires may have an impact on aquatic life due to the release of zinc.”*

Based on an environmental and mutagenicity assessment of artificial turf fields conducted in Italy, Schilirò et al. (2013) concluded that *"On the basis of environmental monitoring, artificial turf football fields present no more exposure risks than the rest of the city."*

Leaching

Among the studies reviewed for the LRGA, leaching studies were frequently represented. Some of these studies addressed laboratory analyses of bulk samples, and other addressed leaching in the natural environment. Conclusions based on these studies are provided below.

Zelibor (1991) analyzed leachate from tire samples and reported that *"The results of the study indicated that none of the tire and other rubber products tested, cured and uncured, exceeded proposed TCLP Regulatory Levels or US EPA Drinking Water Standards. Most compounds detected were found at trace levels (near method detection limits) from ten to one hundred times less than proposed TCLP regulatory limits."*

Based on a study conducted in Canada, Groenevelt and Grunthal (1998) found *"No elevated levels of VOC's or BNA's were detected in the leachate collected. Slightly elevated levels of boron, sodium and zinc, leached from acidic sandy loam soil amended with 30% rubber crumb. Concentrations of these elements from soil mixed with rubber crumb and lime, however, did not differ from those observed for control plots...Rubber also significantly increased the concentration of zinc in turfgrass clippings. However, elevated concentrations were not sufficient to produce zinc toxicity in turfgrass."*

Florida Department of Environmental Protection (FDEP, 1999) evaluated stormwater runoff from a parking lot surface using ground tire rubber and other water samples and found that *"Except for the iron concentrations detected in groundwater samples collected from MW-1, MW-3, and MW-4, all remaining soil, groundwater, rain water, and surface water runoff concentrations were below State guidance concentrations."*

Plesser and Lund (2004) found that *"The leachate from the fibres contained zinc. The concentration is higher than the Norwegian Pollution Control Authority's limit for zinc in water with Environmental Quality Class V (very strongly polluted water), but lower than the permitted zinc concentration in Canadian drinking water...The total concentrations of zinc and PAH in the recycled rubber granulates exceed the Norwegian Pollution Control Authority's normative values for most sensitive land use. The concentrations of dibutylphthalate (DBP) and diisononylphthalate (DINP) exceed the PNEC values for terrestrial life taken from the EU's programme for risk assessment. The concentration of isononylphenol is above the limits specified for cultivated land in the Canadian Environmental Quality Guidelines...The concentration of zinc indicates that the leachate water is placed in the Norwegian Pollution Control Authority's Environmental Quality Class V (very strongly polluted water), but is lower than the permissible zinc* *concentration in Canadian drinking water. The concentration of anthracene, fluoranthene, pyrene and nonylphenols exceed the limits for freshwater specified in the Canadian Environmental Quality Guidelines."*

A laboratory study conducted in Italy by Gualteri et al. (2005) evaluated the effects of leachate from tire debris on human lung cells and *X. laevis*. Gualteri et al. (2005) concluded that the *"results confirm the significant role of zinc in leached [tire debris] and the presence of additional organic toxicants."*

Sheehan et al. (2006) conducted a study in Maine and observed *"Elevated levels of iron, manganese, and several other chemicals…in tire shred leachates. However, chronic toxicity tests with Ceriodaphnia dubia and fathead minnows (Pimephales promelas) showed no adverse effects caused by leachates collected from tire shreds installed above the water table. Exposure to leachates collected from tire shreds installed below the water table resulted in significant reductions to both survival and reproduction in C. dubia."*

Verschoor (2007) observed that zinc from rubber infill in artificial turf in The Netherlands *"leaches to the soil, groundwater and surface water"* and *"environmental quality standards for zinc in surface water and groundwater are exceeded."* However, *"The risks of zinc to public health are of no concern: the human toxicity of zinc is low and WHO drinking water criteria are not exceeded."*

As part of a study conducted in Connecticut, Mattina et al. (2007) examined crumb rubber produced from recycled tires. According to Mattina et al. (2007), *"The laboratory data…support the conclusion that under relatively mild conditions of temperature and leaching solvent, components of crumb rubber produced from tires (i) volatilize into the vapor phase and (ii) are leached into water in contact with the crumbs."*

Based on a study conducted in Washington, Johns and Goodlin (2008) suggested that *"The available literature demonstrates that some chemicals can leach from tire crumb when it is exposed to water. While some studies report the presence of organic chemicals in leachate, the chemicals were detected at such low concentrations that authors considered them to be of little environmental relevance. The most consistent chemical to be detected in leachate tests is the metal zinc."*

Based on a study in Japan, Aoki (2008) found that *"The concentrations of leaching heavy metals [from infills on artificial turf] increased with an increase in the acidity of the acid solutions."*

Based on a Danish study, Nilsson et al. (2008) reported that *"a number of environmentally harmful substances were found in the contact water from leaching tests on infills and artificial turf mats."*

Bocca et al. (2009) conducted a laboratory study in Italy to identify and quantify metal concentrations in leachate from crumb rubber samples. According to Bocca et al. (2009), *"The total amount and the amount leached during the acidic test varied from metal to metal and from granulate to granulate. The highest median values were found for Zn (10,229 mg/kg), Al (755 mg/kg), Mg (456 mg/kg), Fe (305 mg/kg), followed by Pb, Ba, Co, Cu and Sr... The highest leaching was observed for Zn (2300 µg/l) and Mg (2500 µg/l), followed by Fe, Sr, Al, Mn and Ba. Little As, Cd, Co, Cr, Cu, Li, Mo, Ni, Pb, Rb, Sb and V leached, and Be, Hg, Se, Sn, Tl and W were below quantification limits. Data obtained were compared with the maximum tolerable amounts reported for similar materials, and only the concentration of Zn (total and leached) exceeded the expected values."*

Based on a study in Portugal, Mota et al. (2009) stated that *"PAH leaching is negligenciable...heavy metals content in the acidic water leachates considerably lower than the limit values."*

Kanematsu et al. (2009) found that *"aqueous extracts of rubber mulches (RM) contain high concentrations of zinc (Zn) compared with wood mulches (WM), and its concentration increased at lower pH and higher temperature...Our results suggest that organic constituents in water extracts of RM which have AhR activity may not be of significant concern while leaching of Zn from RM appears to be a potentially larger water quality issue for RM."*

The Connecticut Department of Environmental Protection concluded that *"Zinc is the most prevalent contaminant in the leachate and stormwater studies." "The DEP concludes 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...This study did not identify any significant risks to groundwater protection criteria in the stormwater runoff from artificial turf fields"* (CDEP, 2010).

Rhodes et al. (2012) found that *"zinc leaching from tire crumb rubber increases with smaller crumb rubber and longer exposure time."*

Cheng et al. (2014) reviewed studies where the toxicity characteristic leaching procedure (TCLP) was used and indicated that constituent concentrations were well below maximum contaminant limits (MCLs) or TCLP regulatory limits.

In a case study of PAH and other hazardous contaminant occurrence in recycled tire rubber surfaces at a restaurant playground in an indoor shopping center, Celeiro et al. (2014) found that, *"fourteen out of the sixteen EPA priority PAHs were identified and quantified in the investigated recycled tyre rubber playground surfaces. The analytical measurements also confirmed the presence of other harmful compounds including* *phthalates, adipates, antioxidants and benzothiazole among others, in some cases at high concentration levels*."

Crampton et al. (2014) assessed the effects of leachate from crumb rubber and zinc in green roofs on the survival, growth, and resistance characteristics of *Salmonella enterica subsp. enterica serovar typhimurium. "The median concentration of zinc in the crumb rubber-amended roof was 0.2 mg/liter ..., while the median concentration of zinc in the commercial medium was 0.15 mg/liter."*

The results of an Ohio study conducted by Dorsey et al. (2015) *"suggest that at the higher temperatures such as those on artificial athletic field surfaces, the crumb rubber infill on these artificial athletic fields can become the source of a water soluble agent with mutagenic potential in bacteria."*

Selbes et al. (2015) observed *"...a constant rate of leaching was observed for iron and manganese, which are attributed to the metal wires present inside the tires. Although the total amounts that leached varied, the observed leaching rates were similar for all tire chip sizes and leaching solutions."*

Air Concentration, Volatilization/Off-gassing, and Particulate Matter

Several of the studies reviewed collected air samples using stationary, personal breathing zone monitors, or other methods to assess the potential for volatilization of chemical constituents from artificial turf or other materials that contain tire crumb rubber. Conclusions from these studies are provided below.

Dye et al. (2006) conducted a study in Norway to obtain measurements of air quality for three indoor artificial turf pitches. The measurements were taken in a hall with recently laid rubber granulate (SBR rubber or Styrene Butadiene Rubber) and a hall with rubber granulate (SBR rubber) which had been in use for one year and a hall which used granulate made from thermoplastic elastomer. *"In all three halls, 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. Possible problem areas linked to latex exposure via the skin and air passages should be assessed by specialists."*

Van Bruggen (2007) conducted a study in The Netherlands to assess releases of nitrosamines from crumb rubber by taking measurements at two different levels above artificial turf surfaces, and found that *"None of the measurements showed the presence of nitrosamines in the atmosphere above the pitch. Supplementary laboratory tests on the materials showed that nitrosamines can only be released from rubber crumb to a very limited extent."*

EHHI (2007) concluded that *"It is clear that the recycled rubber crumbs are not inert, nor is a high-temperature or severe solvent extraction needed to release metals, volatile organic compounds, or semi-volatile organic compounds. The release of airborne chemicals and dust is well established by the current information. There are still data gaps that need to be filled in and additional studies are warranted."*

Vetrano and Ritter (2009) stated that *"An analysis of the air in the breathing zones of children above synthetic turf fields [in New York City] did not show appreciable levels from COPCs contained in the crumb rubber,"* but constituent characterization of bulk samples revealed lead and zinc concentrations that were above soil cleanup objectives for restricted residential land use.

California OEHHA (2010) collected air samples from 4 artificial fields and 4 natural fields and found that *"PM2.5 and associated elements (including lead and other heavy metals) were either below the level of detection or at similar concentrations above artificial turf athletic fields and upwind of the fields" and "The large majority of air samples collected from above artificial turf had VOC concentrations that were below the limit of detection."*

The University of Connecticut Health Center (UCHC) (2010) found that *"Of the 60 VOCs tested in air, 4 VOCs appear to be associated with turf. Of 22 PAHs, 6 were found in the air on the turf at 2 fold greater concentrations than in background locations on at least two fields…benzothiazole and butylated hydroxytoluene were the only chemicals detected in the personal and area air samples from outdoor turf fields ranging from <80-1200 ng/m*^{3} *and <80-130 ng/m*^{3}*, respectively. Nitrosamine air levels were below reporting levels. PM10 air concentrations were greater in background locations than on the turf at all fields with the exception of Field B. However, the PM10 air concentration on turf at Field B, 5.89 ug/m*^{3}*, was within the range of other PM10 background concentrations. All of the composite samples of turf fibers and crumb rubber were below the level EPA considers as presenting a "soil-lead hazard" in play areas (400 ppm)."*

Li et al. (2010) found that *"Ten volatile compounds were identified in the vapor phase over all commercial [crumb rubber] samples and two aged field [crumb rubber] samples by SPME coupled with GC–MS. Six volatile compounds were quantitated by direct vapor phase injection. In all 16 virgin commercial [crumb rubber] samples, [benzothiazole] was the most abundant volatile compound. Zinc was the highest of all extractable metals in the acidified extraction fluid."*

Simcox et al. (2011) conducted a synthetic turf field investigation in Connecticut. The *"Results showed that personal concentrations were higher than stationary concentrations and were higher on turf than in background samples for certain VOC. In some cases, personal VOC concentrations from natural grass fields were as high as those on turf.*

Naphthalene, BZT, and butylated hydroxytoluene (BHT) were detected in greater concentration at the indoor field compared to the outdoor fields. Nitrosamine air levels were below reporting levels. PM10 air concentrations were not different between on-field and upwind locations. All bulk lead (Pb) samples were below the public health target of 400 ppm."

Microbial Assessment

Assessments of microbial populations associated with artificial turf were limited compared to those of other topics areas. Conclusions for some of these studies are summarized below.

McNitt et al. (2006) collected crumb rubber samples from both "high use" areas and "low used" areas in fields used by elementary to professional athletes in Pennsylvania. "*While microbes exist in the infill media the number was low compared to natural turfgrass field soils."* The range of CFU was 0-80,000 in the infill material compared to 259,500 found in natural soil.

California OEHHA (2010) found that *"Fewer bacteria were detected on artificial turf compared to natural turf."*

Serentis et al. (2011) found that in Pennsylvania, *"Indoor fields tended to have lower overall microbial populations (0–7267CFU/g of infill) than outdoor fields (0–80 000CFU/g)… While it is clear that microbes exist on synthetic turf surfaces, the number was low compared with those on natural turf grass." "S. aureus colonies were not found to be present on any field; however, S. aureus colonies were found on other tested surfaces, including blocking pads, used towels, and weight equipment."*

Bass and Hintze (2013) compared *"the occurrence of microbial populations on two infilled synthetic turf fields (year old turf vs. 6 year old turf) in three locations...Much higher microbial populations were found on the older turf field"* compared to the newer turf. *"Counts from the MSA plates revealed a relatively high number of mannitol-fermenting salt-tolerant bacteria, a possible indication of staphylococci."*

Weathering/Aging

Based on a study in Taiwan, Chang et al. (1999) found that *"Two years after the track installation, the VOC concentrations measured at 1.5 m above the track, the breathing height of school children, were not significantly higher than the background levels."* Chang et al. (1999) also noted that the synthetic fields were all installed with adhesive and backings which might also contribute to VOC offgassing.

Based on a study in The Netherlands, Hofstra (2007b) concluded that *"The impact of weathering of the rubber crumb for the technical lifetime of an artificial turf field* *(approx. 10 to 15 years) does not cause the leaching of zinc from the rubber crumb made from recycled car tyres to exceed the threshold values for dissolved zinc in surface water or the derived threshold value from the Decree on Soil Quality for the emission of zinc into the soil."*

Verschoor (2007) observed that *"Laboratory experiments and measurements of field samples of the rubber infill show that the emission of zinc increases over time, due to chemical and physical changes of the rubber particle."*

Zhang et al. (2008) reported on studies conducted in New York and concluded that *"Rubber granules often, especially when the synthetic turf fields were newer, contained PAHs at levels above health-based soil standards. PAH levels generally appear to decline as the field ages."*

A report on a study conducted at the Connecticut Agricultural Experiment Station (CAES) concluded that *"...although there is a decrease in the amounts of all six compounds which outgas over the ten weeks of this experiment, the decrease is the least for 4-t-octylphenol. Second, at approximately 20 days of weathering under the conditions in this experiment, the five compounds appear to reach a consistent level of outgassing"* (CAES, 2010).

Data Gaps/Recommendations for Further Study

Several studies provided information on data gaps and recommendations for further study. These conclusions ranged from statements about the general need for further investigation to specific suggestions for further research. Some examples of these recommendations are provided below.

Zelibor (1991) recommended *"that a field study be prepared in conjunction with key states (Ohio, Illinois, Pennsylvania, California, Texas, New York, New Jersey, North and South Carolina, Florida, Georgia, among others) and coordinated by the Scrap Tire Management Council."* Its purpose would be to address questions *"concerning the effect of leachate from scrap tire products in the environment...[specifically], 1) Which regulatory standards are appropriate to evaluate potential adverse effects on human health and environment from compounds leached from scrap tire or rubber products?;* ***2)*** *Are there any realistic environmental conditions/applications where scrap tires leach compounds that exceed regulatory standards? 3) Are compounds leached from scrap tire products in the environment under specific applications? If so, what is the fate of those compounds in the environment?; [and] 4) Is there an adverse effect on groundwater, surface water or wetlands from the storage or application of scrap tires?"*

Plesser and Lund (2004) found that *"recycled rubber granulates give off a significant number of alkylated benzenes in gaseous form. Trichloromethane (sample 1) and cis-1,2-dichlorethene (sample 5) were also found."* They also recommended that *"measurements be taken of air quality above pitches to determine whether the air quality is satisfactory."*

Sullivan (2006) concluded that *"The actual amount of contamination leaching from artificial turf used on playgrounds or athletic fields needs further research to determine the potential harm to human health or the environment."* In term of human health, Sullivan et al. (2006) suggested that *"It is not clear whether dermal or inhalation exposure to tire rubber can lead to sufficient absorption of chemicals to cause mutagenic or carcinogenic effects. The degree of direct contact between the rubber used in artificial turf is not well enough known at this time to determine whether the level of the potential for harm to humans playing on artificial turf containing crumb rubber."* In terms of aquatic toxicity, Sullivan et al. (2006) stated that *"The unknown factor is how much zinc or organic compounds would be released from crumb rubber used on or beneath artificial turf."*

In 2006, KEMI, the Swedish Chemicals Inspectorate, published a status report on synthetic turf from a chemical perspective. Data gaps with regard to health risks from the use of synthetic turf were summarized as follows: *"Certain investigations and assessments have been carried out in order to illuminate the risks of using synthetic turf, but there remain major gaps in our knowledge. This is particularly true with respect to the extent to which the hazardous substances are released from the rubber, and the subsequent exposure to these substances of people and the environment."*

Verschoor (2007) made the following recommendations: *"Mechanisms of behaviour and ageing of (different types of) rubber should be investigated to obtain a better understanding of the risks of zinc and other components leaching from rubber…It is recommended that measurements are first taken in drainage water from existing artificial turf with rubber infill of differing age and quality. Sampling at several time intervals in different seasons is preferred...Bioassay is recommended to assess the toxicity of the drainage water...A mini artificial turf field (1x1x1 m) can be built and exposed to outdoor weather conditions in a lysimeter...more advanced models can be used for a refined risk assessment."*

LeDoux (2007) conducted a preliminary assessment of the toxicity from exposure to crumb rubber based on a literature review and concluded that *"Insufficient information was found to perform a complete formal exposure assessment/risk characterization on crumb rubber for the stated outdoor use at this time due to existing data gaps in the available information. After reviewing the information available, with the possible exception of allergic reactions among individuals sensitized to latex, rubber and related products, there was no obvious toxicological concern raised that crumb rubber in its intended outdoor use on playgrounds and playing fields would cause adverse health effects in the normal population."*

Based on a literature review, ChemRisk (2008) concluded that *"The current state of knowledge indicates that there are data gaps which significantly limit a scientifically robust analysis of the potential environmental health risks associated with the selected* *tire materials and tire wear particles [TWP]" "It was concluded that the most significant data gaps are: 1) lack of understanding of the chemical composition of TWP, 2) lack of understanding of the levels of TWP in the environment (air, soil, and sediments) and their potential associated health risks; and 3) lack of understanding of the potential for TWP to leach chemicals into the environment." "As such is it recommended that the following research be conducted to allow for environmental health risk assessment of TWP: chemical composition analysis of TWP generated under representative driving conditions; acute aquatic toxicity studies of TWP; characterization of TWP leachate under simulated environmental/biological conditions; development of chemical marker for TWP in environmental media; and, measurement of TWP in air, soil, water and sediment to determine representative exposure concentrations."*

In a 2008 editorial, Lioy and Weisel (2008) stated that *"At the present time, we believe that the million dollar expense to produce and install a synthetic field by communities and athletic facilities demands a much more thorough understanding of the environmental impacts, human exposure and health risk implications associated with all synthetic turf products available on the market. This calls for a comprehensive evaluation of artificial turf by exposure scientists, and others in environmental science and environmental health sciences."*

The New York Department of Environmental Conservation (NYDEC, 2008) noted that *"Many governmental bodies including Norway, Sweden and California have recently reviewed the health issues associated with the use of crumb rubber as infill at playgrounds and synthetic turf fields. Their assessments did not find a public health threat. However, several recent preliminary studies... indicated the presence of organic compounds, such as polycyclic aromatic hydrocarbons (PAH) and heavy metals, such as zinc, and raised concerns that these substances could have potential adverse impacts on the environment and public health, especially for children playing on these synthetic turf fields for extended time periods....to address these concerns, the DEC has initiated a study to assess the potential environmental impacts from the use of crumb rubber as an infill material in synthetic turf fields and to collect data that would be relevant for a public health and environmental assessment."*

U.S. EPA (2009) conducted a scoping-level field monitoring study of synthetic turf and playgrounds in the U.S. and concluded that *"On average, concentrations of components monitored in this study were below levels of concern; however, given the very limited nature of this study (i.e., limited number of components monitored, samples sites, and samples taken at each site) and the wide diversity of tire crumb material, it is not possible to reach any more comprehensive conclusions without the consideration of additional data."*

Based on a study conducted by the University of Connecticut Health Center (UCHC, 2010) *"airborne concentrations of VOCs, targeted SVOCs (e.g. benzothiazole) and miscellaneous SVOCs were highest at the indoor field. These data were collected from* *only one indoor facility. Higher concentrations of these chemicals at the indoor field likely reflects the lack of air movement relative to outdoor fields."* UCHC (2010) suggested that *"more research is needed to better understand chemical exposures in indoor facilities."*

Simcox et al. (2011) concluded that *"More research is needed to better understand air quality at indoor facilities."*

Menichini et al. (2011) suggested that *"Further work is needed to assess the actual scenarios of exposure to PAHs by inhalation and the corresponding risks, and to reach more comprehensive conclusions."*

Krüger et al. (2012) suggested that *"Considering the risk assessment of artificial turf systems, emphasis should be placed not only on the plastic components but also on mineral aggregates used for basic layers, which might contribute to the release of contaminants, especially of zinc. For a thorough and realistic risk assessment, column tests of complete artificial turf systems, simulating the actual installation, may be more realistic."*

Cheng et al. (2014) conducted a literature review of environmental and health impacts of artificial turf and stated *"There remains a significant knowledge gap that must be urgently addressed with the fast expansion of the artificial turf market. Given the wide range of designs, ages, and conditions of artificial turf fields, it is likely that the contaminant release and the environmental impacts are variable from site to site. It is also important to assess more systematically the risk posed by the tire rubber crumb on the environment and human health"*.

The health impact assessment of the use of artificial turf in Toronto, conducted by the city of Toronto (2015) concluded that there are *"still some information gaps: the allergenic potential of latex in crumb rubber has not been thoroughly investigated; exposure to lead, other metals, carbon nanotubes, as well as other contaminants have not been fully evaluated in all types of turf systems"*.

The Virginia Department of Health (VDOH, 2015) suggested that studies *"done exclusively in a controlled laboratory setting may not necessarily represent a "real world exposure" to chemicals in crumb rubber. However, laboratory analysis provides an alternative to identifying chemicals (by employing strong extraction techniques and concentrating chemicals to detectable concentration before analysis) in crumb rubber that might be present in low concentrations in the environment."*

Dorsey et al. (2015) conducted a study in Ohio and concluded that *"Risk assessment studies are needed to consider the health impact of repeated exposure to crumb rubber at the conditions relevant to artificial athletic fields."*

VII. Gaps Analysis Based on the Literature Review

Despite the use of tire crumb rubber in synthetic fields over the last several decades, there is not an extensive body of scientific research on the exposure to and toxicity of tire crumb rubber, and questions about the effects of this material on human health and the environment remain. The Literature Review/Gaps Analysis (LRGA) effort considered 97 reference sources for information related to tire crumb rubber. Eighty-eight of the references were included in the analysis. The LRGA analysis categorized the studies according to a set of general topic areas, to evaluate the relative areas of data richness and data gaps. Important data gaps remain in the characterization of tire crumb rubber material used in synthetic turf fields and playgrounds, assessing exposures for users of these fields and playgrounds, human and ecological risk assessment, and in health impact assessments. Selected data gaps described in Table B-12 focused on potential human exposure and health impact assessments for exposure to tire crumb rubber and its constituents. Some concerns related to synthetic turf fields and playgrounds were not addressed in this Literature Review/Gaps Analysis, including heat exposure and injury. Other potential gaps that might be important, but were not directly addressed in the reviewed literature included limitations in tools and methodology available for characterizing constituents, exposure, and health impacts among user populations.

One of the LRGA topic areas was risk assessment characterizing the human and ecological effects of interaction with tire crumb rubber. While there are many definitions of the term "risk", the U.S. EPA considers risk to be the chance of harmful effects to human health or to ecological systems resulting from exposure to an environmental stressor (U.S. EPA, *About Risk Assessment*). In general terms, risk depends on the following three factors:

- How much of a stressor (e.g., chemical) is present in an environmental medium (e.g., soil, water, air),
- How much contact (exposure) a person or ecological receptor has with the contaminated environmental medium,
- The inherent toxicity of the stressor.

In the ideal world, risk assessments would be based on a very strong knowledge base (i.e., reliable and complete data on the nature and extent of contamination, fate and transport processes, the magnitude and frequency of human and ecological exposure, and the inherent toxicity of all of the chemicals). Based on the tire crumb rubber literature reviewed here, data are not available for all of these factors in all of the studies, and only a limited number of studies provided quantitative estimates of risk to human or ecological population from tire crumb rubber constituents.

Only a subset of the 88 available references evaluated risks associated with constituents of tire crumb rubber. Among the studies that estimated human health risks, both cancer and non-cancer endpoints were considered, and the available studies each considered one or more routes of exposure (i.e., inhalation, ingestion, and dermal). A limited number of studies examined the activity patterns associated with tire crumb rubber exposures or provided population - and activity-specific exposure factors (e.g., time spent in contact with artificial turf fields) for use in risk assessment. There was a balance in the populations studied with respect to adults, children and athletes. Fewer studies addressed occupational exposures from turf and playground installations. Given the relative paucity of investigations on worker-associated risks and activity-related studies, there remains uncertainty in potential risks associated with the use of tire crumb rubber at synthetic turf fields and playgrounds.

Table B-12. Data Gaps for Research on Tire Crumb Rubber in Synthetic Fields and Playgrounds

	Research Area	Data Gaps
Tire Crumb Rubber Characterization	Chemical Characterization	• Studies that have measured metal, volatile organic chemicals (VOCs), and semi-volatile organic chemicals (SVOCs) (e.g., polycyclic aromatic hydrocarbons [PAHs] and benzothiazole) were usually based on small numbers of tire crumb rubber samples. The wide range of organic chemicals potentially used in tire manufacture, or their degradates, have not been analyzed systematically across a large range of tire crumb rubber samples from synthetic fields and playgrounds in the United States. • Limited information is available on chemical constituents in molded rubber products made with tire crumb rubber used in some playground settings.
	Emissions Assessments	• Few laboratory-based studies have investigated VOC and SVOC emissions from synthetic fields and playgrounds under different temperature conditions. Measurements using dynamic emission chamber measurements have been reported, but the number and types of measured chemical emissions have been limited.
	Microbial Assessments	• Microbiological assessments for synthetic turf fields and playgrounds have been limited and have been based on traditional culture methods. The use of molecular methods has not been applied in studies of tire crumb rubber.
	Bioaccessibility	• Several studies have examined potential bioaccessibility of metals and PAHs. However, studies that systematically measure a wider range of metal and organic chemical constituents, using multiple simulated biological fluids, and across a large range of tire crumb rubber samples are lacking.
	Variability	• Most studies characterizing tire crumb rubber from synthetic fields and playgrounds in the United States have been relatively small, and restricted to a few fields or playgrounds. Measurements for samples collected from a wider range of tire recycling plants, synthetic fields, and playgrounds across the United States is lacking. Also, information is limited on the range of chemical, microbiological, and physical characteristics and factors related to variability in tire crumb rubber and potential exposures.

Table B-12 (continued). Data Gaps for Research on Tire Crumb Rubber in Synthetic Fields and Playgrounds

	Research Area	Data Gaps
Exposure/Risk Characterization	Exposure Factors	• Exposure and risk assessments have typically relied on generic exposure factors. Information specific to the frequency and duration of synthetic field and playground uses, physical activities, contact rates, and hygiene are limited. • Exposure factor data are not available either across the wide variety of sports and recreational users of synthetic turf fields and playgrounds with tire crumb rubber, or for occupational exposures.
	Dermal/Ingestion Exposures	• While multiple studies have attempted to characterize potential inhalation exposures to tire crumb rubber chemical constituents, more limited information is available for understanding dermal and ingestion exposures.
	Broken Skin/Ocular Exposures	• Little information is available on the potential for increased exposures via broken skin (i.e., due to cuts and scrapes) and through ocular fluids.
	Particle Exposures	• There is limited information on exposure to tire crumb particles and their constituents through inhalation, dermal, and ingestion. Information on the exposure potential as synthetic fields and playgrounds age and weather, and for various uses and activities on synthetic fields and playgrounds is limited.
	Variability	• Few studies have evaluated the variability of exposures to tire crumb rubber constituents by activity type, exposure scenario, age, material type and condition, facility type and condition, and ambient conditions such as temperature and wind or ventilation. Limited information is available on the variability of exposures and related factors across a wide range of user groups and scenarios. • A few studies suggest that inhalation exposures at indoor facilities are higher compared to those at outdoor facilities, but the available information is limited.
	Biomonitoring	• Only a few biomonitoring studies have been performed. Only hydroxypyrene has been measured as a biomarker in athletes and workers. • Additional tire rubber-specific biomarker measurements have not been reported for synthetic field and playground users and biomarker analysis methods might be lacking for some chemicals. • Large scale biomonitoring studies of populations exposed and not-exposed to synthetic turf fields and playgrounds with tire crumb rubber have not been reported.
	Cumulative/Aggregate Assessments	• Exposures to multiple tire crumb constituents are likely to occur via multiple pathways (e.g., inhalation, ingestion, and dermal contact). However, studies that evaluated cumulative and aggregate exposure and risks are limited.
	Epidemiology Studies	• No epidemiological investigations for synthetic turf field or playground users were identified in the literature review. • Survey and biomonitoring tools for accurate assessment of relative exposures for synthetic field and playground users in an epidemiological study are lacking.
Alternative Assessments	Alternative Infills/Materials	• Most research to date has focused on characterizing tire crumb rubber infill. Similar research on other infill materials, including natural materials, ethylene propylene diene monomer (EPDM), thermoplastic elastomers (TPE), and recycled shoe rubber are either lacking or limited.
	Natural Grass Fields	• Few studies have been performed to assess potential chemical exposures from natural grass playing fields.
	Other Exposure Sources	• Only a few comparative assessments have been performed on relative exposures to chemicals associated with tire crumb rubber from other sources.

Many of the studies that did not characterize risks, examined factors related to potential public or environmental health impacts (e.g., identifying chemical constituents, or assessing leaching or off-gassing of chemicals from artificial turf). Among these other topic areas, there was relatively less information available on microbiological and bioavailability aspects of tire crumb rubber exposures. The availability of biomonitoring studies was also limited. No studies were identified that produced or evaluated epidemiological data on potential associations between the incidence of health effects and exposures related to tire crumb rubber. Related to sampling locations, there were more studies conducted in laboratories and synthetic fields. Thus data gaps may be more pronounced for locations such as playgrounds and indoor fields, as well as studies that compare site-specific concentrations of tire crumb rubber constituents to background levels. Another less-studied factor relates to potential differences between constituent levels in environmental media and corresponding exposures based on activity levels (e.g., active versus inactive play) on artificial turf fields.

A wide range of chemicals were evaluated in the literature reviewed for the LRGA, and a significant portion of the LRGA involved compiling a list of potential tire crumb rubber constituents identified in the available literature. The constituents list spreadsheet, which can be found on the Status Report website, identifies more than 350 distinct chemical compounds. A list of the chemicals is provided in Appendix F. This spreadsheet is a comprehensive list of unique chemicals that were identified in the LRGA literature. Some major classes of constituents identified in the LRGA include inorganics, and VOCs/SVOCs. Frequently studied inorganics include lead, zinc, cadmium, and chromium. Frequently studied VOCs/SVOCs include benzothiazole and PAHs. Less frequently studied constituents included microbials, and a variety of complex organic compounds. In general, the available studies do not establish whether the observed results are widespread and generalizable. Systematic studies based on larger numbers of athletic fields and playgrounds designed to include a range of characteristics (rubber material source, location, age, etc) for the population of such fields and playgrounds across the United States have not been performed.

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IX. Appendices

Appendix A - CDC Review of Published Literature and Select Federal Studies on Crumb Rubber and Synthetic Turf

Review of Published Literature and Select Federal Studies on Crumb Rubber and Synthetic Turf

Product Sampling and Chemical Composition Studies

1. Synthetic Turf Field Investigation in Connecticut

N. Simcox, A. Bracker, G. Ginsberg, B. Toal, B. Golembiewski, T. Kurland, C. Hedman; *Journal of Toxicology and Environmental Health, Part A*; **2011**.

The purpose of the study is to characterize concentrations of VOCs, SVOCs, rubber-related chemicals, and PM10 in ambient air at selected fields with crumb rubber infill in Connecticut during summertime conditions and during active field use.

Methods:

- During July 2009, three types of fields were sampled:
  - Outdoor field with crumb rubber infill
  - Indoor facility with crumb rubber infill
  - Outdoor field with grass turf as background location
- Air samples collected at older fields (>3 years) and at new fields (< 2 years).
- Personal air sampling during simulated soccer game:
  - VOCs
  - SVOCs
  - Benzothiazole (BZT)
  - 2-mercaptobenzothiazole
  - 4-tert-octylphenol
  - Butylated hydroxyanisole
  - Butylated hydroxytoluene (BHT)
  - Nitrosamines
  - PM10

Study results and/or conclusions:

- For turf fiber and crumb rubber infill, lead levels were below the EPA "soil-lead hazard" limit and below the 300ppm target set by Consumer Product Safety Act for products to be used by children.
- Of 60 VOCs, 31 were detected on field.
- Personal air monitoring concentrations were higher on artificial turf than on grass for 21 VOCs.
- Stationary samples on the outdoor fields were similar to background.
- Total VOCs were higher indoors than outdoors, however, only a few VOCs were elevated indoors compared to background.
- Benzo(a)pyrene was higher at the outdoor field than background (range ND-0.19 versus ND-0.05).
- For the indoor field, 1-methylnapthalene, 2-methylnapthalene, fluorene, napthalene, and pyrene were 10-fold higher than background.
- There were several other PAHs found only on the indoor turf, acenapthene, acenaphthylene, fluorene, napthalene, and 2,6-dimethylnapthalene.
- BZT and BHT were higher on the indoor field than outdoor field (BZT range 11,000-14,000 ng/m^3 versus <80-1,200 ng/m^3; BHT range 1,240-3900 ng/m^3 versus <80-130 ng/m^3).

Study limitations:

- Potential selection bias as field location participation was voluntary.
- Sample size was small.
- Summer 2009 temperatures were lower than normal.
- Personal sampling occurred at waist height, not in the breathing zone.
- Some VOCs were found in the personal samples, but not the turf or background indicated non-turf related sources.

2. Hazardous organic chemicals in rubber recycled tire playgrounds and pavers

M. Llompart, L. Sanchez-Pardo, J. Lamas, C. Garcia-Jares, E. Roca; *Chemosphere*; **2013**.

The purpose of the study was to investigate the presence of hazardous organic chemicals in recycled tire playground surfaces.

Methods:

- 21 samples from 9 urban playgrounds
- 2 types of ground covers - floor tiles compositions and carpet covers
- 7 samples from a local store; 2 puzzle pavers and 5 recycled rubber tire tiles of different colors
- Ultrasound-assisted extraction followed by pressurized solvent extraction
- GC-MS for PAHs, plasticizers and other phthalates (31 compounds total)
- Solid-phase microextraction (SPME) for vapour phase composition profiles

Study results and/or conclusions:

- For playground samples
  - Full GC-MS scan identified a large number of VOCs, SVOCs, and POPs.
  - All samples contained PAHs with a range of 1.25 µg g-1 to 70.4µg g-1 total PAH amount with one sample having a concentration of 178µg g-1
  - Pyrene was the most abundant congener found in all samples.
  - Napthalene, phenanthrene, fluoranthene, and chrysene were found in 20 or 21 samples.
  - B(a)P was found in 5 samples with values ranging from 0.4µg g-1 to 5.0µg g-1.
  - Benzothiazole (BTZ) was found in all playground samples with a mean concentration of 10µg g-1.
  - 2-mercaptobenzathiole (MBTZ) was found in playground samples, but there were methodological issues with the analysis.
  - 4-tert-butylphenol (TBP) was present in half the playground samples at low concentrations.
  - Butylated hydroxytoluene (BHT) was found in all samples but butylated hydroxyanisole (BHA) was not found in the samples.
  - Phthalates were found in all samples with the most abundant congener being di(2-thylhexyl)phthalate, concentrations ranging from 4 to 64 µg g-1.
  - Diisononyl phthalate (DINP) was found in 8 of 21 playground samples but was not detected in commercial pavers.
  - For the SPME analysis, all PAHs found in the samples were detected excluding the less volatile ones. BZT, DEP, DIBP, DBP, DEHP, and BHT were found in all cases.

- For commercial pavers:
  - Higher PAH concentrations compared to playground samples.
  - For 5 of 7 samples, concentrations were extremely high - 2000µg g-1 to 8000µg g-1.
  - All PAHs were found in all samples with a mean concentration of B(a)P = 500µg g-1.
  - BZT was found in all commercial pavers with concentrations ranging from ~20 to >150 µg g-1.
  - MBTZ was not detected in commercial pavers.
  - TBP was present in all pavers with concentrations ranging from 8.6 to 21µg g-1.
  - BHT was found in all pavers with a mean concentration 19µg g-1.
  - Phthalate concentrations were higher in pavers than playground samples. DEHP concentrations ranged from 22 to 1200µg g-1.
  - For the SPME analysis, volatile PAHs and some less volatile PAHs (including B(a)P) were found in some samples. BZT, DEP, DIBP, DBP, DEHP, and BHT were found in all cases.
  - TBP was also found in most samples.
- Research is ongoing as a high number of compounds (excluding the ones in this study) were found in the samples.

Study Limitations:

- The study did not determine bioavailability of the chemicals after ingestion or upon dermal exposure.
- For the SPME analysis, inhalation exposure is indicated as possible by the authors; however, laboratory vapor phase composition does not mimic field conditions and thus potential exposure conditions.

3. Metals contained and leached from rubber granulates used in synthetic turf areas

B. Bocca, G. Forte, F. Petrucci, S. Costantini, P. Izzo; *Science of the Total Environment*; **2009**.

The purpose of the study was to quantify metals contained in and leached from different types of rubber granulates used in synthetic turf.

Methods:

- 32 samples from 32 different playgrounds in Italy were collected with samplings performed at different positions in the playground to obtain a representative sample for each area with 250g granulate obtained from 12 sectors.
- 50g granulate from each of the 12 samples pooled to obtain 1 sample per playground.
- Each sample was analyzed for metal content.
    - Al, As, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Li, Mg, Mn, Mo, Ni, Pb, Rb, Sb, Se, Sn, Sr, Tl, V, W, Zn
- The levels were compared to the maximum concentrations allowable for soils.

Study results and/or conclusions:

- The rubber granulates contained all the metals included in the analysis, but the concentration range was wide in the different samples.
- Relatively high levels of Al, Fe, Mg, and Zn were found.
- All samples had metal concentrations significantly lower than the allowable limit, except Co, Sn, and Zn.
- 50% of samples exceeded the Co and Sn limit, while 97% of samples exceeded the limit for Zn with values around 100x higher than the standard.
- The highest leaching was observed for Zn (2,300 µg/L).
- Very low concentrations of As, Cd, CO, Cr, Cu, Li, Mo, Ni, Pb, Rb, Sb, and V were leached and Be, Hg, Se, Sn, Tl, and W were under the LOQ.

Study Limitations:

- Assessments of risk should be conducted for each individual case at a local level due to differences in local ground conditions, type of drainage, and the composition of the filler material.
- The results were compared to the allowable limit for metals in soil which may not be an appropriate comparison.

4. Health Risk Assessment for Artificial Turf Playgrounds in School Athletic Facilities: Multi-route Exposure Estimation for Use Patterns

H. Kim, Y. Lim, S. Kim, I. Yeo, D. Shin, J. Yang; *Environmental Health and Toxicology*; **2012**.

The purpose of the study was to identify major exposure routes and calculate total risk through a health risk assessment for chemicals released from artificial turf playgrounds and urethane flooring tracks.

Methods:

- 50 schools with artificial turf and urethane flooring at the playgrounds; 27 elementary schools and 23 middle and high schools
- Inhalation of VOCs and formaldehydes due to volatile outdoor air from surfaces of artificial turf and urethane flooring
- Dermal uptake from surfaces of artificial turf and urethane flooring
- Ingestion exposure to fine particles
- Trace metals (Pb, Cr, Ni, Cd, Zn, Hg)
    - Dust collected at 5L/min for 8 hours.
    - Urethane layer collected from flooring materials in schools.
    - Infill chip layer collected from chip flooring material in parks.
    - Product surface sampling was conducted using texwipe.
    - Hand surface sampling was performed using texwipe after children played on the facility.
- VOCs
    - Air samples collected at 0.2L/min at 1.5m for 2 hours
    - Infill chips (see Metals #2 and #3).
    - Air samples collected
    - Infill materials (see Metals #2 and #3; surface sampling and hand sampling not performed)
- Phthalates
    - Infill materials (see Metals #2 and #3)
    - Surface sampling (see Metals #4)
    - Hand sampling (see Metals #5)
- Sampling was conducted at the top of the central playground so as to eliminate other potential emission sources.

Study results and/or conclusions:

- Infill content for heavy metals had highest concentration of Zn > Pb > Cr.
- Pb exceeded standard in infill from 8 of the schools and exceeded the domestic standard (10mg/kg) in 2 of the schools.
- For the air monitoring, Zn had the highest concentration; Pb was detected but levels were 10% of Korean ambient air standards.
- Bioavailability values were estimated and for infill chips were shown to be 10-10,000 times lower than the measured content level; for the urethane flooring, the bioavailability was estimated to be approximately 10x lower than the infill chips.
- The excess cancer risk (ECR) for individual chemicals was estimated to be a level of one person out of one million (1×10^{-6}) or less.

- The ECR for carcinogens in children with pica, who represent the most extreme exposure type among the facility users, was shown to be 1.14×10-7 for benzene and 8.47×10-7 for PAHs.
- The hazard index (HI) of the facility users for each individual chemical according to the mean exposure scenario was shown to be less than 0.1, which was low, except for children with pica.
- The HI of children with pica for non-carcinogenic materials was shown to be less than 0.001for Pb, 0.067 for Cr, Cd and Hg, 0.005 for Zn, 0.001 for VOCs; and 0.273 for phthalates, all of which were low, except for phthalates.

Study Limitations:
- The study did not consider asthma or allergic reactions in the health assessment.
- The authors assumed that all chemicals in the air sampling were from artificial turf or urethane flooring, and that there were no other air emission sources.

5. Comparison of Batch and Column Test for the Elution of Artificial Turf System Components

O. Kruger, U. Kalbe, W. Berger, K. Nordhaub, G. Christoph, H.P. Walzel; *Environmental Science and Technology*; **2012**

The purpose of the study was to compare the behavior of synthetic sports flooring components at different elution methods.

Methods:
- Artificial turf components from 6 German producers.
- Batch tests were performed with a liquid to solid ratio of 2L/kg.
- Column tests were performed with a liquid to solid ratio of 26.5 L/kg.
- pH, electric conductivity, turbidity of the eluates, and contaminant release were measured.
- Specific emphasis placed on zinc (ICP-OES) and PAHs (15 measured with HPLC).

Study results and/or conclusions:
- Lead and cadmium were under the LOQ while zinc concentrations varied from below LOQ - 129 mg/L.
- The PAH concentrations varied from 0.07-3.41 µg/L.
- The batch testing produced higher concentrations of zinc; however, column testing provides conditions closer to actual field conditions.

Study Limitations:
- Batch test conditions did not mimic actual field conditions.

6. Release of Polycyclic Aromatic Hydrocarbons and Heavy Metals from Rubber Crumb in Synthetic Turf Fields: Preliminary Hazard Assessment for Athletes

L. Marsili, D. Coppola, N. Bianchi, S. Maltese, M. Bianchi, M.C. Fossi; *Journal of Environmental and Analytical Toxicology*; **2014**.

The purpose of the study was to quantify the PAHs and heavy metals contained in the crumb rubber (tires produced before 2010), to determine whether PAHs are released and at what concentrations, and to estimate respiratory uptake by athletes training on these fields.

Methods:
- Samples were taken from nine different synthetic turfs from football fields in Italy
- 4 samples were new tire crumb rubber that was not yet on a fields.
- 4 samples of tire crumb rubber from fields 1-8 years old, and 1 sample from virgin rubber (i.e. not recycled tires)
- Heavy metals: Pb, Cu, Ni, Zn, Cr, Cd, Fe
    - Concentrations determined via spectrophotometer and spectrometer
- PAHs: 14 analytes determine via HPLC

Study results and/or conclusions:
- The majority of samples had concentrations of heavy metals that were below the maximum limits set by the Italian National Amateur League.
- Cd exceed the limit in 3 samples, 2 new and 1 installed.
- Zn was very high in all samples, exceeding the limit by a minimum factor of 20.
- PAH concentrations varied by sample. For all crumb rubber samples, highest concentrations were benzo(b)fluoranthene or pyrene.
- The data indicate that PAHs are released continually from the crumb rubber via evaporation and athletes frequenting fields could be exposed to chronic toxicity from PAHs.

Study Limitations:
- The preliminary hazard assessment overestimates the PAH contribution.
- Theoretical approach which must be considered as an extreme worst case scenario.

7. **A Scoping-Level Field Monitoring Study of Synthetic Turf Fields and Playgrounds**
U.S. Environmental Protection Agency; **2009.**

The purpose of the study was to generate limited field monitoring data that will be used by EPA to help determine possible next steps to address concerns regarding the safety of tire crumb infill in recreational fields.

Methods:
- Scoping level study evaluating environmental concentrations of tire crumb constituents in recreational fields.
- Two synthetic turf fields and one playground were chosen as the sampling locations.
- Air sampling was conducted at 1m height:
    - PM10 analyzed for mass, metals, and particle morphology
    - VOCs for 56 analytes (2pm collection time at the fields and at an upwind background location).
- Wipe sampling was conducted at the fields and also with tire crumb infill and turf blade samples
    - Pb, Cr, Zn, As, Al, Ba, Cd, Cu, Fe, Mn, Ni (ICP/MS).
- Percent bioaccessible Pb was calculated.

Study results and/or conclusions:
- All VOCs, PM, and metals were similar to all background levels and were below the national ambient air quality standards.
- Methyl isobutyl ketone was detected at one synthetic turf field and was not detected in the background samples.
- The extractable lead concentrations from the infill, turf blades, and tire crumb materials were low and below the EPA standard for lead in soil.
- Lead concentrations in the wipe samples were low and below the EPA standard for lead in residential floor dust.

Study Limitations:
- Semi volatile organic compounds were not measured in this study.
- Sites where samples were taken could have many variabilities in the materials used and possible environmental differences.
- There were some difficulties obtaining permission to access the playgrounds and synthetic turf fields.

8. **CPSC Staff Analysis and Assessment of Synthetic Turf "Grass Blades"**
Consumer Product Safety Commission

The purpose of the study was to determine the total lead content and accessibility of the lead.

Methods:
- Samples of synthetic turf at the time of installation and samples from when 1 field was dismantled.
- Lead content of grass blades was determined using ICP.
- Samples with detectable lead were tested for accessibility of lead.
- For in-service fields, X-ray fluorescence was used to detect the presence of lead.

Study results and/or conclusions:
- Synthetic turf lead content ranged from 0.09% to 0.96% and varied between the turfs and also within a field depending on color.
- The results for this set of tested synthetic turf fields show no case in which the estimated exposure for children playing on the field would exceed 15 mg lead/day (according to the CPSC's recommendation for chronic lead ingestion not exceeding 15 mg lead/day, daily).

Study Limitations:
- Accuracy of wipe sampling method for estimating exposure to lead contact residue is unknown.
- Dermal contact to skin with lead residue during a typical play event on a field was assumed.
- Experimental wipe method overestimated transfer to a persons' bare skin by a factor of 5 to 13.
- Bioavailability of lead from synthetic turf may not be the same as it is for the food and drink exposures that were the basis of the dose-response.

- Staff did not make adjustments in the assessment to account for differences in lead content as fields can have areas with different lead content (i.e. painted areas, etc.).

9. Environmental–sanitary risk analysis procedure applied to artificial turf sports fields
B. Ruffino, S. Fiore, M. C. Zanetti; *Environmental Science and Pollution Research*; **2013**.

The purpose of the study was to characterize chemicals in crumb rubber and assess their capacity to release the chemicals on contact with water. The study also evaluated if the rubber granules may pose a risk to child and adult players via direct contact, contact with rainwater soaking the field, or inhalation of dusts and gases released.

Methods:
- Four sports turf fields with crumb rubber infill, 1 field with thermoplastic elastomer, and 1 natural turf field.
- Field age varied from 1-3 years old.
- Rubber and soil samples were analyzed for BTX (GC-MS), PAHs (8, GC-MS), and metals (18, ICO-OES).
- In-water extractable compounds (BTX, PAHs, and metals) were analyzed.
- Gases and dusts were collected immediately above the ground, close to the sports fields, and at a point in the center of the city.
    - Samples were analyzed for BTX (gases) and PAHs (dust).

Study results and/or conclusions:
- Concentration of benzene is similar to those in the natural turf field.
- Pyrene concentrations in synthetic turf are approximately 20 mg/kg and B(a)P concentrations were 10 mg/kg.
- Zinc concentrations were substantially higher in synthetic turf compared to the natural turf sample; 115 times higher at the synthetic turf field with the lowest percentage zinc.
- The leaching tests identified higher BTX and PAHs in leachates from new infill material was higher than the old infill materials.
- For all turf fields examined and for all routes considered, the cumulative CR proved to be lower than 10^{-6} and the non-carcinogenic risk (for the sum of COCs) lower than 1, in line with Italian guidelines.
- Additionally, for the inhalation route, the inhalation of dust and gases from activity on artificial turf fields gave risk values less than those due to inhalation of atmospheric dust and gases from vehicular traffic.

Study Limitations:
- Some of the artificial turf fields were in various stages of age (the samples that were from newer fields had higher chemical and metals concentrations than older fields).
- Sample comparison was limited to one city's atmospheric dusts and gases and may not be the best representation of typical vehicular dust and gases being emitted.

10. Human Health Risk Assessment of Synthetic Turf Fields Based Upon Investigation of Five Fields in Connecticut
G. Ginsberg, B. Toal, N. Simcox, A. Bracker, B. Golembiewski, T. Kurland, C. Hedman; *Journal of Toxicology and Environmental Health, Part A*; **2011**.

The purpose of the study was to develop a screening level risk assessment in which high-end assumptions for exposure were used for uncertain parameters and surrogate data were employed for chemicals with inadequate toxicity information so that chemicals did not fall out of the assessment on the basis of missing data.

Methods:
- Personal air samples were taken from volunteers during 2-h sampling event at 5 artificial grass fields (4 outdoor and 1 indoor) with crumb rubber infill.
- Stationary air samples were also taken near the field.
- Air samples were analyzed for VOCs (60), SVOCs (120, including 22 PAHs), lead, nitrosamines (7), and PM10.

Study results and/or conclusions:
- 10 VOCs were considered chemicals of potential concern (COPC) for the outdoor and fields and 13 VOCs for the indoor fields.
- Personal monitoring results were higher for VOCs than the stationary sampling results.
- The VOCs of potential concern were above background concentrations at only one of the outdoor fields (not the same field in every case), except for toluene and hexane which were above background at two fields.

- Personal monitoring samples showed VOCs were 1.5-to-3-fold greater than background at outdoor fields, except methylene chloride which was 12.8-fold higher.
- Indoor VOCs detections tended to have greater elevations relative to background.
- 2 SVOCs were selected as COPC, benzothiazole (BTZ) and butylated hydroxytoluene (BHT).
- BZT was above background at indoor and outdoor fields; max indoor result was 11.7-fold higher than max outdoor result.
- BHT was detected at all fields and results were higher for stationary monitoring.
- BHT is a COPC for the indoor field.
- A variety of PAHs were detected above background but the concentrations were generally low (well below 1µg/m3).
- Less volatile PAHs were detected in the outdoor field while the more volatile PAHs were found indoors but generally not outdoors
- Lead results were below the 300ppm target set by the CPSC for lead in products intended for children.
- Based upon the findings, outdoor and indoor synthetic turf fields are not associated with elevated adverse health risks.

<u>Study Limitations</u>:

- Small number of fields in the study.
- Only one indoor field was included in the study.
- Some limitations in weather variables when taking samples at outdoor fields.
- Small number of samples taken per field.
- The study did not attempt to measure latex antigen in the crumb rubber or in the PM10 collected from on field air samples.
- Some VOC detections in the personal monitoring may have originated in the device.

11. Artificial Turf Football Fields: Environmental and Mutagenicity Assessment

T. Schiliro, D. Traversi, R. Degan, C. Pignata, L. Alessandria, D. Scozia, R. Bono, G. Gilli; *Archives of Environmental Contamination and Toxicology*; **2013**.

The purpose of the study is to develop an environmental analysis drawing a comparison between artificial turf football fields and urban areas relative to concentrations of particles (PM10 and PM2.5) and PAHs, BTEX, and mutagenicity of organic extracts from PM10 and PM2.5.

<u>Methods</u>:

- 24 Air samples were taken from 6 football fields (5 were artificial turf) and 2 urban locations in 2 sampling events to study influence of meteorological and seasonal conditions and the presence of play.
- PM10, PM2.5, BTX (benzene, toluene and Xylene), and PAHs were measured in the air samples.
- The mutagenicity of the organic extracts of the PM and PM2.5 samples were studied using the Ames test.

<u>Study results and/or conclusions</u>:

- Air samples from the artificial turf field had no significant differences from the samples from the urban sites.
- BTX concentrations at the urban site were significantly greater than on the turf fields.
- Seasonal differences were also seen.
- In regards to environmental monitoring, artificial turf fields present no worse exposure risks than those found in the city.
- PAH concentrations, when detected, were low.
- PAH concentrations were greater in the winter than the summer.
- B(a)P was present on the football fields during the winter sampling.
- During the winter season sampling, PAHs, except anthracene, were often present on each football field and at the urban site.
- The mutagenicity showed a seasonal trend and was greater on fields characterized by traffic and/or industrial emissions in the surrounding area.

<u>Study Limitations</u>:

- Urban locations used to compare field results might not be a good overall representation of urban areas in general.
- Non-turf related environmental variables at both the fields and urban areas could be of influence.

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

E. Menichini, V. Abate, L. Attias, S. De Luca, A. di Domenico, I. Fochi, G. Forte, N. Iacovella, A. L. Iamiceli, P. Izzo, F. Merli, B. Bocca; *Science of the Total Environment*; **2011**

The purpose of this study was to identify some potential chemical risks and to roughly assess the risk associated with inhalation exposure to PAHs from materials used to make up artificial turf fields.

Methods:

- Rubber granulates were collected from 13 Italian fields. For the 13 fields, samplings were performed at different positions in the playground to obtain a representative sample for each area (see Bocca et al #4).
- Rubber samples varied and included virgin thermoplastic, coated and uncoated recycled tires, recycled vulcanized rubber, and recycled ground gaskets.
- Samples were analyzed for 25 metals and 9 PAHs.
- Air samples were collected on filter at two fields, using static and personal samplers, and at background locations outside the fields.

Study results and/or conclusions:

- High contents of Zn and benzo(a)pyrene were found in the granules present in playing fields (above the Italian standards for soils).
- Other chemicals such as PAHs, VOCs, PCBs, PCDDs and PCDFs were found in the recycled crumb rubber but were at levels within the mentioned limits.
- Based on the 0.4 ng/m3 concentration and using a worst-case conservative approach, an excess lifetime cancer risk of 1×10^{-6} was calculated for an intense 30-year activity (5h/d, 5d/w, all year long).

Study Limitations:

- Only particle phase air samples were taken (TSP or PM10). So the inhalation exposure may be under-estimated for missing information on contaminants in the gaseous phase.
- Inhalation risk assessment was based on limited data and the risk assessment should be regarded as preliminary.
- Fields may vary in age and type of rubber used which could affect the samples and chemicals found in them. Environmental factors such as climate and weather could have an effect on study samples at the time of sampling.

13. Characterization of substances released from crumb rubber material used on artificial turf fields

X. Li, W. Berger, C. Musante, M. I. Mattina; *Chemosphere*; **2010**.

The purpose of the study was to assess major volatilized and leached chemicals from crumb rubber material (CRM); assess the change of alteration of the pattern of volatile compounds with time after installation for both laboratory and field-aged samples under natural weathering conditions.

Methods:

- Vapor offgas and leachate samples from 15 crumb rubber material (CRM) samples were analyzed.
- The CRM samples were obtained from local schools and commercial suppliers.
- 10 organic chemicals (PAHs and VOCs) were measured in the vapor phase over CRM.

Study results and/or conclusions:

- During the vapor phase, CRM emitted volatile PAHs and other compounds.
- Benzothiazole (BTZ) was the most abundant volatile compound found in all the samples.
- Zinc was found to be the highest of all metals found in the samples' extraction fluid.
- There was a significant reduction in volatile compounds found in samples that were from artificial turf fields that were 2 years old compared to newer fields.
- It was also determined that there is some variability in the out-gassing profile of CRM from different manufacturers.

Study Limitations:

- This study provides mostly qualitative, not quantitative results, which makes the results difficult to compare to other studies.

14. Toxicological Assessment of Coated Versus Uncoated Rubber Granulates Obtained from Used Tires for Use in Sports Facilities

J. Gomes, H. Mota, J. Bordado, M. Cadete, G. Sarmento, A. Ribeiro, M. Baiao, J. Fernandes, V. Pampulim, M. Custodio, I. Veloso; *Journal of the Air and Waste Management Association*; **2012**.

The purpose of the study was to investigate whether coating rubber granulates decreased emissions of leachates and airborne substances.

Methods:

- Raw rubber granulates were obtained along with two coatings, a polyvinyl chloride and a cross-linked alquidic polymer, both which contained color additives and a flame-retarding agent.
- The coated rubber granulates were compared with the raw rubber granulates.
- Chemicals analyzed:
    - PM2.5 and PM10
    - PAHs (16; GC-MS)
    - Heavy metals (Cd, Cr, Hg, Pb, Sn, Zn; ICP-OES)

Study results and/or conclusions:

- Rubber granulates obtained cryogenically and semicryogenically have lower inhalable particles than those obtained mechanically
- For PAHs in raw and coated samples, one type of coating resulted in increased content of some PAHs.
- However, the leaching of PAHs from raw, R1 coated or R2 coated is negligible.
- For heavy metals, the concentrations in the leachate is very small and the coating does appear to prevent leaching of the metals.
- Both R1 and R2 coatings showed lower ecotoxicity than the non-coated rubber granulates.

Study Limitations:

- There are only two types of coating included in the analysis.
- It is noted that one of the coatings include polyvinyl chloride which has been excluded from certain textile products due to concerns over potential adverse health effects after human exposure.

15. Evaluating and Regulating Lead in Synthetic Turf

G. Van Ulirsch, K. Gleason, S. Gerstenberger, D. B. Moffett, G. Pulliam, T. Ahmed, and J. Fagliano; *Environmental Health Perspectives*; **2010**

The purpose of the study was to present data showing elevated lead in fibers and turf-derived dust; identify risk assessment uncertainties; recommend that government agencies determine appropriate methodologies for assessing lead in synthetic turf; and recommend an interim standardized approach for sampling, interpreting results, and taking health-protective actions.

Methods:

- This is a commentary on lead in synthetic turf, using data collected from recreational fields and child care centers on lead levels in turf fibers and surface dusts.

Study results and/or conclusions:

- Synthetic turf can deteriorate to form dust containing lead at levels that may pose a risk to children.
- Given elevated lead levels in turf and dust on recreational fields and in child care settings, it is imperative that a consistent, nationwide approach for sampling, assessment, and action be developed.

Study Limitations:

- N/A. This is a commentary.
- Updated guidelines/standards for lead in synthetic turf blades were released after publication of the article.

Biomonitoring Study

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

J. G. M. Van Rooij, F. J. Jongeneelen; *International Archives of Occupational and Environmental Health*; **2010**.

The purpose of the study was to assess the exposure of football players to PAHs from sporting on synthetic ground with rubber crumb infill (by measuring urinary 1-hydroxypyrene).

Methods:

- All urine samples were collected over 3 days (the days before, of, and after a 2.5-h football match) from 7 football players.
- 1-Hydroxypyrene (PAH biomarker) was measured in urine.

Study results and/or conclusions:

- The football players spent a total of 2.5 hours on the synthetic turf field.
- Three players likely had PAH exposure from pre-sporting activities and were omitted from the analysis.
- Uptake of PAH by football players playing on synthetic turf with rubber crumb infill is minimal.
- If there is any exposure, then the uptake is very limited and within the range of uptake of PAH from environmental sources and diet.

Study Limitations:

- Only 7 football players were in the study. The sample size is too small to represent the target population.
- Short exposure duration (2.5-h) and PAHs from other sources (such as diet) could have affected the player's results.
- Dietary and lifestyle questionnaires were not administered.

Bioavailability Studies

1. **Bio-accessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers**
   B. T. Pavilonis, C. P. Weisel, B. Buckley, P. J. Lioy; *Risk Analysis*; **2014**

   The purpose of the study was to determine whether the bio-accessible fraction of metals and SVOCs found in artificial turf fields exceeded non-cancerous risk-based guidance values for children and adult athletes.

Methods:

- New crumb infill (n=9), new turf fiber products (n=8), and field samples (n=7) were collected.
- Using synthetic biofluid solutions, bio-accessibility analyses for metals and SVOCs were performed for the digestive system, respiratory system, and dermal absorption.

Study results and/or conclusions:

- PAHs were generally below the limit of detection in all three artificial biofluids.
- SVOCs found were not present in toxicological databases evaluated and were in everyday consumer products.
- Trace metals found were at minimal levels.

Study Limitations:

- Possible selection bias and the small number of fields used in this study.
- The simulated digestive fluid may not reflect accurately true digestive capabilities in humans.
- A large amount of variability was found among the field samples used in this study (some samples may have been from older fields or different versions/types of artificial turf).

2. **Health Risk Assessment of Lead Ingestion Exposure by Particle Sizes in Crumb Rubber on Artificial Turf Considering Bioavailability**
   S. Kim, J. Yang, H. Kim, I. Yeo, D. Shin, Y. Lim; *Environmental Health and Toxicology*; **2012**.

   The purpose of the study was to assess the risk of ingestion exposure of lead by particle sizes of crumb rubber in artificial turf filling material with consideration of bioavailability

Methods:

- Lead was measured using ICP-MS in the extracts of tire crumb particles of various size (larger or smaller than 250 um) extracted using artificial digestive and acid extraction methods.
- Average lead exposure amounts were calculated for students.

Study results and/or conclusions:

- Lead was found in the digestion extracts of tire crumb material.
- Acid extraction method resulted in lead concentrations 6.5 times higher than content concentration.
- Digestive extraction resulted in lead concentration 10.3 times higher than content concentration.

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

Study Limitations:
- It appears that only one type of crumb rubber was investigated.
- There is uncertainty as to whether or not the EDPM rubber powder prototype used in the study is representative of the entire artificial turf.

3. **Hazardous chemicals in synthetic turf materials and their bio-accessibility in digestive fluids**
J. Zhang, I. Han, L. Zhang, W. Crain; *Journal of Exposure Science and Environmental Epidemiology*; **2008**.

The purpose of the study was to obtain data that will help assess potential health risks associated with chemical exposure from artificial turf and to determine the bio-accessibility of PAHs and toxic metals in synthetic human saliva, gastric fluid and intestinal fluid.

Methods:
- Seven samples of rubber granules and one sample of artificial grass fiber from synthetic turf fields at different ages of the fields.
- PAHs (15) and metals (Cr, Zn, As, Cd, Pb; ICP-MS) were measured in the granule/grass fiber samples and synthetic digestive fluids (saliva, gastric fluid, intestinal fluid).

Study results and/or conclusions:
- Total PAHs ranged from 4.4ppm to 38.15ppm.
- PAHs in rubber granules had low bio-accessibility (i.e., hardly dissolved) in synthetic saliva, gastric fluid, and intestinal fluid.
- Rubber granules often contained PAHs at levels above health-based soil standards.
- PAH levels declined as the field ages.
- Decay trend may be complicated by adding new rubber granules to compensate for loss of the material.
- Zinc contents were found to far exceed the soil limit, range 5710-9988.
- Lead content was low in all the samples compared to soil standards.
- Lead in the rubber granules was highly bioaccessible in the synthetic gastric fluid.

Study Limitations:
- The digestive system is difficult to simulate, and the simulated digestive fluid may not accurately reflect true digestive capability in humans.

Toxicological Studies

1. **Toxicological Evaluation for the Hazard Assessment of Tire Crumb for Use in Public Playgrounds**
D. A. Birkholz, K. L. Belton, T. L. Guidotti; *Journal of the Air and Waste Management Association*; **2012**.

The purpose of the study was to design a comprehensive hazard assessment to evaluate and address potential human health and environmental concerns associated with the use of tire crumb in playgrounds.

Methods:
- 200g tire crumbs were leached in water to produce the test leachate.
- Genotoxicity was assessed using *Salmonella typhimurium* mutagenicity fluctuation assay, SOS chromotest, and Mutatox.
- Human health concerns were addressed using conventional hazard analyses.

Study results and/or conclusions:
- All samples analyzed did not meet the criteria for genotoxicity and were considered negative.
- Genotoxicity testing of tire crumb samples following solvent extraction concluded that no DNA or chromosome-damaging chemicals were present.
- This suggests that ingestion of small amounts of tire crumb by small children will not result in an unacceptable hazard/risk for development of cancer.
- The use of tire crumb in playgrounds results in minimal hazard to children and the receiving environment.

Study Limitations:
- The authors of this study concentrated only on potential genotoxicity from the exposure to tire crumb material in playgrounds, other adverse health effects that may be caused by other elements/compounds in the tire crumbs may have been overlooked.

2. Benzothiazole toxicity assessment in support of synthetic turf field human health risk assessment

G. Ginsberg, B. Toal, T. Kurland; Journal *of Toxicology and Environmental Health, Part A*; **2011**.

The purpose of the study was to assess benzothiazole (BZT) toxicity in support of a risk assessment of synthetic turf fields conducted by the Connecticut Department of Public Health.

Methods:
- The study reviewed the following information on BZT and its surrogate, 2-mercaptobenzothiazole (2MBZT), to derive BZT toxicity values for cancer and non-cancer effects:
    - properties and uses
    - BZT exposure
    - toxicokinetics of BZT and 2MBZT
    - toxicity of BZT and 2MBZT with regard to acute toxicity, mutagenicity, subchronic and chronic toxicity and cancer, developmental and reproductive effects

Study results and/or conclusions:
- The following BZT toxicity values were derived:
    - Acute air target of 110 µg/m3 based upon a BZT RD50 study in mice relative to results for formaldehyde.
    - A chronic, noncancer target of 18 µg/m3 based upon the no observed adverse effect level (NOAEL) in a subchronic dietary study in rats, dose route extrapolation, and uncertainty factors that combine to 1000.
    - A cancer unit risk of 1.8E-07/µg-m3 based upon a published oral slope factor for 2-MBZT and dose-route extrapolation.

Study Limitations:
- There were numerous uncertainties and limited information in the BZT toxicology database.
- BZT was not tested in sub-chronic/ chronic studies, cancer bioassay, or developmental and reproductive studies.
- Some endpoints were studied using 2-MBZT as a surrogate, which makes an imperfect comparison due to differences in structure and metabolic pathways.
- Only a screening-level assessment for BZT exposure.
- The proposed toxicity values are for BZT in general, not specifically for BZT in synthetic turf.

3. Evaluating the Risk to Aquatic Ecosystems Posed by Leachate from Tire Shred Fill in Roads Using Toxicity Tests, Toxicity Identification Evaluations, and Groundwater Modeling

P.J. Sheehan, J.M. Warmerdam, S. Ogle, D. Humphrey, S. Patenaude; *Environmental Toxicology and Chemistry;* **2006**.

The purpose of the study was to evaluate the toxicity of leachates from tire shreds used as roadbed fill and to define the circumstances under which use of the tire shreds as roadbed fill, both above and below the water table, will pose a negligible hazard to adjacent surface-water ecosystems.

Methods:
- Shred infill obtained from two study sites, one above the water table and one at and below the water table. For this infill, tire shreds contain a mixture of steel and glass belted scrap tires and substantial amounts of steel belts are exposed at the cut edges.
- Site #1 constructed in 1993 with 3 sample collection areas with precipitation infiltrating the road embankment and into collection basins for sampling. There was one "control" basin without a tire shred layer.
- Site #2 was constructed in 1994 and tire shreds come into direct contact with groundwater. Water samples were collected from 3 wells: 1 upgradient, 1 within the trench with direct contact to tire shreds and 1 downgradient.
- Leachates analyzed for metals, VOCs, and sVOCs.
- Short-term chronic *C. dubia* test and short-term chronic fathead minnow test used to determine toxicity.

Study results and/or conclusions:
- Site #1:
    - No adverse effects on *P. promelas* survival or growth

- o Substantial reduction in C. dubia survival in phase 2 of the reference water likely due to high conductivity of the leachate sample.
  - o Metals, VOCs and sVOCs were detected in two samples but the concentrations were low and not indicative of leaching substantial amounts of chemicals.
- Site #2:
  - o Slight reductions in P. promelas survival in both phase 1 and 2 of the reference sample.
  - o No impairment in survival seen in the two samples (at and down gradient).
  - o Significant reductions in growth seen for both the reference sample and the other two site samples.
  - o For *C. dubia*, > 80% mortality was seen in the leachate samples (phase 1); significant reductions in reproduction also seen but reductions in reproduction were also seen in the reference samples.
  - o Elevated levels of some VOCs and metals (especially iron and manganese) indicated chemicals leach from shred fill; however, the leaching of iron is likely from the steel belts exposed on the cut edge.

Study Limitations:

- The type of infill used in road beds is quite different from the crumb rubber infill used in synthetic turf.
- The modeling estimates used numerous different scenarios to determine amount of filtration needed which is not applicable to studies investigating human exposure to chemicals synthetic turf.

4. Impact of tire debris on in vitro and in vivo systems

M. Gualteri, M. Andrioletti, P. Mantecca, C. Vismara, M. Camatini; *Particle and Fibre Toxicology*; **2005**.

The purpose of the study was to investigate tire debris effects on the development of *X. laevis* and on human cell lines.

Methods:

- Tire debris samples were obtained from laboratory processing using tire scrap materials.
- Eluates were obtained after soaking in water (pH 3); organic extracts obtained and used for the cell line test (A549) and the tests using *X. laevis* embryos
- Cell viability assay and Comet assay were used to determine toxicity, doses 10, 50, 60, 75 µg/mL
- in vivo: *X. laevis* embryos were exposed to 50,80,100, 120 µg/mL organic extracts

Study results and/or conclusions:

- A time-dependent increase of Zn in the human liver cell line was seen after treatment with 50µg/ml zinc at 2, 4, and 24 hours.
- An increase in cell death was seen at the higher doses (50, 60, 75 µg/ml) compared to controls.
- Cell proliferation was decreased in a time and dose-dependent manner.
- DNA damage increased at 50 and 60µg/mL as shown by the comet assay.
- Cell morphology was impacted after 72 hours treatment. The highest dose showed visible vacuolization in the cytoplasm and apoptotic nuclear images; present in 50% of cells at 72 hours with 75µg/ml treatment.
- Zn concentration of 44.73µg/ml (50 g/l tire debris) resulted in 80% mortality of embryos and a concentration of 35.28µg/ml (100 g/L tire debris) resulted in 26.8% mortality. Malformation was similar between the two doses. Dilutions of the organic extracts showed significant increases at 1% for 44.73 and at 10% for 35.28.
- The eluates had teratogenic effects for both doses.
- For *X. laevis* development, 80µg/ml and above resulted in significant mortality with 15.9% mortality at 120µg/mL.
- Increase in malformed larvae found at 80 and 100µg/mL; at 120 µg/mL, 37.8% of larvae were malformed.
- Most frequent malformation was gut roiling.

Study Limitations:

- The type of sample used in the analysis (tire debris) is not the same type of tire material as seen in crumb rubber infill.
- The analysis only looked at zinc and did not include other known contaminants of tire crumb/tire debris.
- No indication if the doses used in the laboratory analysis are similar to doses/exposure levels in the environment.

Appendix B - Literature review of microbial work done on tire crumb rubber artificial fields

Overall summary:
Most of the work in tire crumb rubber use in synthetic turf fields has focused on chemicals such as polycyclic aromatic hydrocarbons (PAH), metals, volatile organic carbons (VOCs), polychlorinated biphenyls (PCBs), or ecotoxicity work using sensitive bioindicators such as Pseudokirchneriella subcapitata and Daphnia magna. There is a very limited amount of literature on health risks from biological material (i.e., human pathogens) in tire crumb rubber artificial fields. Of the literature that does exist, most studies have been conducted by academia, or published in open access journals, or by state government/environmental groups, and thus have not undergone thorough peer review and therefore may show inherent bias. Regardless, most work has focused on quantifying total bacteria using non-selective agar, reporting colony forming units per gram (CFU/g) of infill material. Additional work has been done on the ability of opportunistic human pathogens (methicillin-resistant staphylococcus aureus (MRSA) and Burkholderia cepacia complex) to survive in tire crumb rubber leachate, including toxicity to these bacteria due to chemicals such as zinc. There has been no work published on enteric pathogens/risks from artificial turf fields.

1) Keller, Marcus. "The fate of methicillin-resistant staphylococcus aureus in a synthetic field turf system." (2013).
This study looked the survivability of methicillin-resistant staphylococcus aureus (MRSA) on turf infill (rubber, sand, organic, or polymer materials), and turf fibers (monofilament, slit-film or nylon turf blades), and the toxicity of infill materials to MRSA. MRSA was measured as the incubation time in which 50% of the inoculated MRSA are still viable (A50). MRSA persisted longer in infill (A50 = 13hr) vs turf fibers (A50 = 4hr, $p<0.05$). A50 for crumb rubber was 13hr. The role of infill toxicity to the MRSA A50 was assessed using a dialysis assay, which showed that 94% of MRSA cells remained viable following 6 h of exposure to organic infill, 91% for sands, 79% for polymer coated materials, 71% for crumb rubber, 68% for TPE rubber, and 17% for EPDM rubber.
Conclusion: MRSA survived less in crumb rubber materials than other fill materials such as sand/organic.

2) Miller, Suzanne CM, John J. LiPuma, and Jennifer L. Parke. "Culture-based and non-growth-dependent detection of the Burkholderia cepacia complex in soil environments." Applied and environmental microbiology 68.8 (2002): 3750-3758.
This study looked at Burkholderia cepacia complex (Bcc) – an opportunistic human pathogen, in a variety of soils and other surfaces, including turf athletic fields from 3 US cities (Philadelphia, Cleveland, Portland, OR). Bcc was not isolated from any turf samples (n=6).
Conclusion: using PCR, Bcc appears to be prevalent in soil from urban and suburban sites.

3) A Survey of Microbial Populations in Infilled Synthetic Turf Fields. McNitt, Andrew, and Petrunak, Dianne. A Draft Report by Faculty of the Center for Turgrass Science at Penn State University. 2006.
Took samples from a couple of fields in PA, both crumb rubber and soil, specifically looking for MRSA and non-selective cultural bacteria on R2A agar over a 2-week period in 2006. Total number of samples not provided. Sampled areas included a "high use" and "low use" area of each field taking approx. 2-3mL sample of the crumb rubber, and cut fibers from synthetic fields. No samples were S. aureus positive via selective media, gram stain or latex agglutination tests. Of the 8 fields that were tested with crumb rubber only, total culturable bacteria from R2A agar averaged 3.97log10 CFU per gram of crumb rubber. Soil (silty loam and sand-based soil) samples (n=2) averaged 5.4log10 CFU/g soil. S. aureus was positively identified from other public areas and/or athletic facilities such as blocking pads, weight equipment, stretching tables, and used towels.
Conclusion: lower counts of microbes were found indoors as opposed to outdoors, and soil fields had over an order of magnitude more microbes than synthetic crumb-rubber fields.

4) Safety Study of Artificial Turf Containing Crumb Rubber Infill Made From Recycled Tires: Measurements of Chemicals and Particulates in the Air, Bacteria in the Turf, and Skin Abrasions Caused by Contact with the Surface. Report produced under contract by: Office of Environmental Health Hazard Assessment. Pesticide and Environmental Toxicology Branch. California Department of Resources Recycling and Recovery. 2010.

Chapter 3: Sampled 5 artificial turf (soccer) fields with crumb rubber mixed with sand and 2 natural fields in San Francisco, CA in September or October 2009 (all outdoor). 1-2g of material was sampled per event, and each field was sampled 3 times in various areas. The three most prominent species assay was used to quantify culturable bacteria in samples (agar not provided). Artificial turf (n=30) ranged from 0-50,000 CFU per gram crumb rubber compared to 637,000-305,000,000 CFU/g natural soil (n=12). 2/12 and 6/12 samples were positive for Staphylococci in crumb rubber and soil, respectively. No MRSA was detected in crumb rubber or synthetic blades of grass; one sample (n=12) was positive for MRSA from a blade from natural turf.
Conclusion: Synthetic turfs, including crumb rubber, harbor fewer bacteria than soil, which, according to authors, could be due to lower moisture content and high temperatures of artificial turf compared to natural turf.

Chapter 4: using a survey of 33 trainers from collegiate athletic programs in CA and NV, it was reported that athletes experienced ~2-3 times higher turf burn ratios compared to natural soil, but the severity of turf burns between soil and synthetic turfs remained similar.

5) Crampton, Mollee, et al. "Effects of leachate from crumb rubber and zinc in green roofs on the survival, growth, and resistance characteristics of Salmonella enterica subsp. enterica serovar typhimurium." Applied and environmental microbiology 80.9 (2014): 2804-2810.

This study investigated the impact of rainwater leachate from crumb rubber in green roofs on the growth of Salmonella enterica subsp. enterica serovar Typhimurium ATCC 14208S. S. Typhimurium was incubated for up to 48hr in crumb rubber leachate from synthetic rainwater (pH=4.3). When compared to a control of just synthetic rainwater incubation over the same time period, S. Typhimurium survived less in crumb rubber leachate than the control, leading the authors to suggest that crumb rubber contains compounds that are inhibitory to bacterial growth. Dilutions of the crumb rubber leachate showed increased survivability of the bacteria, supporting the idea that crumb rubber contains compounds that are toxic to S. Typhimurium. The same crumb rubber extract was washed 10 separate times with 10mL of synthetic rainwater. The leachate exhibited the same effects on microbial growth, with the authors concluding that the toxic effects that crumb rubber are not expected to decrease with time and additional rainfall/washing events.
Conclusion: crumb rubber leachate contains compounds that inhibit microbial growth and survivability.

6) Bass, Jason J., and David W. Hintze. "Determination of Microbial Populations in a Synthetic Turf System." Skyline-The Big Sky Undergraduate Journal 1.1 (2013): 1. – Open access journal

This study took samples from 2 infilled crumb rubber fields, one 1-year old field and one 6-year old field over a 14-week period in late fall/early winter in Ogden, Utah. Indoors/outdoors field information was not provided. Tryptic Soy Agar was used to determine total microbial load, Mannitol Salt Agar for Staphylococcus, and Eosin Methylene Blue Agar to count the number of enteric organisms such as Escherichia coli. Bacterial counts in the older field were up to 10,000 times higher than the newer field. Bacterial counts were highest on the sideline of the older field with average of 1.1x108 CFU/g soil infill compared to 2.5x105 CFU/g on the sideline of the newer field. A higher number of salt-tolerant organisms were able to grow on MSA, indicating possible staphylococci, with an average of 2.77x102 CFUs per gram on the new field and 6.58x103 CFUs per gram on the older field.
Conclusion: bacterial populations are much higher in older fields and newer fields, and the sideline near the 50-yd line contained the highest bacterial populations. This data suggests that microbial populations can accumulate from year to year in synthetic turf.

Below is less related to micro-related work, but focused on ecotoxicity of turf field leachates

7) Krüger, O., et al. "New approach to the ecotoxicological risk assessment of artificial outdoor sporting grounds." Environmental Pollution 175 (2013): 69-74.

Kruger et al., 2013 investigated growth inhibition (Pseudokirchneriella subcapitata) and acute toxicity tests (Daphnia magna) with leachates obtained from batch tests of granular infill material and column tests of complete sporting ground assemblies. Ethylene propylene diene monomer rubber (EPDM) leachate showed the highest effect on Daphnia magna (EC50 < 0.4% leachate) and the leachate of scrap tires made of styrene butadiene rubber (SBR) had the highest effect on P. subcapitata (EC10 ¼ 4.2% leachate; EC50 ¼ 15.6% leachate). No correlations between ecotoxicity of leachates and zinc or polycyclic aromatic hydrocarbons (PAH) was found.

Appendix C - EPA-NCEA Summary of Available Exposure and Health Risk Assessment Studies on Artificial Turf, Playgrounds and Tire Crumbs

Summary of Available Exposure and Health Risk Assessment Studies on Artificial Turf, Playgrounds and Tire Crumbs

Bulleted Summary

- Artificial turf is made of plastic blades that simulate grass and a layer of "infill" material made of recycled tire crumb or crumb rubber.
- There are benefits to using these materials, but concerns have been raised by the public and others regarding health issues associated with their use.
- EPA formed a workgroup in 2008; performed a scoping study, and published a report in 2009.
- There are several studies found in the literature conducted by federal and state governments, academia, and industry.
- The studies varied in scope ranging from studies focused on environmental concentrations found in air; concentrations of the chemicals found in the bulk material; and health risk assessments. Some studies focused the inhalation pathway, while others considered other pathways including ingestion and dermal exposures. Chemicals studied included VOCs, sVOCs, PM_{10}, and metals. Other studies examine the potential for environmental impacts, including leaching of metal into waterways.
- Federal and state government studies include:
  - Norwegian Institute of Public Health (2006) "Artificial turf pitches – an assessment of the health risks for football players"
  - OEHHA 2007 "Evaluation of Health Effects of Recycled Waste Tires in Playground and Track Products"
  - CPSC 2008 "CPSC Staff Analysis and Assessment of Synthetic Turf Grass Blades"
  - New Jersey Department of Health and Senior Services (April 2008) "New Jersey Investigation of Artificial Turf and Human Health Concerns; Fact Sheet"
  - New York Department of Health (2008) "A Review of the Potential Health and Safety Risks From Synthetic Turf Fields Containing Crumb Rubber Infill"
  - New York City Department of Health and Mental Hygiene (March 2009) "Air Quality Survey of Synthetic Turf Fields Containing Crumb Rubber Infill"
  - New York State Department of Environmental Conservation (May 2009) "An Assessment of Chemical Leaching, Releases to Air, and Temperature at Crumb-Rubber Infilled Synthetic Turf Fields
  - EPA (2009) "A Scoping-Level Field Monitoring Study of Synthetic Turf Fields and Playgrounds"
  - Connecticut Department of Health (2010) "Human Health Risk Assessment of Artificial Turf Fields Based Upon Results from Five Fields in Connecticut"
  - New Jersey Department of Environmental Protection (July 2011) "An Evaluation of Potential Exposures to Lead and Other Metals as the Result of Aerosolized Particulate Matter from Artificial Turf Playing Fields"
- These studies concluded that there is no or limited health risk associated with the use of these materials. However, the studies were limited in scope and not all of them carried out a complete exposure/risk assessment. There are uncertainties associated with the assumptions used to derive these conclusions.
- Some potential future activities can be undertaken including: reviewing additional reports and scientific literature; examining the available data more closely; reviewing exposure assumptions; determine if an exposure/risk assessment can be conducted with the available data; studying other factors that may influence exposure; identify key data gaps; and assess the potential for microbiological exposures.

Background

Artificial turf is made of plastic blades that simulate grass and a layer of "infill" material to keep the blades upright. This "infill" is made of recycled "tire crumb" or "crumb rubber" material. This artificial or synthetic turf is often used to cover the surfaces of athletic field. Tire crumbs and crumb rubber are also used as groundcover under playground equipment, running track material, and as a soil additive on sports and playing fields. Although use of these materials has been recognized as beneficial (e.g., recyling, reduction of sports injuries), concerns have been raised by the public and others regarding health issues associated with these materials.

In 2005, EPA Region 8 Pediatric Environmental Health Specialty Unit (PEHSU) received telephone inquiries from parents concerned about health risks to children exposed to a recycled tire crumb product used in fields and school playgrounds. EPA Region 8 requested that the Agency consider this issue and a workgroup was formed and charged to consider the state of science and make recommendations for future research. A second science workgroup was formed to consider available methods to study the situation, and they recommended conducting a scoping study to assess approaches and methods, and to provide limited measurement data for consideration. The workgroup produced a report entitled "Scoping-level Field Monitoring Study of Synthetic Turf Fields and Playgrounds" published in 2009.

Over the years, there have been several published articles on the health concerns resulting from exposures to the materials used in artificial turf. In October of 2014, a soccer coach reportedly suggested an association between cancer cases found in soccer players and exposures to artificial turf. A list of 38 American soccer players (34 of them goalies) had been diagnosed with cancer (http://www.nbcnews.com/news/investigations/how-safe-artificial-turf-your-child-plays-n220166). In response to the news report, a representative from FieldTurf, an artificial field turf company, requested a meeting with EPA to present their views with regard to the safety of turf fields. A conference call was hosted by Michael Firestone of OCHP. FieldTurf stated that scientific research from academia, federal and state governments has failed to find any link between synthetic turf and cancer. More recently, in March 16, 2015, another news article in claimed that the federal government is promoting artificial turf despite health concerns (http://www.usatoday.com/story/news/2015/03/15/artificial-turf-health-safety-studies/24727111/).

Several studies have been conducted on artificial turf and the use of tire crumb materials. Some focused primarily on obtaining concentration data for various compounds that may off-gas from recycled tire materials, while others attempted to estimate health risks associated with their use. There are also several studies that focus on characterizing the compounds contained in bulk samples of artificial turf. Summarized below are the studies conducted by EPA, CPSC, and the states of New York, Connecticut, and California. Included also is a study conducted in Norway. It is important to note that this list is not comprehensive and focuses primarily on studies conducted by federal and state governments.

Norwegian Institute of Public Health (NIPH) and the Radium Hospital 2006

NIPH conducted a health risk assessment of football players that played in artificial turf fields. They examined 9 scenarios including: inhalation, dermal, and ingestion exposures (only for children) for adults, juniors, older children and children. The assessment included various constituents in the tire crumb: VOCs, PAHs, phthalates, PCBs, PM_{10}, and alkyl phenols. The study was limited because of the absence of toxicity data. The study concluded that the use of artificial turf does not cause any elevated health risk. The estimated Margins of Safety (MOS) were no cause for concern.
http://www.isss.de/conferences/Dresden%202006/Technical/FHI%20Engelsk.pdf

OEHHA California study 2007

Office of Environmental Health Hazard Assessment (OEHHA) conducted a risk assessment of the recycled waste tires in playgrounds and track products in 2007. Their study included VOCs, sVOCs and metals. The pathways included in the risk assessment were the ingestion of the tire crumbs via hand to mouth or surface to mouth and dermal contact. They concluded that risk levels were below the *di minim*is level of 1×10^{-6}.
http://www.calrecycle.ca.gov/publications/Documents/Tires%5C62206013.pdf

CPSC 2008

The U.S. Consumer Product Safety Commission investigated the potential hazards from lead in some artificial turf sports fields across the country. The study focused on ingestion of lead from the material that transfers to the mouth from the skin after contact with the lead containing turf. The study concluded that exposure to children playing on the field would not exceed 15 µg of lead/day.
http://www.cpsc.gov//PageFiles/104716/turfassessment.pdf

New Jersey Department of Health and Senior Services 2008

NJDHSS collected samples of artificial turf fibers from 12 fields. Ten fields with polyethylene fibers had very low Pb levels. Two fields with nylon fibers had 3,400 to 4,100 mg/kg of Pb. In addition, they collected artificial turf samples from consumer products that are used for residential lawns and play surfaces. Two of the products that were nylon or nylon/polyethylene contained Pb at 4,700 and 3,500 mg/Kg. These concentrations higher than the Residential Direct Contact Soil Cleanup Criteria (which is 400 mg/kg). "There is a need for a comprehensive and coordinated approach to evaluating the public health risks and benefits of artificial turf fields." http://www.nj.gov/dep/dsr/publications/artificial-turf-report.pdf

New York Department of Health Study 2008

In 2008, the NY Department of Health conducted a study where they reviewed data from 11 different risk assessments found in the literature on exposures to artificial turf and concluded that the levels found of the contaminants of concern did not result in an increased risk for human health effects as a result of ingestion, dermal or inhalation exposure to crumb rubber. They stated, however, that additional air studies at synthetic turf fields as well as background air measurements would

provide more representative data for characterizing potential exposures related to synthetic field use in NYC, particularly among children.
http://www.nyc.gov/html/doh/downloads/pdf/eode/turf_report_05-08.pdf

New York City Department of Health and Mental Hygiene March 2009
NYCDHMH conducted field sampling for VOCs, SVOCs, metals, particulate matter (PM2.5) in two synthetic fields, one grass field. They used stationary samplers on field during simulate playing conditions. The sampling was conducted during the summer under simulated playing conditions. Eight of the 69 VOC were detected, but concentrations were similar between upwind background and turf fields. None of the SVOCs were detected, including benzothiozole a "chemical marker" for synthetic rubber. Two of 10 metals were detected, but similar concentrations were found in upwind and grass field. PM was within background levels upwind and at grass field. The report concluded that air in the breathing zones of children above synthetic turf fields did not show appreciable levels from contaminants of potential concern contained in the crumb rubber and that a risk assessment from exposure through the inhalation route was not warranted.
http://www.nyc.gov/html/doh/downloads/pdf/eode/turf_aqs_report0409.pdf

New York State Department of Environmental Conservation May 2009
In 2008, NYDEC conducted a laboratory evaluation of four types of tire-derived crumb rubber to assess the release of chemicals using the simulated precipitation leaching procedure. Results indicated that zinc, aniline, phenol, and benzothiazole can potentially be release to ground water. Zinc, aniline, phenol were all below standards; there are no standards for benzothiazole. Lead concentration in the crumb rubber was below federal hazard standard for soil. Risk assessment for aquatic life indicated that zinc may be a problem for aquatic life. Air samples were collected above fields at two locations. Many of the analytes detected (e.g., benzene, 1,2,4-trimethylbenzene, ethyl benzene, carbon tetrachloride) are commonly found in an urban environment. A number of analytes found were detected at low concentrations (e.g., 4-methyl-2-pentanone, benzothiazole, alkane chains. Public health evaluation at the two fields tested concluded measured air levels do not raise a concern for non-cancer or cancer human health Indicators. PM concentrations were not different from concentrations upwind from the fields. http://www.dec.ny.gov/docs/materials_minerals_pdf/crumbrubfr.pdf

EPA 2009
The overall objectives of EPA's study were to evaluate the methodology and protocols for monitoring and analyzing data needed to characterize the contribution of tire crumb constituents to environmental concentrations and to collect limited environmental data from playgrounds and synthetic turf fields. EPA analyzed air samples for 56 volatile organic compounds (VOCs), air particulate matter (PM_{10}) for selected metals and the relative contribution of tire crumb particles to the overall particle mass, wet surface wipe samples for metals including Pb, Cr, Zn, and others, and turf field tire crumb infill granules, turf blades, and playground tire crumb materials for metals. The study protocol was implemented at two synthetic turf fields and one playground. Conclusions: "On average, concentrations of components monitored in the study were below levels of concern." Concentrations for many of the analytes were close to background levels. Due to the limitations of the study, the authors concluded that "it is not possible to reach any more comprehensive conclusions without the consideration of additional data." The study did not evaluate semivolatile organic compounds such as PAHs because of resource limitations. No exposure or risk assessment was conducted by EPA. Potential exposure pathways include: ingestion of loose tire crumbs via hand to mouth or surface to mouth; dermal contact; and inhalation exposures of VOCs and PM_{10}.
http://www.epa.gov/nerl/features/tire_crumbs.html

Connecticut Department of Public Health study 2010
Connecticut Department of Public Health conducted a human health risk assessment of artificial turf in 2010. They collected data from one indoor and four outdoor artificial turf fields. The study focused on two pathways, inhalation of offgassed and particle-bound chemicals. The study included 27 chemicals (VOCs, sVOCs, leand and PM_{10}). Using conservative assumptions, Connecticut Department of Public Health Program found that cancer risks are slightly above *de minimis* in all scenarios, and two fold higher at the indoor field compared to outdoors and being higher for children than adults. The non-cancer risk estimate is below unity for all analytes in all scenarios.
http://www.ct.gov/deep/lib/deep/artificialturf/dph_artificial_turf_report.pdf

New Jersey Department of Environmental Protection 2011
In 2009, NJDEP tested 5 artificial turf fields. They tested for PM and metals including Pb using wipe samples as well as stationary sampling and mobile robot sampling. In addition, a 12 year old boy was recruited to simultaneously collect a personal breathing zone sample. The age of the fields ranged between 1 and 8 years. The testing was done during the summer time. No levels exceeded guidance or NAAQS values; robot air Pb value on one field was 71 ng/m^3 (approx 50% of NAAQS), remainder below 10 ng/m^3

Potential Future Activities

- Review additional reports and scientific literature that may provide information on the chemical constituents in artificial turf, and their bioavailability and toxicity, exposure pathways and factors, and potential human health risks.
- Examine more closely all the available data, especially for indoor fields where inhalation exposures may be higher.
- Determine if sufficient data exist to conduct an exposure/risk assessment with the available data. Given the uncertainties with some of the exposure factors assumptions (e.g., amount of material ingested, exposure frequency), several "what if" scenarios can be developed to determine for example the amount of material that would need to be ingested to exceed some health level. If an assessment cannot be done, identify key data gaps.
- Examine the exposure factor assumptions used by the studies in the literature to evaluate their "reasonableness."
- Study other factors that may influence exposure levels; for example; the age of the fields, uncertainties about the amount of material that can be inadvertently ingested, potential for dermal exposures, and exposure frequency and duration.
- Examine the literature for microbiological exposures and risks from exposures to the materials in these fields and playgrounds.

<u>Other Potentially Useful Sources (not yet reviewed; not based on a comprehensive search)</u>

Reports

CDEP (2010) (Connecticut Department of Environmental Protection). Artificial Turf Study: leachate and stormwater characteristics. http://www.ct.gov/deep/lib/deep/artificialturf/dep_artificial_turf_report.pdf

EHHI (2007) (Environment and Human Health, Inc.). Artificial Turf: exposures to ground-up rubber tires. http://www.ehhi.org/reports/turf/turf_report07.pdf

FDEP (1999) (Florida Department of Environmental Protection) Study of the suitability of ground rubber tire as a parking lot surface. http://www.dep.state.fl.us/waste/quick_topics/publications/shw/tires/FCCJstudy.pdf

NYDEC (2008) (New York Department of Environmental Conservation) A study to assess potential environmental impacts from the use of crumb runner as infill material in synthetic turf fields. http://www.dec.ny.gov/docs/materials_minerals_pdf/tirestudy.pdf

News, Websites, and Fact Sheets

CDEP (2010) (Connecticut Department of Environmental Protection). Recent news concerning artificial turf fields. http://www.fieldturf.com/sites/fieldturf/assets/Circular%20Ltr%202015-02%20Connecticut%20Reaffirms%20Safety%20of%20Artificial%20Turf.pdf

CPSC. CPSC Staff1 Analysis and Assessment of Synthetic Turf "Grass Blades" http://www.cpsc.gov//PageFiles/104716/turfassessment.pdf

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European Tyre and Rubber Association (2008) Rubber infilled artificial turf environmental and health risk assessment. http://tools.etrma.org/public/Pdf%20from%20July/PR/20080305_ETRMA_-_Synthesis_on_synthetic_turf_studies_-_final.pdf

PEER.org. (2013) EPA retracts synthetic turf safety assurances. http://www.peer.org/news/news-release/2013/12/23/epa-retracts-synthetic-turf-safety-assurances

Soccer America (2015) Are tire crumbs on fields a cancer threat? http://www.socceramerica.com/article/62922/are-tire-crumbs-on-fields-a-cancer-threat.html

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USA Today (2015) Fed promote artificial turf as safe despite health concerns. March 17, 2015. http://www.usatoday.com/story/news/2015/03/15/artificial-turf-health-safety-studies/24727111/

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US EPA. Health and Environmental Concerns: Common wastes and materials: Playgrounds and synthetic turf fields. http://www.epa.gov/solidwaste/conserve/materials/tires/health.htm

Scientific papers

Birkholz, DA; Belton, KL; Guidotti, TL (2003) Toxicological evaluation for the hazard assessment of tire crumb for use in public playgrounds. J Air & Waste Manage Assoc 53:903-907. http://www.tandfonline.com/doi/pdf/10.1080/10473289.2003.10466221

Bocca, B; Forte, G; Petrucci, F; Costantini, S; Izzo, P (2009) Metals contained and leached from rubber granulates used in

synthetic turf areas. Sci Total Environ 407:2183-2189. http://ac.els-cdn.com/S0048969708012904/1-s2.0-S0048969708012904-main.pdf?_tid=70225ce6-cf0b-11e4-91f5-00000aab0f01&acdnat=1426861056_50bfc390c1da7ac3d8644667757ce9d2

Cheng, H; Hu, Y; Reinhard, M (2014) Environmental and health impacts of artificial turf: a review. Environ Sci Technol 48(4): 2114-2129. http://pubs.acs.org/doi/pdf/10.1021/es4044193

Claudio, L (2008) Synthetic turf: health debate takes root. Environ Health Persp 116(3): A116-A122. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2265067/pdf/ehp0116-a00116.pdf

Ginsberg, G; Toal, B; Simcox, N; Bracker, A; Golembiewski, B; Kurland, T; Hedman, C (2011a) Human Health Risk Assessment of Synthetic Turf Fields Based Upon Investigation of Five
Fields in Connecticut, Journal of Toxicology and Environmental Health, Part A: Current Issues, 74:17, 1150-1174, DOI:10.1080/15287394.2011.586942; http://dx.doi.org/10.1080/15287394.2011.586942

Ginsberg, G; Toal, B; Kurland, T (2011b) Benzothiazole Toxicity Assessment in Support of

Synthetic Turf Field Human Health Risk Assessment, Journal of Toxicology and Environmental Health, Part A: Current Issues, 74:17, 1175-1183, DOI: 10.1080/15287394.2011.586943; http://dx.doi.org/10.1080/15287394.2011.586943

Kim, S; Yang, J; Kim, H; Yeo, Y; Shin, D; Lim, Y (2005) Health Risk Assessment of Lead Ingestion Exposure by Particle Sizes in Crumb Rubber on Artificial Turf Considering Bioavailability. Environmental Health and Toxicology, Volume: 27, Article ID: e2012005: 10 pages http://dx.doi.org/10.5620/eht.2012.27.e2012005 eISSN 2233-6567 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3278598/pdf/eht-27-e2012005.pdf

Li, X; Berger, W; Musante, C; Incorvia Mattina, MJ (2010) Characterization of substances released from crumb rubber material used on artificial turf fields. Chemosphere 80: 279-285.

Menichini, E; Abate, V; Attias, L; De Luca, S; di Domenico, A; Fochi, I; Forte, G; Iacovella, N; Iamiceli, L; Izzo, P; Merli, F; Bocca, B (2011) Artificial-turf playing fields: Contents of metals, PAHs, PCBs, PCDDs and PCDFs, inhalation exposure to PAHs and related preliminary risk assessment. Sci Total Environ 409(23):4950-4957. http://ac.els-cdn.com/S0048969711007601/1-s2.0-S0048969711007601-main.pdf?_tid=1b9c79f6-cf09-11e4-a4eb-00000aab0f6c&acdnat=1426860055_3ac179a31ccd83f208b1390edfd80c15

Pavilonis, BT; Weisel, CP; Buckley, B; Lioy, PJ (2014) Bio-accessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers. Risk Analysis. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4038666/pdf/nihms565643.pdf

Schiliro, T; Traversi, D; Degan, R; Pignata, C; Alessandria, L; Scozia, D; Bono, R.; Gilli, G(2012) Artificial turf football fields: environmental and mutagenicity assessment. Arch Environ Contam Toxicol. 64(1):1-11. doi: 10.1007/s00244-012-9792-1. Epub 2012 Sep 25 http://www.ncbi.nlm.nih.gov/pubmed/23007896

Simcox, NJ; Bracker, A; Ginsberg, G; Toal, B; Golembiewski, B; Kurland, T; Hedman, C (2011) Synthetic Turf Field Investigation in Connecticut, Journal of Toxicology and Environmental Health, Part A: 74:17, 1133-1149, DOI: 10.1080/15287394.2011.586941; http://dx.doi.org/10.1080/15287394.2011.586941

Zhang, J; Han, I; Zhang, L; Crain, W (2008) Hazardous chemicals in synthetic turf materials and their bioaccessibility in digestive fluids. J Exposure Sci Environ Epidemiol 18:600-607. http://www.nature.com/jes/journal/v18/n6/pdf/jes200855a.pdf

Websites

http://www.nycgovparks.org/news/reports/synthetic-turf-tests

Appendix D - EPA Library Literature Search Results

EPA-RTP LIBRARY

Literature Search Results

February 2016

Summary

Subject: Health effects associated with exposure to tire crumbs or artificial turf fields

Databases searched: ProQuest Environmental Science Collection, Web of Science, ScienceDirect, Google Scholar

Number of citations: 55

Search terms:

“crumb rubber” OR “tire crumb”

AND

(field or infill or turf)

AND

(exposure or risk or toxic*)

Anderson, M. E., et al. (2006). "A Case Study of Tire Crumb Use on Playgrounds: Risk Analysis and Communication When Major Clinical Knowledge Gaps Exist." Environmental Health Perspectives **114**(1): 1-3.
Physicians and public health professionals working with the U.S. Environmental Protection Agency's Region 8 Pediatric Environmental Health Specialty Unit (PEHSU) received several telephone calls requesting information regarding the safety of recycled tire crumb as a playground surface constituent placed below children's play structures. There were no reported symptoms or adverse health effects in exposed children. The literature available on the safety and risk of exposure to crumb rubber constituents was limited and revealed no information quantifying exposures associated with product use. Callers were informed by the PEHSU that no evidence existed suggesting harm from intended use of the product, but gaps in knowledge about the product were identified and communicated. Here the case of crumb rubber on playgrounds is used as a model to present an approach to similar environmental medicine questions. From defining the question, to surveying traditional

and nontraditional resources for information, synthesis of findings, and risk communication, the case provides a model to approach similar questions. ***Already on our list.***

Aoki, T. (2011). "Current State and Perspective for Artificial Turf as Sport Environment: Focusing on Third-generation Artificial Turf as Football Playing Surface." – ***This paper was added to our list.***

Beausoleil, M., et al. (2009). "Chemicals in outdoor artificial turf: a health risk for users." Public Health Branch, Montreal Health and Social Services Agency.[accessed 2015 April 22]. http://www. ncceh. ca/sites/default/files/Outdoor_Artificial_Turf. pdf. ***Already on our list.***

Birkholz, D. A., et al. (2003). "Toxicological evaluation for the hazard assessment of tire crumb for use in public playgrounds." Journal of the Air & Waste Management Association **53**(7): 903-907.
Disposal of used tires has been a major problem in solid waste management. New uses will have to be found to consume recycled tire products. One such proposed use is as ground cover in playgrounds. However, concern has been expressed regarding exposure of children to hazardous chemicals and the environmental impact of such chemicals. We designed a comprehensive hazard assessment to evaluate and address potential human health and environmental concerns associated with the use of tire crumb in playgrounds. Human health concerns were addressed using conventional hazard analyses, mutagenicity assays, and aquatic toxicity tests of extracted tire crumb. Hazard to children appears to be minimal. Toxicity to all aquatic organisms (bacteria, invertebrates, fish, and green algae) was observed; however, this activity disappeared with aging of the tire crumb for three months in place in the playground. We conclude that the use of tire crumb in playgrounds results in minimal hazard to children and the receiving environment. ***Already on our list.***

Bocca, B., et al. (2009). "Metals contained and leached from rubber granulates used in synthetic turf areas." Science of the Total Environment **407**(7): 2183-2190.
The aim of this study was to quantify metals contained in and leached from different types of rubber granulates used in synthetic turf areas. To investigate the total content of metals, ca 0.5 g of material was added with HNO3, HF and HClO4 and microwave digested with power increasing from 250 W to 600 W. Leachates were prepared by extraction of about 5.0 g of material at room temperature for 24 h in an acidic environment (pH 5). Leaching with deionized water was also performed for comparison. Aluminium, As, Ba, Be, Cd, Co, Cr, Cu, Hg, Fe, Li, Mg, Mn, Mo, Ni, Pb, Rb, Sb, Se, Sn, Sr, Tl, V, W and Zn were quantified by high-resolution inductively coupled plasma mass spectrometry (HR-ICP-MS) and ICP optical emission spectrometry (ICP-OES). Results indicated that the developed method was accurate and precise for the multi-element characterization of rubber granulates and leachates. The total amount and the amount leached during the acidic test varied from metal to metal and from granulate to granulate. The highest median values were found for Zn (10,229 mg/kg), Al (755 mg/kg), Mg (456 mg/kg), Fe (305 mg/kg), followed by Pb, Ba, Co, Cu and Sr. The other elements were present at few units of mg/kg. The highest leaching was observed for Zn (2300 µg/l) and Mg (2500 µg/l), followed by Fe, Sr, Al, Mn and Ba. Little As, Cd, Co, Cr, Cu, Li, Mo, Ni, Pb, Rb, Sb and V leached, and Be, Hg, Se, Sn, Tl and W were below quantification limits. Data obtained were compared with the maximum tolerable amounts reported for similar materials, and only the concentration of Zn (total and leached) exceeded the expected values. ***Already on our list.***

Brown, D. "Artificial Turf: Exposures to Ground-up Rubber Tires." - ***This is the same as EHHI 2007 which is already on our list.***

Cheng, H., et al. (2014). "Environmental and Health Impacts of Artificial Turf: A Review." Environmental Science & Technology **48**(4): 2114-2129.
With significant water savings and low maintenance requirements, artificial turf is increasingly promoted as a replacement for natural grass on athletic fields and lawns. However, there remains the question of whether it is an environmentally friendly alternative to natural grass. The major concerns stem from the infill material that is typically derived from scrap tires. Tire rubber crumb contains a range of organic contaminants and heavy metals that can volatilize into the air and/or leach into the percolating rainwater, thereby posing a potential risk to the environment and human health. A limited number of studies have shown that the concentrations of volatile and semivolatile organic compounds in the air above artificial turf fields were typically not higher than the local

background, while the concentrations of heavy metals and organic contaminants in the field drainages were generally below the respective regulatory limits. Health suggested that users of artificial turf fields, even professional athletes, were not exposed to elevated risks. Preliminary life cycle assessment suggested that the environmental impacts of artificial turf fields were lower than equivalent grass fields. Areas that need further research to better understand and mitigate the potential negative environmental impacts of artificial turf are identified. ***Already on our list.***

Claudio, L. (2008). "Synthetic Turf Health Debate Takes Root." Environmental Health Perspectives **116**(3): A116-122. ***Already on our list.***

Dorsey, M. J., et al. (2015). "Mutagenic Potential of Artificial Athletic Field Crumb Rubber at Increased Temperatures." The Ohio Journal of Science **115**(2). ***This paper was added to our list.***

Drakos, M. C., et al. (2013). "Synthetic playing surfaces and athlete health." Journal of the American Academy of Orthopaedic Surgeons **21**(5): 293-302. – ***This paper was added to our list, but it is not suitable. It addresses injuries to athletes.***

Ginsberg, G., et al. (2011). "BENZOTHIAZOLE TOXICITY ASSESSMENT IN SUPPORT OF SYNTHETIC TURF FIELD HUMAN HEALTH RISK ASSESSMENT." Journal of Toxicology and Environmental Health-Part a-Current Issues **74**(17): 1175-1183.
Synthetic turf fields cushioned with crumb rubber may be a source of chemical exposure to those playing on the fields. Benzothiazole (BZT) may volatilize from crumb rubber and result in inhalation exposure. Benzothiazole has been the primary rubber-related chemical found in synthetic turf studies. However, risks associated with BZT have not been thoroughly assessed, primarily because of gaps in the database. This assessment provides toxicity information for a human health risk assessment involving BZT detected at five fields in Connecticut. BZT exerts acute toxicity and is a respiratory irritant and dermal sensitizer. In a genetic toxicity assay BZT was positive in Salmonella in the presence of metabolic activation. BZT metabolism involves ring-opening and formation of aromatic hydroxylamines, metabolites with mutagenic and carcinogenic potential. A structural analogue 2-mercaptobenzothiazole (2-MBZT) was more widely tested and so is used as a surrogate for some endpoints. 2-MBZT is a rodent carcinogen with rubber industry data supporting an association with human bladder cancer. The following BZT toxicity values were derived: (1) acute air target of 110 mu g/m(3) based upon a BZT RD(50) study in mice relative to results for formaldehyde; (2) a chronic noncancer target of 18 mu g/m(3) based upon the no-observed-adverse-effect level (NOAEL) in a subchronic dietary study in rats, dose route extrapolation, and uncertainty factors that combine to 1000; (3) a cancer unit risk of 1.8E-07/mu g-m(3) based upon a published oral slope factor for 2-MBZT and dose-route extrapolation. While there are numerous uncertainties in the BZT toxicology database, this assessment enables BZT to be quantitatively assessed in risk assessments involving synthetic turf fields. However, this is only a screening-level assessment, and research that better defines BZT potency is needed. ***Already on our list.***

Ginsberg, G., et al. (2011). "HUMAN HEALTH RISK ASSESSMENT OF SYNTHETIC TURF FIELDS BASED UPON INVESTIGATION OF FIVE FIELDS IN CONNECTICUT." Journal of Toxicology and Environmental Health-Part a-Current Issues **74**(17): 1150-1174.
Questions have been raised regarding possible exposures when playing sports on synthetic turf fields cushioned with crumb rubber. Rubber is a complex mixture with some components possessing toxic and carcinogenic properties. Exposure is possible via inhalation, given that chemicals emitted from rubber might end up in the breathing zone of players and these players have high ventilation rates. Previous studies provide useful data but are limited with respect to the variety of fields and scenarios evaluated. The State of Connecticut investigated emissions associated with four outdoor and one indoor synthetic turf field under summer conditions. On-field and background locations were sampled using a variety of stationary and personal samplers. More than 20 chemicals of potential concern (COPC) were found to be above background and possibly field-related on both indoor and outdoor fields. These COPC were entered into separate risk assessments (1) for outdoor and indoor fields and (2) for children and adults. Exposure concentrations were prorated for time spent away from the fields and inhalation rates were adjusted for play activity and for children's greater ventilation than adults. Cancer and noncancer risk levels were at or below de minimis levels of concern. The scenario with the highest exposure was

children playing on the indoor field. The acute hazard index (HI) for this scenario approached unity, suggesting a potential concern, although there was great uncertainty with this estimate. The main contributor was benzothiazole, a rubber-related semivolatile organic chemical (SVOC) that was 14-fold higher indoors than outdoors. Based upon these findings, outdoor and indoor synthetic turf fields are not associated with elevated adverse health risks. However, it would be prudent for building operators to provide adequate ventilation to prevent a buildup of rubber-related volatile organic chemicals (VOC) and SVOC at indoor fields. The current results are generally consistent with the findings from studies conducted by New York City, New York State, the U. S. Environmental Protection Agency (EPA), and Norway, which tested different kinds of fields and under a variety of weather conditions. ***Already on our list.***

Gomes, J., et al. (2010). "Toxicological Assessment of Coated versus Uncoated Rubber Granulates Obtained from Used Tires for Use in Sport Facilities." Journal of the Air & Waste Management Association **60**(6): 741-746.
Reuse of tire crumb in sport facilities is currently a very cost-effective waste management measure. Considering that incorporation of the waste materials in artificial turf would be facilitated if the rubber materials were already colored green, coatings were specifically developed for this purpose. This paper presents an experimental toxicological and environmental assessment aimed at comparing the obtained emissions to the environment in terms of polycyclic aromatic hydrocarbons (PAHs), heavy metals, and ecotoxicity for coated and noncoated rubber granulates. This study is a comprehensive evaluation of the major potential critical factors related with the release of all of these classes of pollutants because previous studies were not systematically performed. It was concluded that between the two types of coatings tested, one is particularly effective in reducing emissions to the environment, simultaneously meeting the requirements of adherence and color stability. ***Already on our list.***

Groenevelt, P. H. and P. E. Grunthal (1998). "Utilisation of crumb rubber as a soil amendment for sports turf." Soil and Tillage Research **47**(1–2): 169-172.
In Canada, the Province of Ontario generates about ten million waste tires per year. According to 1991 government statistics less than 20% of these tires are recycled, some of which are granulated to produce crumb rubber. An innovation application for this secondary resource is as an efficient, economical and environmentally sound soil amendment. A rubber crumb-based soil amendment can enhance the physical properties of soils susceptible to the negative effects of compaction. Highly compacted sports fields require constant aeration to maintain a healthy and safe playing surface. Rubber crumb adds resiliency to sports turf. Standard United States Golf Association tests revealed that admixtures containing 20% or less crumb rubber maintained recommended total porosity values. Field tests showed that 10–20% crumb rubber significantly reduced surface hardness. Analysis of metals, VOC's and BNA extractable compounds from admixture leachate revealed no deleterious effects to the environment due to inclusion of rubber crumb in turfgrass root zones. ***This paper was added to our list.***

Haering, S. A. (2012). "Alexandria Health Department."
This memorandum provides information regarding the infill material used in synthetic turf fields in the City of Alexandria – ***This is a memo; not suitable for this effort.***

Johns, D. M. (2008). "Initial evaluation of potential human health risks associated with playing on synthetic turf fields on Bainbridge Island." Windward Environmental LLC. ***Already on our list.***

Johns, D. M. and T. Goodlin (2008). "Evaluation of Potential Environmental Risks Associated with Installing Synthetic Turf Fields on Bainbridge Island." Seattle, Washington: Windward Environmental LLC. ***This paper was added to our list.***

Kim, H.-H., et al. (2012). "Health Risk Assessment for Artificial Turf Playgrounds in School Athletic Facilities: Multi-route Exposure Estimation for Use Patterns." Asian Journal of Atmospheric Environment **6**(3): 206-221. ***This paper was added to our list.***

Kim, S., et al. (2012). "Health risk assessment of lead ingestion exposure by particle sizes in crumb rubber on artificial turf considering bioavailability." Environmental health and toxicology **27**: e2012005-e2012005.

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

Krüger, O., et al. (2013). "New approach to the ecotoxicological risk assessment of artificial outdoor sporting grounds." Environmental Pollution **175**: 69-74.
Artificial surfaces for outdoor sporting grounds may pose environmental and health hazards that are difficult to assess due to their complex chemical composition. Ecotoxicity tests can indicate general hazardous impacts. We conducted growth inhibition (Pseudokirchneriella subcapitata) and acute toxicity tests (Daphnia magna) with leachates obtained from batch tests of granular infill material and column tests of complete sporting ground assemblies. Ethylene propylene diene monomer rubber (EPDM) leachate showed the highest effect on Daphnia magna (EC50 & lt; 0.4% leachate) and the leachate of scrap tires made of styrene butadiene rubber (SBR) had the highest effect on P. subcapitata (EC10 = 4.2% leachate; EC50 = 15.6% leachate). We found no correlations between ecotoxicity potential of leachates and zinc and PAH concentrations. Leachates obtained from column tests revealed lower ecotoxicological potential. Leachates of column tests of complete assemblies may be used for a reliable risk assessment of artificial sporting grounds. ***Already on our list.***

Li, X., et al. (2010). "Characterization of substances released from crumb rubber material used on artificial turf fields." Chemosphere **80**(3): 279-285.
Crumb rubber material (CRM) used as infill on artificial turf fields can be the source of a variety of substances released to the environment and to living organisms in the vicinity of the CRM. To assess potential risks of major volatilized and leached substances derived from CRM, methods were developed to identify organic compounds and elements, either in the vapor phase and/or the leachate from CRM. A qualitative method based on solid phase micro-extraction (SPME) coupled with gas chromatography/mass spectrometry (GC–MS) was developed to identify the major volatile and semi-volatile organic compounds out-gassing from CRM samples under defined laboratory conditions. Direct vapor phase injection into the GC–MS was applied for the quantitative analysis. Ten organic compounds were identified in the vapor phase by the SPME method. Volatile benzothiazole (BT) was detected at the highest level in all commercial CRM samples, in the range 8.2–69 ng g−1 CRM. Other volatile PAHs and antioxidants were quantified in the vapor phase as well. A decrease of volatile compounds was noted in the headspace over CRM samples from 2-years-old fields when compared with the virgin CRM used at installation. An outdoor experiment under natural weathering conditions showed a significant reduction of out-gassing organic compounds from the CRM in the first 14 d; thereafter, values remained consistent up to 70 d of observation. Zinc was the most abundant element in the acidified leachate (220–13 000 μg g−1), while leachable BT was detected at relatively low amounts. ***Already on our list.***

Li, X., et al. (2010). "Corrigendum to “Characterization of substances released from crumb rubber material used on artificial turf fields” [Chemosphere 80 (3) (2010) 279–285]." Chemosphere **80**(11): 1406-1407. ***Already on our list.***

Lioy, P. J., et al. "UMDNJ-EOHSI Crumb Infill and Turf Report–October 31, 2011." ***Already on our list.***

Lioy, P. J. and C. P. Weisel (2008). "Artificial turf: safe or out on ball fields around the world." Journal of Exposure Science and Environmental Epidemiology **18**(6): 533-534. ***Already on our list.***

Llompart, M., et al. (2013). "Hazardous organic chemicals in rubber recycled tire playgrounds and pavers." Chemosphere **90**(2): 423-431. ***Already on our list.***

Marsili, L., et al. (2015). "Release of Polycyclic Aromatic Hydrocarbons and Heavy Metals from Rubber Crumb in Synthetic Turf Fields: Preliminary Hazard Assessment for Athletes." Journal of Environmental & Analytical Toxicology **5**(2): 1-8.
Synthetic turf, made with an infill of rubber crumb from used tyres or virgin rubber, is now common in many sporting facilities. It is known that it contains compounds such as polycyclic aromatic hydrocarbons (PAH) and heavy metals. The researchers evaluated in nine samples of rubber crumb the total content of some heavy metals (Zn, Cd, Pb, Cu, Cr, Ni, Fe) normally found in tyres by microwave mineralization and the levels of the 14 US EPA priority PAHs by Soxhlet extraction and HPLC analysis. The results showed high levels of PAHs and zinc in all rubber crumb samples compared to rubber granulate limits set by Italian National Amateur League. Finally, the aim of this study was to estimate the hazard for athletes inhaling PAHs released at the high temperatures this synthetic turf may reach. Then a sequence of proofs was carried out at 60 degrees Celsius, a temperature that this rubber crumb can easily reach in sporting installations, to see whether PAH release occurs. ***Already on our list.***

Mattina, M. I., et al. (2007). "Examination of crumb rubber produced from recycled tires." The Connecticut Agricultural Experiment Station, New Haven, CT. Available online at: http://www. ct. gov/caes/lib/caes/documents/publications/fact_sheets/examinationofcru mbrubberac005. pdf. Accessed on **12**(10): 07. ***Already on our list as Incorvia Mattina.***

Menichini, E., et al. (2011). "Artificial-turf playing fields: Contents of metals, PAHs, PCBs, PCDDs and PCDFs, inhalation exposure to PAHs and related preliminary risk assessment." Science of the Total Environment **409**(23): 4950-4957.
The artificial-turf granulates made from recycled rubber waste are of health concern due the possible exposure of users to dangerous substances present in the rubber, and especially to PAHs. In this work, we determined the contents of PAHs, metals, non-dioxin-like PCBs (NDL-PCBs), PCDDs and PCDFs in granulates, and PAH concentrations in air during the use of the field. The purposes were to identify some potential chemical risks and to roughly assess the risk associated with inhalation exposure to PAHs. Rubber granulates were collected from 13 Italian fields and analysed for 25 metals and nine PAHs. One further granulate was analysed for NDL-PCBs, PCDDs, PCDFs and 13 PAHs. Air samples were collected on filter at two fields, using respectively a high volume static sampler close to the athletes and personal samplers worn by the athletes, and at background locations outside the fields. In the absence of specific quality standards, we evaluated the measured contents with respect to the Italian standards for soils to be reclaimed as green areas. Zn concentrations (1 to 19 g/kg) and BaP concentrations (0.02 to 11 mg/kg) in granulates largely exceeded the pertinent standards, up to two orders of magnitude. No association between the origin of the recycled rubber and the contents of PAHs and metals was observed. The sums of NDL-PCBs and WHO-TE PCDDs + PCDFs were, respectively, 0.18 and 0.67 × 10− 5 mg/kg. The increased BaP concentrations in air, due to the use of the field, varied approximately from < 0.01 to 0.4 ng/m3, the latter referring to worst-case conditions as to the release of particle-bound PAHs. Based on the 0.4 ng/m3 concentration, an excess lifetime cancer risk of 1 × 10− 6 was calculated for an intense 30-year activity. ***Already on our list.***

Moretto, R. (2007). "Environmental and health assessment of the use of elastomer granulates (virgin and from used tyres) as filling in third-generation artificial turf." EEDEMS (Ademe, Aliapur, Fieldturf Tarkett. ***Already on our list.***

Mota, H., et al. (2009). "Coated rubber granulates obtained from used tyres for use in sport facilities: A toxicological assessment." Ciência & Tecnologia dos Materiais **21**(3-4): 26-30. ***This paper was added to our list.***

Pavilonis, B. T., et al. (2014). "Bioaccessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers." Risk Analysis **34**(1): 44-55.

To reduce maintenance costs, municipalities and schools are starting to replace natural grass fields with a new generation synthetic turf. Unlike Astro-Turf, which was first introduced in the 1960s, synthetic field turf provides more cushioning to athletes. Part of this cushioning comes from materials like crumb rubber infill, which is manufactured from recycled tires and may contain a variety of chemicals. The goal of this study was to evaluate potential exposures from playing on artificial turf fields and associated risks to trace metals, semi-volatile organic compounds (SVOCs), and polycyclic aromatic hydrocarbons (PAHs) by examining typical artificial turf fibers (n = 8), different types of infill (n = 8), and samples from actual fields (n = 7). Three artificial biofluids were prepared, which included: lung, sweat, and digestive fluids. Artificial biofluids were hypothesized to yield a more representative estimation of dose than the levels obtained from total extraction methods. PAHs were routinely below the limit of detection across all three biofluids, precluding completion of a meaningful risk assessment. No SVOCs were identified at quantifiable levels in any extracts based on a match of their mass spectrum to compounds that are regulated in soil. The metals were measurable but at concentrations for which human health risk was estimated to be low. The study demonstrated that for the products and fields we tested, exposure to infill and artificial turf was generally considered de minimus, with the possible exception of lead for some fields and materials. ***Already on our list.***

Rhodes, E. P., et al. (2012). "Zinc leaching from tire crumb rubber." Environmental Science & Technology **46**(23): 12856-12863. ***Already on our list.***

Ruffino, B., et al. (2013). "Environmental-sanitary risk analysis procedure applied to artificial turf sports fields." Environmental Science and Pollution Research International **20**(7): 4980-4992.
Owing to the extensive use of artificial turfs worldwide, over the past 10 years there has been much discussion about the possible health and environmental problems originating from styrene-butadiene recycled rubber. In this paper, the authors performed a Tier 2 environmental-sanitary risk analysis on five artificial turf sports fields located in the city of Turin (Italy) with the aid of RISC4 software. Two receptors (adult player and child player) and three routes of exposure (direct contact with crumb rubber, contact with rainwater soaking the rubber mat, inhalation of dusts and gases from the artificial turf fields) were considered in the conceptual model. For all the fields and for all the routes, the cumulative carcinogenic risk proved to be lower than 10^sup -6^ and the cumulative non-carcinogenic risk lower than 1. The outdoor inhalation of dusts and gases was the main route of exposure for both carcinogenic and non-carcinogenic substances. The results given by the inhalation pathway were compared with those of a risk assessment carried out on citizens breathing gases and dusts from traffic emissions every day in Turin. For both classes of substances and for both receptors, the inhalation of atmospheric dusts and gases from vehicular traffic gave risk values of one order of magnitude higher than those due to playing soccer on an artificial field. [PUBLICATION ABSTRACT] ***Already on our list.***

Schiliro, T., et al. (2013). "Artificial Turf Football Fields: Environmental and Mutagenicity Assessment." Archives of Environmental Contamination and Toxicology **64**(1): 1-11.
The public has recently raised concerns regarding potential human health and environmental risks associated with tire crumb constituents in the artificial turf of football fields. The aim of the present study was to develop an environmental analysis drawing a comparison between artificial turf football fields and urban areas relative to concentrations of particles (PM10 and PM2.5) and related polycyclic aromatic hydrocarbons (PAHs), aromatic hydrocarbons (BTXs), and mutagenicity of organic extracts from PM10 and PM2.5. No significant differences were found between PM10 concentrations at an urban site and on a turf football field, both during warm and in cold seasons, either with or without on-field activity. PM2.5 concentrations were significantly greater at the urban site in the cold season as was the ratio of PM2.5 to PM10. BTXs were significantly greater at urban sites than on turf football fields on both on warm and cold days. The ratio of toluene to benzene (T/B ratio) was always comparable with that of normal urban conditions. The concentration of PAHs on the monitored football fields was comparable with urban levels during the two different sampling periods, and the contribution of PAHs released from the granular material was negligible. PM10 organic extract mutagenicity for artificial turf football fields was greater, whereas PM2.5 organic extract mutagenicity was lower, compared with the urban site studied. However, both organic extract mutagenicity values were comparable with the organic extract mutagenicity reported in the literature for urban sites. On the basis of environmental monitoring, artificial turf football fields present no more exposure risks than the rest of the city. ***Already on our list.***

Simcox, N. J., et al. (2011). "SYNTHETIC TURF FIELD INVESTIGATION IN CONNECTICUT." Journal of Toxicology and Environmental Health-Part a-Current Issues **74**(17): 1133-1149.
The primary purpose of this study was to characterize the concentrations of volatile organic compounds (VOC), semivolatile organic compounds (SVOC), rubber-related chemicals such as benzothiazole (BZT) and nitrosamine, and particulate matter (PM(10)) in air at synthetic turf crumb rubber fields. Both new and older fields were evaluated under conditions of active use. Three types of fields were targeted: four outdoor crumb rubber fields, one indoor facility with crumb rubber turf, and an outdoor natural grass field. Background samples were collected at each field on grass. Personal air sampling was conducted for VOC, BZT, nitrosamines, and other chemicals. Stationary air samples were collected at different heights to assess the vertical profile of release. Air monitoring for PM(10) was conducted at one height. Bulk samples of turf grass and crumb rubber were analyzed, and meteorological data were recorded. Results showed that personal concentrations were higher than stationary concentrations and were higher on turf than in background samples for certain VOC. In some cases, personal VOC concentrations from natural grass fields were as high as those on turf. Naphthalene, BZT, and butylated hydroxytoluene (BHT) were detected in greater concentration at the indoor field compared to the outdoor fields. Nitrosamine air levels were below reporting levels. PM(10) air concentrations were not different between on-field and upwind locations. All bulk lead (Pb) samples were below the public health target of 400 ppm. More research is needed to better understand air quality at indoor facilities. These field investigation data were incorporated into a separate human health risk assessment. ***Already on our list.***

Simon, R. (2010). "Review of the impacts of crumb rubber in artificial turf applications." University of California, Berkeley, Laboratory for Manufacturing and Sustainability, prepared for The Corporation for Manufacturing Excellence (Manex). – ***This paper was added to our list.***

Sullivan, J. P. (2006). "An assessment of environmental toxicity and potential contamination from artificial turf using shredded or crumb rubber." Ardea Consulting **43**. ***Already on our list.***

van Rooij, J. G. and F. J. Jongeneelen (2010). "Hydroxypyrene in urine of football players after playing on artificial sports field with tire crumb infill." International Archives of Occupational and Environmental Health **83**(1): 105-110.
Artificial sports fields are increasingly being used for sports. Recycled rubber from automotive and truck scrap rubber tires are used as an infill material for football grounds. There are concerns that football players may be at risk due to exposure from released compounds from rubber infill. Compounds from crumb infill may be inhaled and dermal exposure may occur. A study was performed to assess the exposure of football players to polycyclic aromatic hydrocarbons due to sporting on synthetic ground with rubber crumb infill. In this study, football players were trained and had a match on the artificial turf pitch during 2.5 h. They had an intensive skin contact with rubber infill. All urine of seven nonsmoking football players was collected over a 3-day period, the day before sporting, the day of sporting and the day after sporting. Urine samples were analyzed for 1-hydroxypyrene. Confounding exposure from environmental sources and diet was controlled for. The individual increase of the amount of excretion over time was used as a measure to assess the uptake of PAH. It appeared that the baseline of excreted 1-hydroxypyrene in 4 of 7 volunteers was sufficient stable and that 1 volunteer out of 4 showed after the 2.5-h period of training and match on the playground an increase in hydroxypyrene in urine. However, concomitant dietary uptake of PAH by this volunteer was observed. This study provides evidence that uptake of PAH by football players active on artificial grounds with rubber crumb infill is minimal. If there is any exposure, than the uptake is very limited and within the range of uptake of PAH from environmental sources and/or diet. [PUBLICATION ABSTRACT] ***Already on our list.***

Zhang, J., et al. (2008). "Hazardous chemicals in synthetic turf materials and their bioaccessibility in digestive fluids." Journal of Exposure Science and Environmental Epidemiology **18**(6): 600-607.
Many synthetic turf fields consist of not only artificial grass but also rubber granules that are used as infill. The public concerns about toxic chemicals possibly contained in either artificial (polyethylene) grass fibers or rubber granules have been escalating but are based on very limited information available to date. The aim of this research was to obtain data that will help assess potential health risks associated with chemical exposure. In this small-scale study, we collected seven samples of rubber granules and one sample of artificial grass fiber from synthetic turf fields at different ages of the fields. We analyzed these samples to determine the contents

(maximum concentrations) of polycyclic aromatic hydrocarbons (PAHs) and several metals (Zn, Cr, As, Cd, and Pb). We also analyzed these samples to determine their bioaccessible fractions of PAHs and metals in synthetic digestive fluids including saliva, gastric fluid, and intestinal fluid through a laboratory simulation technique. Our findings include: (1) rubber granules often, especially when the synthetic turf fields were newer, contained PAHs at levels above health-based soil standards. The levels of PAHs generally appear to decline as the field ages. However, the decay trend may be complicated by adding new rubber granules to compensate for the loss of the material. (2) PAHs contained in rubber granules had zero or near-zero bioaccessibility in the synthetic digestive fluids. (3) The zinc contents were found to far exceed the soil limit. (4) Except one sample with a moderate lead content of 53 p.p.m., the other samples had relatively low concentrations of lead (3.12-5.76 p.p.m.), according to soil standards. However, 24.7-44.2% of the lead in the rubber granules was bioaccessible in the synthetic gastric fluid. (5) The artificial grass fiber sample showed a chromium content of 3.93 p.p.m., and 34.6% and 54.0% bioaccessibility of lead in the synthetic gastric and intestinal fluids, respectively. ***Already on our list.***

Appendix E - List of Literature Reviewed

Ref #	Title	Author
01	A Case Study of Tire Crumb Use on Playgrounds: Risk Analysis and Communication When Major Clinical Knowledge Gaps Exist	Anderson et al.
02	A preliminary chemical examination of hydrophobic tire leachate components Note: This reference is part III of III. Parts I and II were not relevant and therefore, not reviewed	Anthony, D.H.J. and Latawiec
03	Determination of Microbial Populations in a Synthetic Turf System	Bass JJ, Hintze DW
04	Chemicals in outdoor artificial turf: a health risk for users?	Beausoleil M, Price K, Muller C
05	Toxicological Evaluation of Hazard Assessment of Tire Crumb for Use on Public Playgrounds	Birkholz et al.
06	Metals contained and leached from rubber granulates used in synthetic turf areas	Bocca B, Forte G., Petrucci F., Costantini S., Izzo P.
07	Evaluation of Health Effects of Recycled Waste Tires in Playground and Track Products	California Office of Environmental Health Hazard Assessment
08	Safety Study of Artificial Turf Containing Crumb Rubber Infill Made from Recycled Tires: Measurements of Chemicals and Particulates in the Air, Bacteria in the Turf, and Skin Abrasions Caused by Contact with the Surface	California Office of Environmental Health Hazard Assessment
09	Review of the Human Health & Ecological Safety of Exposure to Recycled Tire Rubber found at Playgrounds and Synthetic Turf Fields	Cardno Chem Risk
10	Assessment of exposure to chemical agents in infill material for artificial turf soccer pitches: development and implementation of a survey protocol	Castellano P, Proietto AR, Gordiani A, Ferrante R, Tranfo G, Paci E,
11	Emission characteristics of VOCs from athletic tracks	Chang, F; Lin, T.; Huang, C.; Chao, H.; Chang, T.; Lu, C.
12	Environmental and Health Impacts of Artificial Turf: A Review	Cheng H., Hu Y., Reinhard M.
13	Assessment of occupational health hazards in scrap-tire shredding facilities	Chien YC, Ton S, Lee MH et al.
14	Synthetic Turf: Health Debate Takes Root	Claudio L.
15	Human Health Risk Assessment of Artificial Turf Fields Based Upon Results from Five Fields in Connecticut	Connecticut Department of Public Health. (CDPH)
16	Artificial Turf Field Investigation in Connecticut Final Report	Connecticut: University of Connecticut Health Center (UCHC)
17	2009 Study of Crumb Rubber Derived from Recycled Tires, final report	Connecticut Agricultural Experiment Station (CAES)
18	Artificial Turf Study: leachate and stormwater characteristics	Connecticut Department of Environmental Protection (CDEP)
19	Peer Review of an Evaluation of the Health and Environmental Impacts Associated with Synthetic Turf Playing Fields	Connecticut Academy of Science and Engineering. (CASE)
20	CPSC Staff Analysis and Assessment of Synthetic Turf Grass Blades	CPSC
21	Effects of leachate from crumb rubber and zinc in green roofs on the survival, growth, and resistance characteristics of Salmonella enterica subsp. enterica serovar typhimurium	Crampton M, et al.
22	A Review of the Potential Health and Safety Risks from Synthetic Turf Fields Containing Crumb Rubber Infill Note: See reference #59	Denly E., Rutkowski K., Vetrano K.M.
23	Measurement of Air Pollution in Indoor Artificial Turf Halls	Dye C., Bjerke A, Schmidbauer N., Mano S.
24	Artificial Turf – Exposures to Ground-Up Rubber Tires – Athletic Fields – Playgrounds – Gardening Mulch	Environment & Human Health Inc. (EHHI)
25	Study of the suitability of ground rubber tire as a parking lot surface	Florida Department of Environmental Protection (FDEP)
26	Human Health Risk Assessment of Synthetic Turf Fields Based Upon Investigation of Five Fields in Connecticut	Ginsberg et al.
27	Benzothiazole Toxicity Assessment in Support of Synthetic Turf Field Human Health Risk Assessment	Ginsberg, G; Toal, B; Kurland, T.
28	Toxicological Assessment of Coated Versus Uncoated Rubber Granulates Obtained from Used Tires for Use in Sports Facilities	Gomes et al.

29	Design of a New Test Chamber for Evaluation of the Toxicity of Rubber Infill	Gomes JF, Mota HI, Bordado JC, Baião M, Sarmento GM, Fernandes J, Pampulim VM, Custódio ML, Veloso I.
30	Impact of tire debris on in vitro and in vivo systems	Gualteri, M.; Andrioletti, M.; Mantecca, P.; Vismara, C.; Camatini; M.
31	Identification of Benzothiazole Derivatives and Polycyclic Aromatic Hydrocarbons as Aryl Hydrocarbon Receptor Agonists Present in Tire Extracts	He, G., Zhao, B., Denison, M.S.
32	A Scoping-Level Field Monitoring Study of Synthetic Turf and Playgrounds	U.S. Environmental Protection Agency (U.S. EPA)
33	Environmental and Health Risks of Rubber Infill: Rubber crumb from car tyres as infill on artificial turf	Hofstra, U
34	Examination of Crumb Rubber Produced from Recycled Tires. Department of Analytical Chemistry	Incorvia Mattina, MJ; Isleyen, M; Berger, W; Ozdemir, S.
35	Initial evaluation of potential human health risks associated with playing on synthetic turf fields on Bainbridge Island	Johns, DM
36	Characterization and potential environmental risks of leachate from shredded rubber mulches	Kanematsu, M; Hayashi, A; Denison, MS; Young, TM.
37	The fate of methicillin-resistant staphylococcus aureus in a synthetic field turf system	Keller, M.
38	Synthetic turf from a chemical perspective--a status report	KemI (Swedish Chemicals Inspectorate)
39	Health Risk Assessment of Lead Ingestion Exposure by Particle Sizes in Crumb Rubber on Artificial Turf Considering Bioavailability	Kim, S; Yan, JY; Kim, HH; Yeo, IY; Shin, DC; Lim, YW.
40	New approach to the ecotoxicological risk assessment of artificial outdoor sporting grounds	Krüger, O; Kalbe, U; Richter, E; Egeler, P; Rombke, J; Berger, W.
41	Comparison of Batch and Column Tests for the Elution of Artificial Turf System Components	Krüger, O; Kalbe, U; Berger, W; Nordhauβ, K; Christoph, G; Walzel, HP.
42	Preliminary Assessment of the Toxicity from Exposure to Crumb Rubber: Its Use in Playgrounds and Artificial Turf Playing Fields	LeDoux, T.
43	Characterization of Substances Released from Crumb Rubber Material Used on Artificial Turf Fields	Li, X; Berger, W; Musante, C; Incorvia Mattina, MJ.
44	Artificial Turf: Safe or Out on Ball Fields Around the World	Lioy, P; Weisel, C.
45	Crumb Infill and Turf Characterization for Trace Elements and Organic Materials	Lioy, P; Weisel, C.
46	Hazardous organic chemicals in rubber recycled tire playgrounds and pavers	Llompart, M; Sanchez-Pardo, L; Lamas, J; Garcia-Jares, C; Roca, E.
47	Release of Polycyclic Aromatic Hydrocarbons and Heavy Metals from Rubber Crumb in Synthetic Turf Fields: Preliminary Hazard Assessment for Athletes	Marsili, L; Coppola, D; Bianchi, N; Maltese, S; Bianchi, M; Fossi, MC.
48	A Survey of Microbial Populations in Infilled Synthetic Turf Fields	McNitt, AS; Petrunak, D; Serensits, T.
49	Artificial-turf Playing Fields: Contents of Metals, PAHs, PCBs, PCDDs and PCDFs, Inhalation Exposure to PAHs and Related Preliminary Risk Assessment	Menichini, E; Abate, V; Attias, L; DeLuca, S; DiDomenico, A; Fochi, I; Forte, G; Iacovella, N; Iamiceli, AL, Izzo, P; Merli, F; Bocca, B.
50	~~Culture-based and non-growth-dependent detection of the Burkholderia cepacia complex in soil environments~~ Note: This reference is not relevant, therefore not reviewed.	~~Miller et al~~
51	Evaluation of the Environmental Effects of Synthetic Turf Athletic	Milone and MacBroom, Inc.
52	Environmental and Health Evaluation of the Use of Elastomer Granulates (Virgin and From Used Tyres) as Filling in Third-generation Artificial Turf	Moretto, R.
53	~~Emission and evaluation of health effects of PAHs and aromatic amines from tyres~~ Note: This study does not meet our search criteria (focuses on problematic substances in whole tires).	~~Nilsson, NH; Feilberg, A; Pommer, K. (2005).~~
54	Mapping Emissions and Environmental and Health Assessment of Chemical Substances in Artificial Turf	Nilsson, NH; Malmgren-Hansen, B; Thomsen, US.
55	Artificial Turf Pitches: An Assessment of the Health Risks for Football Players	Norwegian Institute of Public Health and the Radium Hospital
56	A study to assess potential environmental impacts from the use of crumb runner as infill material in synthetic turf fields	New York Department of Environmental Conservation (NYDEC)
57	An assessment of chemical leaching, releases to air and temperature at crumb-rubber infilled synthetic turf fields	New York Department of Environmental Conservation (NYDEC)

58	New York City Department of Parks and Recreation: Synthetic Turf Lead Results (online)	New York City Department of Parks and Recreation
59	~~A Review of the Potential Health and Safety Risks From Synthetic Turf Fields Containing Crumb Rubber Infill~~ Note: Same as Denly et al. 2008. See reference # 22.	~~New York City Department of Health and Mental Hygiene (DOHMH)~~
60	Bioaccessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers	Pavilonis, BT; Weisel, CP; Buckley, B; Lioy, PJ.
61	Potential health and environmental effects linked to artificial turf systems-final report	Plesser, T; Lund, O.
62	Zinc Leaching From Tire Crumb Rubber	Rhodes, EP; Ren, Z; Mays, DC.
63	Environmental Sanitary Risk Analysis Procedure Applied to Artificial Turf Sports Fields	Ruffino, B; Fiore, S; Zanetti, MC.
64	Used Tire Recycling to Produce Granulates: Evaluation of Occupational Exposure to Chemical Agents	Savary, B; Vinvent, R.
65	Artificial Turf Football Fields: Environmental and Mutagenicity Assessment	Schilirò, T; Traversi, D; Degan, R; Pignata, C; Alessandria, L; Scozia, D; Bono R; Gilli, G.
66	Leaching of DOC, DN and inorganic Constituents from Scrap Tires	Selbes, M; Yilmaz, O;, Khan, AA; Karanfil, T.
67	Human health issues on synthetic turf in the USA	Serentis,T J; McNitt, AS; Petrunak, DM.
68	An Evaluation of Potential Exposures to Lead and Other Metals as the Result of Aerosolized Particulate Matter from Artificial Turf Playing Fields	Shalat, SL.
69	Evaluating the Risk to Aquatic Ecosystems Posed by Leachate from Tire Shred Fill in Roads Using Toxicity Tests, Toxicity Identification Evaluations, and Groundwater Modeling	Sheehan, PJ; Warmerdam, JM; Ogle, S; Humphrey, D; Patenaude, S.
70	Synthetic Turf Field Investigation in Connecticut	Simcox, NJ; Bracker, A; Ginsberg, G; Toal, B; Golembiewski, B; Kurland, T; Hedman, C
71	An Assessment of Environmental Toxicity and Potential Contamination from Artificial Turf using Shredded or Crumb Rubber	Sullivan, JP.
72	Environmental risk assessment of artificial turf systems	Torsten Kallqvist
73	Hydroxypyrene in Urine of Football Players After Playing on Artificial Sports Fields with Tire Crumb Infill	Van Rooij, JGM; Jongeneelen, FJ.
74	Evaluating and Regulating Lead in Synthetic Turf	Van Ulirsch, G; Gleason, K; Gerstenberger, S; Moffett, DB; Pulliam, G; Ahmed, T; Fagliano, J.
75	Leaching of Zinc from rubber infill in artificial turf (football pitches)	Verschoor, AJ.
76	Air Quality Survey of Synthetic Turf Fields Containing Crumb Rubber Infill	Vetrano, KM; Ritter, G.
77	Memo to Gloria Addo-Ayensu, Fairfax County Health Dept., from Dwight Flammia, Virginia Department of Health	Virginia Department of Health (VDH)
78	The RMA TCLP assessment project: Leachate from tire samples	Zelibor, J L.
79	Hazardous Chemicals in Synthetic Turf Materials and Their Bioaccessibility in Digestive Fluids	Zhang, J; Han, IK; Zhang, L; Crain, W.
80	~~Technical and environmental properties of tyre shreds focusing on ground engineering applications~~ Note: Not reviewed-not applicable.	~~Edeskar, T.~~
81	~~Expert Witness: Evaluation of health risks caused by skin contact with rubber granulates used in synthetic turf pitches~~ Note: Not a scientific study, expert opinion only; Not reviewed.	~~Hametner, C.~~
82	Investigation of PAH and other hazardous contaminant occurrence in recycled tyre rubber surfaces: case study: restaurant playground in an indoor shopping centre	Celeiro, M. et al.
83	~~Current State and Perspective for Artificial Turf as Sport Environment: Focusing on Third-generation Artificial Turf as Football Playing Surface~~ Note: This document reviews many of the documents already on this list that have been reviewed. Also includes information from Aoki 2008, see reference 91.	~~Aoki, T.~~
84	Mutagenic Potential of Artificial Athletic Field Crumb Rubber at Increased Temperatures	Dorsey et al.
85	~~Synthetic playing surfaces and athlete health~~ Note: Not suitable; it addresses injuries to athletes.	~~Drakos, M. C., et al.~~

86	Utilisation of crumb rubber as a soil amendment for sports turf	Groenevelt, P. H. and P. E. Grunthal
87	Evaluation of Potential Environmental Risks Associated with Installing Synthetic Turf Fields on Bainbridge Island.	Johns, DM; Goodlin, T.
88	Health Risk Assessment for Artificial Turf Playgrounds in School Athletic Facilities: Multi-route Exposure Estimation for Use Patterns	Kim, HH et al.
89	Coated rubber granulates obtained from used tyres for use in sport facilities: A toxicological assessment	Mota, H., et al.
90	Review of the impacts of crumb rubber in artificial turf applications	Simon, R.
91	Leaching of heavy metals from infills on artificial turf by using acid solutions	Aoki, T.
92	~~Environmental and Health Evaluation of the use of Elastomer Granulates (Virgin and From Used Tyres) as Filling in Third-Generation Artificial Turf~~ Note: Same as Moretto et al 2007. See Study 52.	~~French National Institute for Industrial Environment and Risks~~
93	~~ACT Global Crumb Rubber Safety Study~~ Note: Summary only; no information on the types and source of materials studied	~~Tilford, RW~~
94	State of Knowledge Report for Tire Materials and Tire Wear Particles	ChemRisk, Inc.
95	Health Impact Assessment of the Use of Artificial Turf in Toronto	Toronto Public Health
96	Nitrosamines released from rubber crumb	van Bruggen et al.
97	FOLLOW-UP STUDY OF THE ENVIRONMENTAL ASPECTS OF RUBBER INFILL A lab study (performing weathering tests) and a field study rubber crumb from car tyres as infill on artificial turf	Hofstra et al.

Appendix F - Constituents List

Analyte	Synonym(s)	CAS#
Aluminum		7429-90-5
Antimony		7440-36-0
Arsenic		7440-38-2
Barium		7440-39-3
Beryllium		7440-41-7
Cadmium		7440-43-9
Calcium		7440-70-2
Chloride		16887-00-6
Chromium		7440-47-3; 16065-83-1 (CrIII); 18540-29-9 (CrVI)
Cobalt		7440-48-4
Copper		7440-50-8
Iron		7439-89-6
Lead		7439-92-1
Lithium		7439-93-2
Magnesium		7439-95-4
Manganese		7439-96-5
Mercury		7439-97-6
Molybdenum		7439-98-7
Nickel		7440-02-0
Phosphorous		7723-14-0
Potassium		7440-09-7
Rubidium		7440-17-7
Selenium		7782-49-2
Silver		7440-22-4
Sodium		7440-23-5
Strontium		7440-24-6
Sulfur		7704-34-9
Thallium		7440-28-0
Tin		7440-31-5
Titanium		7440-32-6
Tungsten		7440-33-7
Vanadium		7440-62-2
Zinc		7440-66-6
Cadmium and Zinc Soaps		
Acenaphthene		83-32-9
Acenaphthylene		208-96-8
Acetaldehyde	Ethanone	75-07-0
Acetamide, N-cyclohexyl-		1124-53-4
Acetone		67-64-1
Acetone-diphenylamine condensation product (ADPA)		
Acetonitrile		75-05-8
Acetophenone		98-86-2
6-Acetoxy-2,2-dimethyl-m-dioxane	Dimethoxane	828-00-2
Acrolein		107-02-8
Alcohols	Ethanol	64-17-5
Aldehydes		
Alkyl benzenes		
Alkyl dithiols		
Alkyl naphthalenes		
Alkyl phenols		
Alpha pinene	alpha-Pinene	80-56-8

Amine (N-dialkyl analine derivative)		
Amines		
Anathrene		
Aniline	Benzeneamine; aminobenzene	62-53-3
Anthanthrene		191-26-4
Anthracene		120-12-7
Aromatic oil		
9,10-Anthracenedione, 2-ethyl	2-Ethylanthracene-9,10-dione	84-51-5
Azobenzene		103-33-3
Benz(e)acenaphthylene	Acephenanthrylene	201-06-9
Benzaldehyde, 3-hydroxyl-4-methoxy	3-Hydroxy-4-methoxy-benzaldehyde	621-59-0
Benz(a)anthracene		56-55-3
Benzene		71-43-2
Benzene, 1,3-bis(1-methylethenyl)-	1,3-bis(1-methylethenyl)benzene; 1,3-Diisopropenylbenzene	3748-13-8
Benzene, 1,4-bis(1-methylethenyl)-	1,4-Bis(1-methylethenyl)benzene	1605-18-1
1,4-Benzenediamine, N,N'-diphenyl-	N,N'-Diphenyl-p-phenylenediamine	74-31-7
1,4-Benzendiamin, N-(1-methylethyl)-N'-phenyl-, (IPPD)	N-Isopropyl-N'-phenyl-p-phenylenediamine, Isopropylaminodephenylamine (IPPD)	101-72-4
Benzene, isocyanato-	Phenyl isocyanate	103-71-9
Benzenemethanol	Benzyl alcohol	100-51-6
Benzo(def)dibenzothiophene	Phenanthro[4,5-bcd]thiophene	30796-92-0
Benzo(g)dibenzothiophene		
Benzo(b)fluoranthene		205-99-2
Benzo(bjk)fluoranthene	2,11-(Metheno)benzo[a]fluorene	
Benzo(ghi)fluoranthene	Benzo[ghi]fluoranthene,	203-12-3
Benzo(i)fluoranthene	Benzo(j)fluoranthene	205-82-3
Benzo(k)fluoranthene		207-08-9
Benzo(mno)fluoranthene		
Benzo(a)fluorene	11H-Benzo[a]fluorene	238-84-6
Benzo(b)fluorene	2,3-Benzofluorene	243-17-4
Benzo(def)naphthobenzothiophene		
6H-Benzo[cd]pyren-6-one	6H-Benzo(cd)pyren-6-one	3074-00-8
Benzo(a)pyrene		50-32-8
Benzo(e)pyrene		192-97-2
Benzo(ghi)perylene	Benzo(g,h,i)perylene	191-24-2
Benzoic acid		65-85-0
Benzothiazole		95-16-9
Benzothiazole, 2-(methylthio)	2-(Methylthio)benzothiazole	615-22-5
Benzothiazole, 2-phenyl	2-Phenylbenzothiazole	883-93-2
Benzothiazolone	2-Hydroxybenzothiazole, 2(3H)-Benzothiazolone, 2(3H) benzothiazolone	934-34-9
Benzoyl and other peroxides		
Benzylbutyl phthalate	Butyl benzyl phthalate	85-68-7
Biphenyl	1,1'-Biphenyl	92-52-4
1,1'-Biphenyl, 4, 4', 5', 6'-tetramethoxy-		
(N,N`-Bis(1,4-dimethylpentyl)pphenylendiamine) (7PPD)	N,N'-Bis(1,4-dimethylpentyl)-4-phenylenediamine	3081-14-9
Bis(2-ethylhexyl) phthalate	Di(2-ethylhexyl) phthalate	117-81-7
Bis-(2,2,6,6-tetramethyl-4-piperidinyl)sebacate	Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	52829-07-9
Bisthiol acids		
Black rubber		
Bromodichloromethane		75-27-4
Bromoform		75-25-2
Butadiene oligomers		
Butoxyethoxyethanol	2-(2-Butoxyethoxy)ethanol, diethylene glycol monobutyl ether	112-34-5
Butylated hydroxyanisole		25013-16-5
Butylated hydroxytoluene	2,6-Di-tert-butyl-4-methylphenol (BHT)	128-37-0
Butylbenzene		104-51-8
Caprolactam disulfide (CLD)	1,1'-Disulfanediyldiazepan-2-one	23847-08-7

Carbazole		86-74-8
Carbon Black	Furnace Black	1333-86-4
Carbon Disulfide		75-15-0
Carbon Tetrachloride		56-23-5
Chlorobenzene		108-90-7
Chloroform	Trichloromethane	67-66-3
Chloromethane	Methyl chloride	74-87-3
Chrysene		218-01-9
Coronene		191-07-1
o-Cyanobenzoic acid	2-Cyanobenzoic acid	3839-22-3
Cyclohexanamine	Cyclohexylamine	108-91-8
Cyclohexanamine, N-cyclohexyl-	Dicyclohexylamine	101-83-7
Cyclohexanamine, N-cyclohexyl-N-methyl-	N-Cyclohexyl-N-methylcyclohexanamine	7560-83-0
Cyclohexane		110-82-7
Cyclohexane, isocyanato	Isocyanatocyclohexane	3173-53-3
Cyclohexane, isothiocyanato-		1122-82-3
Cyclohexanone		108-94-1
N-Cyclohexyl-2-benzothiazolesulfenamide (CBS)	N-Cyclohexyl-2-benzothiazolesulfenamide	95-33-0
n-Cyclohexyl-formamide	N-Cyclohexylformamide; Formamide, N-cyclohexyl	766-93-8
Cycloninasiloxane, octadecamethyl-	Octadecamethylcyclononasiloxane	556-71-8
Cyclopenta[cd]pyrene		27208-37-3
4H-cyclopenta[def]phenanthren-4-one	4H-Cyclopenta(def)phenanthren-4-one	5737-13-3
4H-cyclopenta[def]-phenanthrene	4-H-Cyclopenta(d,e,f)phenanthrene	203-64-5
Cyclopentane, methyl-	Methylcyclopentane	96-37-7
Decane		124-18-5
Diazoaminobenzenes		
Dibenzo(a,h) anthracene	Dibenz(a,h)anthracene	53-70-3
Dibenzofurane	Dibenzofuran	132-64-9
Dibenzo(ae)pyrene	Naphtho(1,2,3,4-def)chrysene	192-65-4
Dibenzo(ai)pyrene	Dibenzo[a,i]pyrene	189-55-9
Dibenzo(ah)pyrene	Dibenzo[a,h]pyrene	189-64-0
Dibenzothiophene		132-65-0
Dibutyl phthalate		84-74-2
1,4-Dichlorobenzene	p-dichlorobenzene	106-46-7
Dichlorodifluoromethane	Freon 12	75-71-8
1,2-Dichloroethane	Ethylene dichloride	107-06-2
cis-1,2-Dichloroethene	(Z)-1,2-Dichloroethylene	156-59-2
1,2-Dichloropropane		78-87-5
N,N-Dicyclohexyl-2-benzothiazolesulfenamide (DCBS)	N,N-Dicyclohexyl-2-benzothiazolesulfenamide	4979-32-2
Dicyclohexylphthalate (DCHP)	Dicyclohexyl phthalate	84-61-7
1,3-Dicyclohexylurea	N,N'-Dicyclohexylurea	2387-23-7
Diethenylbenzene	Divinylbenzene	1321-74-0
Di(2-ethylhexyl) adipate	Hexanedioic acid, bis(2-ehtylhexyl); Bis(2-ethylhexyl)hexanedioic acid	103-23-1
Diethyl phthalate		84-66-2
Diethylthiourea (DETU)	N,N'-Diethylthiourea	105-55-5
Dihydrocyclopentapyrene	2,3-Acepyrene	25732-74-5
Diisobutyl phthalate		84-69-5
Diisodecylphthalate	bis(8-Methylnonyl) phthalate	89-16-7
Diisononyl phthalate	DINP	28553-12-0
9,l0-Dimethyl-1,2-Benzanthracene	7,12-Dimethylbenz(a)anthracene	57-97-6
(N-1,3-dimethyl-butyl)-N'- phenyl-p-phenylenediamine (6PPD)	N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine	793-24-8
Dimethyldiphenylthiuram disulfide (MPTD)	Dimethyldiphenylthiuram disulfide	53880-86-7
2,6-Dimethylnaphthalene		581-42-0
2,4-Dimethylphenol		105-67-9
Dimethyl phthalate		131-11-3
Dinitroarenes		
Di-n-octyl phthalate	Dioctyl phthalate	117-84-0
Di-ortho-tolylguanidine		97-39-2

Dipentamethylenethiuramtetrasulfide (DPTT)	Bis(pentamethylenethiuram)tetrasulfide	120-54-7
Diphenylamine		122-39-4
N,N'-Diphenylguanidine (DPG)	1,3-Diphenylguanidine	102-06-7
N,N'-Diphenyl-p-phenylenediamine (DPPD)	N,N'-Diphenyl-p-phenylenediamine	74-31-7
Disulfides		
Di-(2-ethyl)hexylphosphorylpolysulfide) (SDT)	Bis-(ethylhexylthiophosphoryl) polysulfide	
3,5-Di-tert-Butyl-4-hydroxybenzaldehyde		1620-98-0
2,2’-Dithiobis(benzothiazole)	2,2'-Dithiobisbenzothiazole	120-78-5
Dithiocarbamates		
Dithiomorpholine (DTDM)	4,4'-Dithiodimorpholine	103-34-4
Dithiophosphates		
N,N`-Ditolyl-p-phenylenediamine (DTPD)	N,N'-Ditolyl-p-phenylenediamine	27417-40-9
Docosanoic acid		112-85-6
Dodecanoic acid		143-07-7
Dotriacontane		544-85-4
Drometrizol	2-(2H-Benzotriazol-2-yl)-4-methylphenol	2440-22-4
Eicosane		112-95-8
Erucylamide	Erucamide	112-84-5
Esters		
Ethanol, 2-butoxy-	2-Butoxyethanol	111-76-2
Ethanol, 1-(2-butoxyethoxy)	1-(2-Butoxyethoxy)ethanol	54446-78-5
Ethanone, 1,1'-(1,3-phenylene)bis-	Benzene-1,3-bis(acetyl)	6781-42-6
Ethanone, 1,1'-(1,4-phenylene)bis-	1,1-(1,4-Phenylene)bis-ethanone	1009-61-6
Ethanone, 1-[4-(1-methylethenyl)phenyl]-	1-[4-(1-Methylethenyl)phenyl]ethanone	5359-04-6
Ethyl Acetate		141-78-6
Ethyl benzene	Ethylbenzene	100-41-4
Ethyl benzene aldehyde	Benzaldehyde, 2-ethyl-	22927-13-5
Ethylene thiourea (Ethylene thiourea)		96-45-7
2-Ethyl-1-hexanol		104-76-7
1-Ethyl-4-Methyl Benzene	4-Ethyltoluene	622-96-8
Fluoranthene		206-44-0
Fluorene		86-73-7
Formaldehyde		50-00-0
Furan, 2-methyl	2-Methylfuran	534-22-5
2(3H)-Furanone,dihydro-4-hydroxy-	Dihydro-4-hydroxy-2(3H)-furanone; beta-Hydroxybutyrolactone	5469-16-9
Guanidines		
Halocarbon 11	Trichlorofluoromethane, Trichloro-fluoromethane, Freon 11	75-69-4
Hemeicosane		
Heptadecane		629-78-7
Heptane		142-82-5
Heptanonitrile	Heptanenitrile	629-08-3
Hexacosane		630-01-3
Hexadecane		544-76-3
Hexa(methoxymethyl)melamine	N,N,N',N',N'',N''-Hexakis(methoxymethyl)-1,3,5-triazine-2,4,6-triamine	3089-11-0
Hexamethylenetetramine	Methenamine	100-97-0
Hexane	n-Hexane	110-54-3
Hexanedioic acid, methyl ester	Methyl hexanedioate	627-91-8
Hexanoic acid, 2-ethyl-	2-Ethylhexanoic acid	149-57-5
Hydrocarbon (olefin/aromatic)		
7-Hydroxybenzo[f]flavone	7-Hydroxy-3-phenyl-1H-naphtho[2,1-b]pyran-1-one	86247-95-2
1-Hydroxypyrene		5315-79-7
Indeno[l,2,3-cd]pyrene	o-Phenylenepyrene	193-39-5
1H-isoindole-1,3 (2H)-dione	Phthalimide	85-41-6
iso-nonylphenol	3-Nonylphenol	11066-49-2
Isophorone		78-59-1
Isopropyl Alcohol	2-Propanol, Isopropanol	67-63-0
Isopropylbenzene	Cumene	98-82-8

Isopropyltoluene	1-Methyl-2-(propan-2-yl)benzene	527-84-4
Ketones		
Latex protein		
Limonene		138-86-3
MEK	Methyl ethyl ketone	78-93-3
2-Mercaptobenzothiazole		149-30-4
Methane, diethoxy-cyclohexane	Diethoxycyclohexanemethane; Bis(cyclohexyloxy)methane	1453-21-0
Methyl Alcohol	Methanol	67-56-1
2-Methylanthracene		613-12-7
2-Methyl-Butane	2-Methylbutane	78-78-4
2,2-Methylene-bis-(4-methyl-6-tert-butylphenol) (BPH)		119-47-1
Methylene Chloride	Dichloromethane	75-09-2
5-Methyl-2-hexanone	Methyl isoamyl ketone	110-12-3
1-Methylnaphthalene		90-12-0
2-Methylnaphthalene		91-57-6
3-Methyl-Pentane	3-Methylpentane	96-14-0
4-Methyl-2-pentanone	MIBK	108-10-1
1-Methylphenanthrene	1-Methyl phenanthrene	832-69-9
2-Methylphenanthrene		2531-84-2
3-Methylphenanthrene		832-71-3
9-Methylphenanthrene		883-20-5
2-Methylphenol	o-Cresol	95-48-7
4-Methylphenol	p-Cresol	106-44-5
MES (special purified aromatic oil)		
2-(4-morpholino)benzothiazole	2-morpholinothio benzothiazole (MBS); Morpholinothio-benzothiazole; N-Oxydiethylenebenzothiazole-2-sulfenamide	102-77-2
2-Morpholinodithiobenzothiazole (MBSS)	2-(Morpholin-4-yldithio)-1,3-benzothiazole	95-32-9
Naphthalene		91-20-3
Naphthalene, 2-(bromomethyl)-	2-Bromomethylnaphthalene	939-26-4
Naphthalic Anhydride	1H,3H-Naphtho(1,8-cd)pyran-1,3-dione	81-84-5
Napthenic oil		
Nitro compound (isomer of major peak)		
Nitro compound (nitro-ether derivative)		
Nitrogen containing substances		
Nitrosodibutylamine (n-)	N-Nitrosodibutylamine	924-16-3
Nitrosodiethylamine (n-)	N-Nitrosodiethylamine	55-18-5
Nitrosodimethylamine (n-)	N-Nitrosodimethylamine	62-75-9
n-Nitrosodiphenylamine	N-Nitrosodiphenylamine	86-30-6
Nitrosodipropylamine (n-)	N-Nitrosodipropylamine	621-64-7
Nitrosomorpholine (n-)	N-Nitrosomorpholine	59-89-2
Nitrosopiperidine (n-)	N-Nitrosopiperidine	100-75-4
Nitrosopyrrolidine (n-)	N-Nitrosopyrrolidine	930-55-2
Nonadecane		629-92-5
Nonanale	Nonanal	124-19-6
Nonane		111-84-2
4-n-nonylphenol	4-Nonylphenol	104-40-5
Octadecanoic acid, methyl ester	Methyl stearate	112-61-8
Octane		111-65-9
4-t-octylphenol	4-(1,1,3,3-Tetramethylbutyl)phenol, 4-tert-(octyl)-phenol	140-66-9
Optadecane		
Organic thiola and sulfides		
Orthocarbonate - Carboxy compound)		
N-Oxydiethylenedithiocarbamyl-N`-oxydiethylenesulfenamide (OTOS)		13752-51-7
PAHs	Polycyclic aromatic hydrocarbons	
Parrafinic oils	Mineral oil	8012-95-1
PCB sum		

PCDD/F sum		
Pentacosane		629-99-2
Pentane		109-66-0
Perylene		198-55-0
Petroleum Naphtha	Naphtha	8030-30-6
Phenalone	Phenalen-1-one	548-39-0
Phenanthrene		85-01-8
1-Phenanthrenecarboxylic acid, 1,2,3,4,4	1,2,3,4,4-1-Phenanthrene carboxylic acid; Dehydroabietic acid	1740-19-8
Phenol	2,4-Di-tert-butylphenol	108-95-2
Phenolics		
Phenol, 2,4-bis(1,1-dimethylethyl)-		96-76-4
Phenol, 2,4-bis(1-methyl-1-phenylethyl)-	2,4-Bis(1-methyl-1-phenylethyl)phenol	2772-45-4
Phenol, m-tert-butyl-	3-tert-Butylphenol	585-34-2
Phenylbenzimidazole	2-Phenylbenzimidazole	716-79-0
p-Phenylenediamines		
Phenylenediamines		
2-(1-phenylethyl)-phenol	2-(1-Phenylethyl)phenol	26857-99-8
3-Phenyl-2-propenal	3-Phenylprop-2-enal	104-55-2
Phthalates		
PM 2.5		
PM10		
Poly- and di-nitrobenzenes		
Poly-p-dinitrosobenzene		
Propene	1-Propene; propylene	115-07-1
Propylbenzene		103-65-1
Pyrazole		288-13-1
Pyrene		129-00-0
Pyrimidine, 2-(4-pentylphenyl)-5-propyl-		94320-32-8
2-Pyrrolidinone. 1-methyl-	N-Methyl-2-pyrrolidone	872-50-4
Quinones		
Resorcinol		108-46-3
Rethene		
Siloxanes		
Styrene		100-42-5
Styrene oligomers		
Substituted p-Phenylenediamines		
Sulfur containing organics		
Sulfur Donors		
Sulphenamides		
TDAE (special purified aromatic oil)		
Tertbutylacetophenone	3,3-dimethyl-1-phenylbutan-1-one	31366-07-1
N-tert-Butyl-2-benzothiazolesulfenamide (TBBS)		95-31-8
4-tert butylphenol	4-tert-Butylphenol	98-54-4
Tetraalkylthiuram disulfides		
Tetrabenzylthiuram disulfide (TBZTD)		10591-85-2
Tetrabutylthiuram disulfide (TBTD)		1634-02-2
Tetrachloroethene	Tetrachloroethylene; perchloroethylene	127-18-4
Tetracosane		646-31-1
Tetraethylthiuram disulfide	Disulfiram	97-77-8
Tetrahydrofuran		109-99-9
Tetramethylthiuram disulfide	Thiram	137-26-8
Tetramethylthiuram monosulfide		97-74-5
Thiazoles		
Thioureas		
Thiurams		
Thiuram sulfides		
Toluene		108-88-3
Total petroleum hydrocarbons		
Trans trans-muconic acid	(E,E)-Muconic acid	3588-17-8

Trimethyl-1,2-dihydroquinoline (TMDQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1
1,1,1-Trichloroethane		71-55-6
Trichloroethylene		79-01-6
1,1,2-Trichloro-1,2,2-trifluoroethane		76-13-1
Trichloro-trifluoroethane	1,1,1-Trichloro-2,2,2-trifluoroethane	354-58-5
Tricosane		638-67-5
1,2,3-Trimethyl benzene	1,2,3-Trimethylbenzene	526-73-8
1,2,4-Trimethyl benzene	1,2,4-Trimethylbenzene	95-63-6
1,3,5-Trimethyl benzene	1,3,5-Trimethylbenzene	108-67-8
2,2,4-Trimethyl-1,2-dihydroquinoline (TMQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1
Vinyl Acetate		108-05-4
White gasoline	Natural gasoline	8006-61-9
o-Xylene		95-47-6
Xylenes		1330-20-7
Zn-Dibenzyldithiocarbamate (ZBEC)		136-23-2
Zn-Diethyldithiocarbamate (ZDEC)	Zinc diethyldithiocarbamate	14324-55-1
Zn-Dimethyldithiocarbamate (ZDMC)	Ziram	137-30-4
Zn-dibutyldithiocarbamate (ZDBC)		
ZnO	Zinc Oxide	1314-13-2

Appendix C – Data Collection for Synthetic Turf Fields/Summary of Activity to Date

The agencies finalized the "Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds" (referred to subsequently as the Federal Research Action Plan or FRAP) in February 2016. EPA and CDC/ATSDR, in collaboration with CPSC, prepared a research protocol to implement portions of the research activities outlined under the FRAP. Specifically, the design of the research protocol implemented three of the research elements described in the FRAP:

- conduct a Literature Review/Gaps Analysis,
- perform tire crumb rubber characterization research,
- perform human exposure characterization research.

Section B and Appendix B of this status report cover the Literature Review/Gaps Analysis. Section C and this appendix update the two key data collection studies on synthetic turf fields. One of the studies is an evaluation of tire crumb samples collected from tire crumb manufacturing plants and from indoor and outdoor synthetic turf fields across the country. The second is a pilot-scale exposure study that will gather activity data from people who regularly perform activities on synthetic turf fields.

The protocol document received an external peer-review, as well as reviews by the CDC's IRB and EPA's Human Subjects Research Review Official (HSRRO). The OMB conducted an ICR review on the data collection components of the study, and, as part of that process, the agencies received and addressed public comments. Comments and the agencies' responses are publicly available on the OMB's website (http://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201607-0923-001).

The study team obtained final approval to commence work on August 5, 2016. Field collections began in mid-August. Collections for the tire crumb characterization component of the study is complete as proposed. Analysis of the samples is in progress. Recruitment of fields and participants for the exposure characterization also is in progress.

Tire Crumb Rubber Characterization

Federal researchers have made substantial progress in developing a research protocol, recruiting synthetic fields and recycling plants, sample collection, and sample analysis for the tire crumb rubber characterization research.

1. A research protocol was
   - developed by EPA and CDC/ATSDR with input and review by CPSC and the U.S. Army Medical Command, Army Public Health Center (APHC);
   - externally peer reviewed and revised;
   - reviewed by the CDC IRB and approved following revision;
   - reviewed and approved by the EPA HSRRO;
   - reviewed by OMB as an ICR and approved following revision.
2. The study team prepared, reviewed, and approved quality assurance project plans, sample collection and analysis standard operating procedures (SOPs).
3. The study team achieved recruitment and sample collection goals for recycling plants and synthetic turf fields through
   - field sample collection training provided to members of the APHC and their subsequent collection of tire crumb rubber samples at 19 synthetic turf fields at Army installations across the United States;
   - recruitment and tire crumb rubber sample collection successfully completed by CDC/ATSDR and EPA for nine tire recycling facilities across the United States;
   - recruitment and tire crumb rubber sample collection successfully completed by CDC/ATSDR and EPA for 21 "community" synthetic turf fields across the United States.
4. Laboratory analyses for chemicals, physical properties, and microbes associated with tire crumb rubber are underway or in preparation at several EPA and CDC laboratories.

An overview of the tire crumb rubber characterization research effort and accomplishments and additional details regarding the procedures and status are provided below.

Overview

The tire crumb rubber characterization research is intended to characterize a wide range of chemical, physical, and microbiological constituents and properties for tire crumb rubber infill material collected from tire recycling plants and synthetic turf fields around the United States and to assess factors that may affect exposures to these constituents by field users. Substantial progress has been made in the tire crumb rubber characterization research. Collection of samples at tire recycling plants and synthetic turf fields has been completed, meeting the research objectives of collecting tire crumb rubber samples from nine tire recycling plants and 40 synthetic turf fields across the four U.S. census regions. Chemical and microbiological analyses of the collected tire crumb rubber are underway at several EPA and CDC laboratories.

The tire crumb rubber characterization involves the collection of crumb rubber material from tire recycling plants and synthetic turf fields around the United States, with laboratory analysis for a wide range of metals, VOCs, and SVOCs. Laboratory analyses include dynamic emission chamber measurements for VOCs and SVOCs under different temperature conditions and bioaccessibility measurements for metals and SVOCs. The emissions and bioaccessibility experiments will provide important information about the types and amounts of tire crumb rubber chemical constituents available for human exposure through inhalation, dermal, and inhalation pathways. In addition to quantitative target chemical analyses, suspect screening and nontargeted analysis methods are being applied for VOCs and SVOCs in an attempt to identify whether there may be potential chemicals of interest that have not been identified or widely reported in previous research. The study also includes collection of tire crumb rubber infill from synthetic turf fields to assess microbial populations; however, microbial assessments will not be conducted for tire crumb rubber collected at tire recycling plants.

IRB/OMB Process and Approvals

As required by the Paperwork Reduction Act, agency researchers submitted the activities under the FRAP requiring contact with participants to the OMB for review and approval. As part of the OMB review process, the agencies posted a 60-day FR notice describing the activities on February 17, 2016. Prior to the end of the 60-day public comment period, the public requested additional time to submit comments for the 60-day FR notice. A 2-week extension period was granted, and the public comment period ended on May 2, 2016.

The agencies submitted the Research Protocol to the CDC's IRB for accelerated review on June 17, 2016, and received IRB approval on July 6, 2016. EPA's HSRRO approved the IRB Reliance on July 6, 2016. On July 11, 2016, ATSDR submitted an emergency request, along with the data collection package, "Collections Related to Synthetic Turf Fields with Crumb Rubber Infill," to OMB for review and approval. Agency researchers received final OMB approval on August 5, 2016 and initiated recruitment of community fields August 8, 2016.

Recycling Plant Selection and Recruitment

Researchers aimed to recruit and consent nine tire recycling plants producing tire crumb rubber for use as synthetic turf infill. The researchers had a second goal of recruiting five plants using the ambient production process and four plants using the cryogenic production process. ATSDR and EPA contacted seven companies operating tire recycling plants producing tire crumb rubber for synthetic turf infill. ATSDR and EPA reached sample collection agreements with six companies, resulting in successful sample collection at nine recycling plants operated by those companies around the United States. Six recycling plants used the ambient process, and three used the cryogenic process.

Synthetic Turf Field Selection and Recruitment

Field Selection Criteria - Researchers aimed to recruit and consent 40 synthetic turf fields with recycled tire crumb rubber infill, 10 fields in each of the four U.S. census regions. However, if the study team could not obtain the maximum sample size in a specific U.S. census region by the end of the recruitment period, researchers enabled a previously consented field in a different census region to be eligible to participate. The study team defined the target "population" for the community fields as synthetic turf fields with recycled tire crumb rubber infill and defined the recycled tire crumb rubber infill as either manufactured with a cryogenic process or an ambient process. There were no restrictions on field age, "grass blade" composition or color, or field type (i.e., soccer, baseball). Researchers requested field size, but that was not a specific exclusion criterion. The study team excluded synthetic turf fields with encapsulated or colored or painted crumb rubber from the study and limited participation to two outdoor fields per facility; however, the fields must meet one of two criteria: (1) the fields must be of different ages, or (2) the fields must be installed by different manufacturers if the same age. Indoor fields co-located with outdoor fields were permitted.

U.S. Army Installation Synthetic Turf Fields - The U.S. Army has constructed athletic and physical training synthetic turf fields at many of its installations. The APHC collaborated in the research effort through identification of eligible synthetic turf fields at Army installations in the United States and by collecting tire crumb rubber samples at synthetic turf fields. Following training by EPA and ATSDR researchers, APHC personnel collected samples at 16 outdoor and 3 indoor synthetic turf fields between August and September 2016.

Community Synthetic Turf Fields - ATSDR recruited the remaining 21 synthetic turf fields, and they were sampled by trained ATSDR or EPA staff members. The term "community fields" is used to represent fields not on military installations (i.e., at parks, schools, etc.). ATSDR/EPA used a convenience sampling approach for the recruitment and consent of facilities with synthetic turf fields. Researchers found prospective facilities using the search engine website Google and the following key search terms: "recreational fields," "sports training facilities," "sports training," "sport fields," "sporting fields," "soccer fields," "baseball fields," "football fields," and "parks and recreation." The researchers followed these key search terms by the state or area of focus. For example, a search would be "recreational fields in Georgia." Often, these searches provided the address, contact information, and website about the prospective facilities in the target area. Additionally, the study team allowed self-identification of facilities with synthetic turf fields. For inclusion in the study, agency researchers required agreement to recycled tire crumb rubber sample collection and answering a questionnaire on field maintenance procedures and field use.

Researchers initiated contact with potential facilities and fields on August 8, 2016 and classified responses to initial contacts in six categories: (1) no answer (a voicemail was left if applicable); (2) incorrect contact person (correct contact information was requested); (3) immediate declination; (4) requested additional information; (5) noneligible (i.e., grass field); and (6) verbal consent. The researchers limited contact with facilities to five times for those in categories 1 and 2. For those requesting additional information, the researchers sent a fact sheet describing the study and the facility agreement form via email. For those agreeing, researchers administered the eligibility screening and sent the agreement form to those facilities deemed eligible. The researchers categorized eligible fields as indoor or outdoor and by age (2008 or older, 2009 to 2012, and 2013 to 2016). The researchers contacted weekly the facilities verbally agreeing to participate until (1) obtaining written consent, (2) the maximum number of facilities consented for census region, or (3) the project recruitment period ended.

Once written consent was obtained from the field owner, the research team scheduled a date and time for sample collection. The study team provided a questionnaire regarding facility installation, use, and maintenance to each facility or field prior to computer-assisted administration via telephone.

Between August and November 2016, the researchers contacted a total of 306 community field owners (Table C-1). The researchers obtained participation agreement and completed sample collection at 21 fields, including 9 outdoor fields and 12 indoor fields (Tables C-2 and C-3).

For those immediately declining participation in the study, researchers requested information regarding the declination. In general, those declining to participate gave reasons that were limited to three main issues.

- Liability: Many field owners and managers expressed concern about the potential liability associated with sampling their fields. Specifically, the concerns centered around the potential for specific actions that would need to be taken based on the outcome of the study.
- Confidentiality: As expressed in the agreement forms, EPA/ATSDR will not be releasing individual facility names or results in the public reports; EPA/ATSDR will release the number of fields sampled per U.S. census region. However, EPA/ATSDR could not assure the facility of complete anonymity or confidentiality.
- Not at this time: Although many field owners and managers were interested in the study, they declined participation in the current study.

Table C-1. Community field recruitment efforts

Region	Contacted[a]	Ineligible	Refused[b]	Participated
Northeast	118	22	20	5
Midwest	96	10	9	8
South	40	11	13	2
West	52	8	9	6
Total	306	51	51	21

[a]Facilities with more than one field were only counted as n=1.
[b]Facilities that did not return phone calls or other attempts (i.e., email) at recruiting are not included in the number of refusals; however, the majority of fields contacted that were not included in the ineligible column, the refused column, or the participated column were facilities that failed to respond to recruitment attempts.

Table C-2. Synthetic Turf Field Final Recruitment and Sampling Status

Region	Community Fields Consented/Sampled	U.S. Army Fields Sampled	Total (Army and Community) Fields Sampled
Northeast	4	5	9
Midwest	8	0	8
South	5	8	13
West	4	6	10
Total	21	19	40

Table C-3. Outdoor and Indoor Synthetic Turf Field Final Sampling Status

Region	Outdoor Fields	Indoor Fields	Total Fields Sampled
Northeast	5	4	9
Midwest	2	6	8
South	11	2	13
West	7	3	10
Total	25	15	40

Recycling Plant Sample Collection

Researchers collected recycled tire crumb rubber samples of the size category used in synthetic turf fields (typically 10 to 20 mesh) from nine tire recycling plants around the United States. The samples collected were from three different storage containers at each plant. For each storage container, the study team filled two 1-l high-density polyethylene (HPDE) jars for metals analysis, two 1-l amber glass jars for organic chemical analysis, and one 1-l HPDE jar for particle characterization. At most plants, the study team used precleaned stainless steel scoops to gather tire crumb rubber into precleaned and certified 1-l amber glass wide-mouth jars with Teflon-lined lids for organics analysis. Researchers used precleaned plastic scoops to gather tire crumb rubber into precleaned and certified 1-l polyethylene wide-mouth jars for metals analysis and particle characterization. At one plant, researchers collected samples from storage bags using a stainless steel sampling spike designed to include material from multiple levels of the storage bag in the vertical and horizontal dimensions using that plant's established equipment and protocol.

The study team enrolled nine plants located across all four census regions. Three of the plants used a cryogenic process for creating tire crumb rubber, whereas the remaining six plants used the ambient process. Researchers generated a total of 27 samples for organic chemical analysis (including emissions testing and bioaccessibility analysis), 27 samples for metals analysis (including bioaccessibility analysis), and 27 samples for particle characterization.

Synthetic Turf Field Sample Collection

Researchers collected tire crumb rubber samples from 40 synthetic turf fields to support characterization of chemical constituents and to examine microbial species. Chemical characterization includes analysis of SVOC and metal analytes in tire crumb rubber, bioaccessibility analysis of SVOCs and metals from tire crumb rubber, and emissions testing of VOCs and SVOCs from tire crumb rubber.

Substantial variability in tire crumb rubber chemical concentrations have been reported; therefore, researchers used a composite sample collection approach at synthetic turf fields. Researchers collected individual samples from seven locations at each field separately for SVOC, metal, microbial, and particle characterization analyses. Researchers used specified sampling locations for different types of fields (e.g., rectangular fields and baseball fields). To support between-field assessments, the study team returned the individual location samples to the laboratory where a composite sample was created from the seven individual location samples. To support within-field variability assessment of chemical constituents, researchers identified some of the individual location samples from a subset of five fields for separate analyses. For microbial analyses, the study team scheduled all seven of the individual location samples from each field for separate analyses.

Information about the synthetic turf field locations in the four U.S. census regions and the number of outdoor and indoor fields in each region is shown in Table C-4. Researchers collected samples from between 8 and 13 fields in each census region and from 25 outdoor fields and 15 indoor fields. One field was a baseball/softball field, three were Army physical training fields, and the remainder were soccer/football-type playing fields. Field installation dates ranged from 2004 to 2016.

Table C-4. Samples Collected for Analyses at Synthetic Turf Fields

Region	Individual Location Samples Collected Across 40 Fields[a]				Total Composite Samples Prepared[c]
	For Organic Chemical Analysis	For Metals Analysis	For Particle Characterization	For Microbial Analysis	
Northeast	63	63	63	63	18
Midwest	56	56	56	56	16
South	91	91	91	91	26
West	70	70	69[b]	70	20
Total	280	280	279	280	80

[a]At each field, samples were collected from seven individual locations.
[b]The cap came off of one sample collection container during transport.
[c]For each synthetic turf field, one composite sample was prepared in the laboratory from the seven individual location samples for organic chemical analyses and one composite sample was prepared for metals analyses.

The study team collected tire crumb rubber samples for SVOC samples using a small handheld metal rake to pull tire crumb rubber from the field at each location. The collection depth in the field was no more than about 3 cm from the surface. Researchers placed collected tire crumb rubber into certified precleaed 250-ml amber glass wide-mouth containers with Teflon-lined lids. For metals samples, researchers used a small handheld plastic rake to pull tire crumb rubber from the field at each location, with the collection depth no more than about 3 cm from the surface. The study team placed collected tire crumb rubber into certified precleaned 250-ml polyethylene wide-mouth containers. For samples to be used for particle characterization, researchers used a small handheld plastic rake to pull tire crumb rubber from the field at each location, with the collection depth no more than about 3 cm from the surface and placed collected tire crumb rubber into certified precleaned 250-ml polyethylene wide-mouth containers. Researchers incorporated an alternate tire crumb rubber collection technique using spatulas as required at some fields, particularly older fields with greater wear and higher blade and rubber compression.

The study team prepared a single composite sample from the seven SVOC samples for each field at a central processing laboratory. Researchers added a weighed amount (approximately 35 g) of the tire crumb rubber material from each of the seven individual location samples to a single certified precleaned 500-ml amber wide-mouth glass container with Teflon-lined lid and mixed the composite sample thoroughly. Researchers then removed subsamples of the composite sample and added them to smaller precleaned and certified amber glass containers to distribute to the analysis laboratories. Researchers retained the remaining individual samples in their sealed containers and stored all samples in a freezer at -20 °C. Researchers used the same procedure to prepare composite samples for metals analysis using certified precleaned HPDE containers. Researchers also prepared subsamples for analysis from individual field locations to support analyses from individual field locations for a subset of five fields. For particle characterization analysis, the study team combined the entire contents from each 25-ml individual location container prior to analysis.

Researchers also collected tire crumb rubber samples from synthetic turf fields to support microbiome analysis but did not analyze samples collected from tire recycling plants for microbes. Researchers collected individual samples from each field at all seven locations that were also used for metals and organic analysis sample collections. The study team employed aseptic techniques while collecting and handling samples and sampling equipment by wearing clean nitrile gloves at all times and donning new gloves at each of the seven field locations to handle the sample collection container and sampling equipment. The researchers wore a new disposable lab coat during sample collection and used a sterile polypropylene spatula to collect each sample and used a new spatula at each of the seven locations. The researchers inserted the sterile spatula into the athletic field surface to maximum depth of about 3 cm from the surface and moved it forward to collect tire crumb material. The researchers added the tire crumb rubber to a new sterile 50 ml polypropylene container with volumetric lines at each of the seven locations. The researchers filled the containers with tire crumb rubber material to the 25-ml line. Once samples were collected, the study team placed them immediately into a cooler with ice packs and shipped the samples the same day they were collected in a container with ice packs to the appropriate laboratory by overnight shipment. The study team kept the samples separate for analysis of all individual location samples collected at all fields.

Table C-5 shows the total number of samples and subsamples prepared for the range of analyses to be applied. This table includes the totals from both tire recycling plants and synthetic turf fields. The table does not include quality control samples and analyses.

Table C-5. Number of Recycling Plant and Synthetic Turf Field Tire Crumb Rubber Samples Prepared for Analyses[a,b]

Sample Type	Number of Composite Samples	Number of Individual Samples	Total Number of Samples
Direct Constituent Analysis			
Samples for metals constituent ICP/MS analyses	40	60	100
Samples for metals constituent XRF analyses	40	60	100
Samples for targeted SVOC constituent LC/MS analyses[c]	40	62	102
Samples for targeted SVOC constituent GC/MS analyses[c]	40	62	102
Dynamic Chamber Emissions Experiments			
Chamber experiments for VOCs at 25 °C	40	42	82
Chamber experiments for VOCs at 60 °C	40	42	82
Chamber experiments for SVOCs at 25 °C	40	42	82
Chamber experiments for SVOCs at 60 °C	40	42	82
Emissions Sample Analyses			
Samples for targeted VOC emissions analyses[c]	80	84	164
Samples for formaldehyde emissions analyses	80	84	164
Samples for targeted SVOC emissions LC/MS analyses[c]	80	84	164
Samples for targeted SVOC emissions GC/MS analyses[c]	80	84	164
Particle Characterization Analysis			
Particle size characteristics	40	27	67
Scanning electron microscopy	40	27	67
Microbial Sample Analysis			
Samples for microbial analyses - targeted	0	280	280
Samples for microbial analyses – non-targeted	0	280	280
Bioaccessibility Analysis			
Samples for metals bioaccessibility – simulated saliva	40	42	82
Samples for metals bioaccessibility – simulated gastric	40	42	82
Samples for metals bioaccessibility – simulated sweat	40	42	82
Samples for SVOC bioaccessibility analyses – simulated saliva	40	42	82
Samples for SVOC bioaccessibility analyses – simulated gastric	40	42	82
Samples for SVOC bioaccessibility analyses – simulated sweat	40	42	82

[a]Does not include quality control/quality assurance samples or analyses; does not include chamber background samples.
[b]The total numbers of samples are based on 40 synthetic turf field composite samples, 15 to 35 synthetic turf field individual location samples, and 27 individual recycling plant samples from 9 recycling plants; except for microbial analysis where all 280 individual synthetic turf field location samples are scheduled for analysis.
[c]In addition to analysis for target analytes, 12 of the samples will be selected for non-targeted analysis.

Tire Crumb Rubber Characterization Sample Analyses

Laboratory analyses for a wide range of chemical, physical, and microbiological constituents and properties for tire crumb rubber infill material collected from tire recycling plants and synthetic turf fields around the United States is in progress or in preparation to begin. Although other research studies have examined crumb rubber constituents, most studies have been relatively small, restricted to a few fields or material sources, and measured a limited number of constituents. In this study, tire crumb rubber samples collected directly from tire recycling plants will provide information on constituents in unused material, and samples collected from outdoor and indoor synthetic turf fields will provide a better understanding of constituents potentially available for exposure under different conditions of weathering and facility type. Characterization will include direct measurement of metal and SVOC constituents of tire crumb rubber, studies of VOC and SVOC emissions and emission rates from tire crumb rubber, and bioaccessibility testing of metal and SVOC constituents. Multiple analytical methods will be used to provide information on a wide range of metals and organic chemicals. A combination of targeted quantitative analysis, suspect screening, and nontargeted approaches will be applied for VOCs and SVOCs. The research will help fill data gaps regarding the types and concentrations of the chemical constituents in crumb rubber material and their potential availability for human exposure. Physical characteristics, such as particle size, will be examined to better understand potential exposures. The research also will address gaps in the knowledge regarding microbial pathogens associated with tire crumb rubber on synthetic turf fields.

Table C-6 shows the status of the laboratory analyses. Researchers are performing direct constituent analyses for metals by inductively coupled plasma mass spectrometry (ICP/MS) and x-ray fluorescence (XRF) analyses. Researchers also are extracting tire crumb rubber samples for quantitative and suspect screening analyses for many SVOCs by both gas chromatography/mass spectrometry (GC/MS) and liquid chromatography/mass spectrometry (LC/MS) methods (including LC/MS in both positive and negative ion modes). In addition to direct constituent analyses, emissions testing and bioaccessibility experiments will provide important information about the types and amounts of tire crumb rubber chemical constituents available for human exposure through inhalation, dermal, and inhalation pathways. Researchers also are performing dynamic emission chamber measurements for SVOCs using microchambers and for VOCs (including formaldehyde) using small chambers at both 25 °C and 60 °C. In addition to quantitative target chemical analyses, the study team will apply suspect screening and nontargeted analysis methods for VOCs and SVOCs in an attempt to identify whether there may be potential chemicals of interest that have not been identified or widely reported in previous research. Preparation is underway for bioaccessibility measurements for metals and SVOCs using simulated saliva, gastric, and sweat fluids. Researchers are assessing tire crumb rubber particle size using separation and gravimetric approaches and particle morphology using scanning electron microscopy. Researchers are using both nontargeted (polymerase chain reaction [PCR]) and targeted (droplet digital polymerase chain reaction [ddPCR]) DNA testing to characterize microbial species on tire crumb rubber infill collected from synthetic turf fields.

Table C-6. Status of Laboratory Analyses for Tire Crumb Rubber Characterization

Sample Type	Status
Direct Constituent Analysis	
Metals constituent ICP/MS analyses	In progress
Metals constituent XRF analyses	In progress
SVOC constituent LC/MS analyses	In preparation
SVOC constituent GC/MS analyses	In preparation
Dynamic Chamber Emissions Experiments	
Chamber experiments for VOCs in TC[c] at 25 °C	Completed
Chamber experiments for VOCs in TC at 60 °C	Completed
Chamber experiments for SVOCs in TC at 25 °C	Completed
Chamber experiments for SVOCs in TC at 60 °C	Completed
Emissions Sample Analyses	
VOC emissions analyses	In progress
Formaldehyde emissions analyses	In progress
SVOC emissions LC/MS analyses	In progress
SVOC emissions GC/MS analyses	In progress
Particle Characterization Analysis	
Particle size characteristics	In progress
Scanning electron microscopy	In preparation
Microbial Sample Analysis	
Microbial analyses - targeted	In progress
Microbial analyses – nontargeted	In progress
Bioaccessibility Analysis	
Metals bioaccessibility analyses	In preparation
SVOC bioaccessibility analyses	In preparation

Exposure Characterization

Researchers have made progress in several exposure characterization research activities.

- As described in Section C.1, a research protocol was developed, reviewed, and approved, which included the exposure characterization research elements.
- Quality assurance project plans and activity data collection and sample collection SOPs were prepared.
- Exposure and activity assessment questionnaires were developed for adult and child synthetic turf field users.
- Identification of extant public video data collection for synthetic turf field users is in progress.
- Preparation of sampling equipment and materials for the exposure measurement study is in progress.
- Recruitment of exposure study research participants is in progress.

An overview of the exposure characterization study and additional details regarding the procedures and status are provided below.

Overview

The tire crumb rubber characterization research activities described in the Tire Crumb Rubber Characterization Section are important and necessary to reduce gaps in the understanding of what chemical, physical, and microbial constituents and properties may be of interest or concern. However, that information cannot be put into proper context with regard to potential impacts on human health without understanding exposure. The exposure characterization study component is a pilot-scale effort to collect information on human activity parameters for synthetic turf field users that affect potential exposures to tire crumb rubber constituents and to implement a human exposure measurement study to further develop and deploy appropriate sample collection methods and to generate data for improved exposure characterization.

There are important data gaps in human activity parameters for various synthetic turf field users that are needed for estimating exposures and evaluating risks from contact with tire crumb rubber constituents. Although the potential for inhalation exposures has been characterized for some constituents, there is far less information for characterizing dermal and ingestion exposure pathways. Improved exposure factor information is needed for estimating and modeling exposures from the inhalation, dermal, and ingestion pathways. Goals for this research include collecting information using questionnaires from adults and youth who use synthetic turf fields with crumb rubber infill for several types of active uses. Video data collection for a subset of participants engaged in activity on synthetic fields is intended to obtain objective information about important dermal and ingestion contact rates. Extant videography of users engaged in activities on synthetic fields is intended to provide additional data on contact rates for people using synthetic turf fields that are difficult to capture consistently using questionnaires. The pilot exposure study is intended to develop and assess questionnaire and video approaches for activity data collection.

Human exposure measurement data for synthetic turf field users are also limited. Important data gaps exist, particularly for potential dermal and ingestion exposures to synthetic turf field and tire crumb rubber chemical constituents. There are also important limitations in the types of methods that have been developed and used for human exposure measurements during activities on synthetic fields. Challenges include collecting relevant surface, dust, and personal air samples. Few studies have performed measurements of dermal exposures. In addition, few studies have collected urine or blood samples that might be used for measuring biomarkers of exposures to chemicals in crumb rubber infill. As a pilot-scale effort, this study is intended to implement a human exposure measurement study to further develop, deploy, and assess appropriate sample collection methods and to generate data for improved exposure characterization.

Activity Questionnaire

Researchers have developed two questionnaires to collect activity information from synthetic turf field users, one for adults and one for children (to be completed by an adult parent or caregiver). Researchers designed the questionnaire to collect information about characteristics and activity parameters that may affect the magnitude, frequency, and duration of exposure to tire crumb rubber infill constituents, including

- frequency of field use across a range of activity types,
- duration of field use across a range of activity types,
- levels of physical exertion that affect breathing rates,
- contact rates for different types of activities,
- clothing types and uses,
- demographic characteristics.

The researchers have coded the questionnaires into EpiSuite software for computer-assisted interviewing and will administer at fields the questionnaires to synthetic turf field users who engage in a sport or activity that brings them into contact with field materials. Researchers will recruit participants at community fields that took part in the tire crumb rubber characterization study. Participant recruitment is in process.

Extant Publicly-Available Video Activity Data Collection

The study team is identifying publicly available videos (e.g., YouTube) for collection of activity pattern data for adults, adolescents, youth, and children playing and practicing on artificial turf fields that contain tire crumb rubber infill at athletic facilities. Researchers are collecting the extant videography to provide an objective assessment of user activity patterns potentially impacting exposure to chemicals found in tire crumb rubber infill that are difficult to capture consistently using questionnaires. Researchers also are collecting the videography to record specific types of activity data, including type of activity or sport; type of field (e.g., indoor or outdoor); participant's age group; durations of rest or low, moderate, and high activity; and hand-to-mouth, object-to-mouth, and skin-to-surface contact rates on turf. Researchers have identified approximately 45 of the goal of 60 activity videos to date, with between 30 and 60 minutes of videotaped footage of discrete individuals engaged in sporting activities on artificial turf fields. The study team will complete video identification and perform a structured extraction of the specified activity data elements.

Videography of Exposure Measurement Study Participants

Researchers will use videography to collect activity pattern data on a subset of exposure measurement study participants who routinely play on artificial turf fields that contain tire crumb rubber infill at athletic facilities. The purpose of the video data collection is to supplement the information obtained from the facility user questionnaire on the participants' activity patterns that may impact the magnitude and frequency of their exposures to chemicals found in tire crumb rubber infill. The study team will videotape participant's activities for up to 1 hour while playing or practicing sports at the facilities. Researchers have prepared equipment and SOPs for collecting video from synthetic turf field users who agree to participate in the exposure measurement study (see below).

Exposure Measurement Pilot Study

The study team will recruit adults and youth who use synthetic turf fields with tire crumb rubber infill for participation in an exposure measurement pilot study. Researchers will collect a set of personal, biological, and field environment samples around a sport or training activity performed on a synthetic turf field. Researchers will analyze personal and environmental samples for metal, VOC, and SVOC analytes and subject a subset of SVOC samples to suspect screening and nontargeted analysis. Researchers will hold biological samples in a biorepository for future analysis once potential biomarker chemicals of interest are identified based on the tire crumb rubber and exposure characterization studies. As noted above, the researchers also will ask a subset of participants to allow videography of their on-field activities. The study team has prepared equipment, materials, and SOPs for collecting most of the proposed sample types (see Table C-7). Researchers also have performed several on-field method assessment experiments toward development of a synthetic field vacuum dust collection method; however, we have not yet finalized a suitable method.

Table C-7. Types of Samples for Exposure Characterization Measurements

Sample Type	Number of Samples Per Person or Locations Per Field	Analytes
Personal Samples		
Air	1	VOCs
Dermal	3	SVOCs
Dermal	3	Metals
Urine	2	PAH metabolites
Urine	2	Metals
Urine	2	Creatinine
Blood	2	Metals
Serum	2	Metals
Facility Samples		
Air	3[a]	VOCs
Air	3[a]	SVOCs
Air	3[a]	Particulates/Metals
Surface wipe (drag sled)	3	SVOCs
Surface wipe (by hand)	3	SVOCs
Surface wipe (by hand)	3	Metals
Dust[b]	3	SVOCs
Dust[b]	3	Metals
Dust[b]	3	Characterization

[a]Includes one off-field background location for each field and two on-field locations.
[b]Additional dust sample collection method development is required.

Appendix D – Playground Surfaces with Recycled Tire Materials

The U.S. Consumer Product Safety Commission (CPSC) is an independent federal agency charged with protecting the public from unreasonable risks of injury and death associated with the use of the thousands of types of consumer products under the agency's jurisdiction. The *Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds* identifies the CPSC as a partner in the research activities conducted by the EPA and ATSDR. The CPSC's role in the Federal Research Action Plan is to assess the risks associated with the use of recycled tire crumb rubber in playground surfaces, while the EPA and ATSDR investigate tire crumb rubber and its uses on synthetic turf athletic fields.

The Federal Research Action Plan differentiates playing fields from playgrounds without defining these terms. The CPSC has not published an official definition of a "playground." For this research activity, the CPSC staff has interpreted a "playground" to be a designated area intended for recreational play that includes engineered recreational equipment including, but not limited to, climbing structures, swings, slides, seesaws. Many modern playgrounds have structures that integrate multiple pieces of playground equipment. A "use zone" as defined in the CPSC's *Public Playground Safety Handbook,*[15] is the surface under and around a piece of equipment onto which a child falling from or exiting from the equipment would be expected to land (CPSC, 2010). The scope of the CPSC's review of playground surfacing made from recycled tire materials includes the surfaces found in the use zone and extending to the playground border.

Playground surfaces differ from synthetic turf fields in their construction and purpose. Synthetic turf fields are intended to be lower-maintenance and reduce certain injuries sustained while playing field sports, in comparison to natural turf. Modern playground surfaces are intended to reduce the risk of injury and death from vertical falls from playground equipment, compared to harder surfaces. A recent study of 2,691 playground equipment-related incidents reported to the CPSC from 2001 to 2008 indicated that falls are the most common hazard (44% of injuries) on playgrounds (O'Brien, et al., 2009). The CPSC has periodically published and revised the *Public Playground Safety Handbook* since 1981, to promote safety awareness to those who purchase, install, and maintain public playground equipment used by children ages 6 months through 12 years. The current version of the handbook was published in 2010 (CPSC, 2010). The handbook includes guidelines on playground surfacing. A "public" playground refers to the playground areas of commercial (non-residential) child care facilities, institutions, multiple family dwellings, such as apartments and condominium buildings, parks (city, state and community maintained), restaurants, resorts and recreational developments, schools, and other areas of public use (CPSC, 2010). The CPSC (2005) also published the *Outdoor Home Playground Safety Handbook*[16] to provide similar guidance for playgrounds at homes and residential child care facilities.

The recommendations in the *Public Playground Safety Handbook* are intended as guidelines and are not mandatory rules. However, many state and local jurisdictions adopt the recommendations in the *Public Playground Safety Handbook* as enforceable rules for public playgrounds. In

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[15] The *Public Playground Safety Handbook* is available at https://www.cpsc.gov/s3fs-public/325.pdf
[16] The *Outdoor Home Playground Safety Handbook* is available at https://www.cpsc.gov/s3fs-public/324.pdf.

addition to addressing hazards such as sharp edges and strangulation, the recommendations include those that address the potential for falls from, and impact with, equipment as well as the need for impact-attenuating protective surfacing under and around equipment. In December 2015, the CPSC attached an addendum to the front of the *Public Playground Safety Handbook* to clarify that "*. . . Section 2.4 of the Handbook identifies shredded/recycled rubber mulch as an 'Appropriate Surfacing' product, given that this product can meet the impact attenuation requirements of ASTM F1292, as long as minimum depths of the material are maintained, as specified in Table 2 of Section 2.5. This notation is solely focused on the impact attenuation to minimize serious head injuries and not on other aspects that may pose other risks, such as chemical exposure or ingestion*" (CPSC 2010). The CPSC's studies of recycled tire materials used in playground surfacing per the Federal Research Action Plan seek to improve understanding of potential chemical hazards to children using playgrounds.

CPSC Activities Supporting the Federal Research Action Plan

In 2016, the CPSC began several activities to gather information about the chemical safety of recycled tire materials in playground surfacing. As described in the Federal Research Action Plan, the CPSC joined its partner agencies, EPA and ATSDR, in the general activities of the recycled tire crumb rubber research effort, which include:

- conducting data knowledge gap analysis
- reaching out to key stakeholders
- characterizing the chemical composition of recycled tire crumb rubber,
- characterizing human exposures to recycled tire crumb rubber.

The Federal Research Action Plan includes data collection efforts by the federal partners, which would support future risk assessments of recycled tire crumb rubber used in fields and playgrounds. However, the partner agencies have not yet determined whether comprehensive risk assessments of recycled tire crumb rubber used in fields and playgrounds will be needed to determine if there are human health risks.

Playground Surface Types

While recycled tire crumb rubber is used with few variations as infill on synthetic turf athletic fields, a wider variety of options for recycled tire materials of various sizes and shapes is marketed for use as playground surfacing. CPSC staff used a combination of resources to gather information about how recycled tire materials are used in playground surfacing. These resources included ASTM voluntary standards regarding playground surfacing, online marketing websites for playground surfacing manufacturers and installers, in-person tours of tire recycling facilities, public meetings with representatives of the Synthetic Turf Council and the Recycled Rubber Council, research on playground surface installation and rubber tile production, and visits to public playgrounds in the Washington, D.C., metropolitan area. In addition, CPSC staff reviewed a guide for choosing playground surfaces for compliance with the Americans with Disabilities Act, published by the International Playground Equipment Manufacturers Association[17] (IPEMA, 2013). Based on these resources, meetings and observations, CPSC staff identified five general types of playground surfaces that are made with recycled tire materials: (1) loose-fill

[17] *Choosing IPEMA-Certified Playground Surfacing to Meet ADA Requirements, A Resource* is available at http://www.ipema.org/documents/IPEMA%20Installation%20Guide_Final.pdf.

rubber, (2) rubber tiles, (3) poured-in-place, (4) bonded rubber, and (5) synthetic turf. Other non-rubber surfacing types commonly found on playgrounds include loose-fill wood products (*e.g.*, mulch, chips, and engineered wood fiber), sand, and pea gravel. These non-rubber options are not addressed in the Federal Research Action Plan. Additionally, this review does not include the use of playground equipment (*e.g.*, tire swings or climbing structures) made from whole or partial tires. The *Public Playground Safety Handbook* describes that appropriate playground surfacing should be designed and tested to comply with ASTM F1292-13, *Standard Specification for Impact Attenuation of Surfacing Materials Within the Use Zone of Playground Equipment*[18] (CPSC, 2010; ASTM International, 2013b).

Playground surfaces can be divided into two main categories: loose-fill systems and unitary systems. A loose-fill system consists of small, independent, moveable components, such as sand, gravel, wood chips, engineered wood fiber, rubber particles, and similar materials (ASTM International, 2015a). A unitary system consists of one or more components bound together, such as foam composites, urethane/rubber systems, like prefabricated blocks, tiles, or mats, or as poured-in-place and similar materials (ASTM International, 2015a).

Loose-Fill Rubber is a loose-fill system consisting of rubber nuggets or buffings and is sometimes described as rubber mulch. Nuggets are rubber granules, irregular in shape, with a maximum dimension of approximately 3⁄8 in. to 7⁄8 in. (9.5 mm to 22.2 mm) (ASTM International, 2014a). Buffings are elongated rubber strands with approximate dimensions of 0.039 in. to 0.375 in. thick (1 mm to 9.5 mm), 0.039 to 0.50 in. (1 mm to 12.7 mm) wide, and 0.079 in. to 3.0 in. (2 mm to 76.2 mm) long (ASTM International, 2014a). The nuggets or buffings are typically created from recycled tires. Rubber mulch intended or marketed for landscaping or gardening uses may not be appropriate for use as a playground surfacing; consumers should verify on the packaging or product label that it is safe for use on playgrounds. All playground surfacing should comply with the impact attenuation standards per ASTM F1292-13 (ASTM International, 2013). The *Public Playground Safety Handbook* describes that a 6-inch depth of loose-fill rubber protects to a fall height of 10 feet (CPSC, 2010). ASTM F3012-14 describes specifications for loose-fill rubber as a playground surface and includes standards for rubber particle size, hazardous metal content, total lead content, tramp metal content, and sharp tramp metal content (ASTM International, 2014a). Loose-fill surfacing requires frequent maintenance to ensure surfacing levels never drop below the minimum depth. Areas under swings and at slide exits are more susceptible to displacement; special attention must be paid to maintenance in these areas. In addition, wear mats can be installed in these areas to reduce displacement. The *Public Playground Safety Handbook* notes that loose-fill systems should be avoided for playgrounds intended for toddlers (CPSC, 2010).

Rubber Tiles provide a unitary system consisting of factory-formed tiles, mats, or pavers made of an energy-absorbing material, such as recycled tire rubber. Rubber pieces of varying sizes are formed into solid design shapes with pressure and heat and/or a binder such as polyurethane. Tiles are considered low maintenance. Some manufacturers produce tiles with surface coatings to provide color options and/or durability from wear. The *Public Playground Safety Handbook* and ASTM standards do not provide specific recommendations for rubber tile playground

[18] All ASTM standards can be found at: https://www.astm.org/.

surfacing, except that all playground surfacing should comply with the impact attenuation standards per ASTM F1292-13 (CPSC, 2010; ASTM International, 2013).

Poured-in-Place (PIP) describes a unitary system that consists of a combination of rubber crumb, chips, or rubber buffing, or all three, with a polymer binder in specific percentages determined by the manufacturer/installer that is mixed proximate to the playground and poured in one or more layers on a prepared base to provide a smooth and seamless surface. The poured-in-place surface is generally installed in two layers, with the lower layer being a cushioning layer and the top being a wearing course (ASTM International, 2012). The wear-coarse layer usually consists of ethylene propylene diene monomer (EPDM) or thermoplastic vulcanizate (TPV) particles mixed with a polymer binder. Polyurethane is commonly used as the polymer binder. The wear-coarse layer may be colored for cosmetic effect and provides a durable contact surface to protect the cushioning rubber crumb layer from wear and erosion. ASTM F2479-12 describes the standards for specification, installation, and maintenance of PIP surfacing (ASTM International, 2012). All playground surfacing should comply with the impact attenuation standards per ASTM F1292-13 (ASTM International, 2013).

Bonded Rubber describes a type of PIP system that is typically made with a single layer of buffing-size rubber particles mixed with a polymer binder and less densely applied than the two-layer PIP systems described above. Bonded rubber often provides a lower-cost option than other unitary surfaces, and it is porous, allowing water to flow through it. Bonded rubber surfacing is not specifically described in the *Public Playground Safety Handbook* or ASTM standards (CPSC, 2010). Because it is a type of PIP surfacing, ASTM F2479-12 standards should apply, as well as the impact attenuation standards per ASTM F1292-13 (ASTM International, 2012; ASTM International, 2013).

Synthetic Turf is an engineered artificial grass product that gives a playground surface the appearance of natural grass but offers impact attenuation protection. Less information is available on synthetic turf as a playground surface type than for the loose-fill and PIP surfaces. Synthetic turf used on playgrounds appears to differ from the synthetic turf used on athletic fields. A review of the marketing material (*i.e.*, websites) for synthetic turf on playgrounds indicates that it consists of an artificial grass “carpet” installed over a PIP unitary system (buffing or crumb-size rubber) or a layer of porous closed-cell composite or other cushioning material. Synthetic turf on playgrounds may include an infill material to support the artificial grass blades. However, CPSC staff was unable to find any installers that advertise the use of recycled tire crumb rubber as an infill as it is used in athletic fields. Sand with or without a polymer coating appears to be the most common infill material used on playground turf. The *Public Playground Safety Handbook* does not address synthetic or artificial turf as a playground surfacing material (CPSC, 2010). The published ASTM standards for synthetic turf appear to be specific to turf used on athletic fields and not playgrounds (ASTM International, 2009a, 2009b, 2015b, 2014b, 2011, 2015c, 2016). However, because the sub-turf layer appears to be a type of PIP surfacing, ASTM F2479-12 standards should apply, as well as the impact attenuation standards per ASTM F1292-13 (ASTM International, 2012; ASTM International, 2013).

Distribution of Playgrounds in the U.S.

No information was found regarding the total number of public playgrounds in the U.S. One survey reports that there are 13,486 public park playgrounds in the 75 largest cities in the U.S., with a median value of 2.3 playgrounds per 10,000 residents of those cities (The Trust for Public Land, 2016). CPSC staff presumes the actual count of public playgrounds would be several-fold higher, because large regions of the country are not captured in the Trust for Public Land survey. The survey does not capture public/private schools, child care facilities, restaurants, or residential housing developments. Additionally, CPSC staff did not find information about whether there are regional variations or preferences for any of the five playground surface types described above.

Literature Review/Gaps Analysis for Playgrounds

The interagency Literature Review/Gaps Analysis (LRGA) report is presented in Appendix B of this status report. Thorough searches of scientific literature databases for studies of recycled tire crumb rubber and its uses on athletic fields and playgrounds identified 95 references for consideration. Seven of these were not included in the final analysis because they were not directly related to the scope of the project. Of the remaining 88 relevant references, eight were identified by the LRGA team that specifically examined "playground" environments with recycled tire surfacing. Descriptions of these references and others identified by CPSC staff are provided below. Some references identified in the literature searches use the term "playground" to describe playing fields or athletic fields and do not refer to children's playgrounds as recognized by the CPSC. These studies (Bocca, et al., 2009; Kim, et al., 2012b; Menichini, et al., 2011) were included in the LRGA review for recycled tire crumb rubber on fields, but they were excluded from the CPSC's specific review of playgrounds.

Two reports described original laboratory studies of direct health effects of playground surfacing made of recycled tire rubber.

Birkholz, et al. (2003) tested a dimethyl sulfoxide (DMSO) extract of tire crumb rubber in a series of three *in vitro* screening assays for genetic toxicity. No signs of mutagenicity or other genetic toxicity, with or without metabolic activation, were reported. The researchers also performed a battery of aquatic toxicity assays using bacteria, invertebrates, fish and algae. The test materials were water leachates of both new tire crumb rubber and samples of tire crumb rubber collected from a playground 3 months after application on the playground (the playground surface type was not specified). All leachate samples were found to be toxic to all test species; but when potency was quantified, the aqueous leachate from 3-month-old tire crumb rubber collected at a playground was 59 percent less potent than leachate from unused tire crumb. The authors concluded: *"the use of tire crumb in playgrounds results in minimal hazard to children and the receiving environment."* Limitations of this study for evaluating the potential health effects of recycled tire material on playgrounds include: (1) the genetic toxicity assays reported only address one possible health effect pathway (mutagenicity and carcinogenicity); (2) DMSO extraction may not be representative of the bioavailability of tire crumb rubber constituents in a playground exposure scenario; (3) no information was available about the chemical composition or concentrations of the extract or aqueous leachate.

California's Office of Environmental Health Hazard Assessment (OEHHA, 2007) conducted a skin sensitization assay of three recycled rubber playground surfaces. The researchers used a modified Buehler method for solid materials according to testing guidelines (US EPA, 1998) and in accordance with Good Laboratory Practices at Product Safety Laboratories. Guinea pigs were the test animals. The three test materials included loose crumb rubber made from recycled tires, tiles molded from tire shreds mixed with a binder, and tiles molded from particles of the synthetic rubber EPDM mixed with a binder. Appropriate positive and negative controls were included in the study design for induction and challenge phases. None of the components of rubberized playground surfaces caused any skin sensitization, while the positive control substance (alpha-Hexylcinnamaldehyde) produced positive reactions in 40 percent to 50 percent of the animals. The researchers concluded that "*playground surfaces made of recycled tires do not constitute a skin sensitization risk to children*."

Five reports described laboratory analyses of extractable organic compounds and metals from recycled rubber playground surfacing, and two of these used exposure modeling to estimate risk of adverse health effects.

Llompart, et al. (2013) analyzed the chemical composition of recycled tire playground surfacing and pavers. Loose-fill rubber mulch made from recycled tires was collected from nine playgrounds. Pavers (rubber tiles) made from recycled tires were purchased new from a retail source. Heated (120 ˚C) ethyl acetate extractions were analyzed by gas chromatography–mass spectrometry (GC-MS). The researchers concluded that "*[t]he analysis confirmed the presence of a large number of hazardous substances including polyaromatic hydrocarbons (PAHs), phthalates, antioxidants, benzothiazole and derivatives, among other chemicals. The study evidences the high content of toxic chemicals in these recycled materials. The concentration of PAHs in the commercial pavers was extremely high, reaching values up to 1%.*" Limitations of this study for evaluating the potential health effects of recycled tire material on playgrounds include: (1) the ethyl acetate extraction is not representative of the bioavailability of the analytes in a realistic exposure scenario, and (2) the study was apparently conducted in Spain, so the recycled tires in the products analyzed may not be representative of recycled tires in the U.S..

Celeiro, et al. (2014) analyzed samples of recycled tire playground surface material (from an indoor playground) for the presence of PAHs and other organic compounds. Samples of a poured-in-place indoor playground surface with a green wear-course layer were cut into small pieces and extracted with ultrasound assistance in ethyl acetate. The lower black tire crumb rubber layer was analyzed separately from the green upper wear-course layer (possibly made of EPDM or TPV). The solvent extractions were analyzed by GC-MS to identify and quantify PAHs and other target compounds. The analyses found that the solvent extracts contained 14 PAHs and other compounds of concern including phthalates, adipates, antioxidants and benzothiazole. Total PAH concentrations were 170 µg/g and 295 µg/g in the green and black layers, respectively. Diethylhexyl phthalate (DEHP) was found at concentrations greater than 3000 µg/g in the green wear course layer. In the black recycled tire layer, concentrations of DEHP at more than 4,500 µg/g were found. An additional aqueous leaching study of the rubber playground surface found a concentration of 2223 ng/mL total PAHs (nine PAH substances) in the water leachate. The researchers concluded that "*[t]he presence and the high concentrations* *of these chemical compounds in playgrounds should be a matter of concern owing to their high toxicity*."

Highsmith, et al. (2009) conducted a scoping-level field monitoring study of synthetic turf and playgrounds in the U.S. Air samples were collected 1 m above a loose-fill rubber playground surface, and loose-fill rubber samples were collected at the same playground. The report described the playground surface as "tire crumb"; but based on the report's description of the rubber (*i.e.*, "pieces were larger than 1 g"), it appears that the surface was loose-fill rubber "mulch"-sized pieces, rather than the "crumb size" particles used as synthetic turf infill. Air and rubber samples were analyzed. Concentrations of PM_{10} particles and metals at the playground site with high play activity were higher than background levels. All PM_{10} air concentrations were well below the National Ambient Air Quality Standards (NAAQS) for PM_{10} (150 $\mu g/m^3$). All air concentrations for lead (Pb) were well below the NAAQS for Pb (150 ng/m^3). The researchers concluded: "*concentrations of components monitored in this study were below levels of concern; however, given the very limited nature of this study (i.e., limited number of components monitored, samples sites, and samples taken at each site) and the wide diversity of tire crumb material, it is not possible to reach any more comprehensive conclusions without the consideration of additional data."* This was a limited scoping-level study designed to evaluate the methods for generating quality environmental data for selected tire crumb rubber constituents and for understanding potential exposure routes and pathways. The study was not designed to provide representative U.S. environmental measurement data for all tire crumb rubber constituents or applications. The researchers intended to collect samples at more playgrounds, but they experienced difficulty gaining permission to collect samples.

OEHHA (2007) used a wipe sampling method to estimate the chemicals that might be transferred to a child's hand through contact with a unitary playground surface made of recycled waste tires. The protocol was modified from the US EPA (2003) protocol used to wipe-sample arsenic from CCA-treated wood using 9-inch-by 9-inch square polyester wipes. Field control wipes were performed on nearby sections of cement sidewalk. See OEHHA (2007) for sampling and analytical method details. One metal (zinc) and four PAHs (chrysene, fluoranthene, phenanthrene, and pyrene) were measured at levels that were at least three times background. No semi-volatile organic compounds (SVOCs) were detected in any wipe sample. The researchers used exposure factor values found in the literature to estimate the chronic hand-to-mouth contact exposure to selected chemicals playing at a playground with a unitary recycled tire surface by a 15-kg 3-year-old child. Assuming ingestion of the above five chemicals via chronic hand-to-mouth contact, exposures were below the corresponding chronic screening values, suggesting a low risk of adverse non-cancer health effects. Of the five substances, only chrysene was identified as a carcinogen by California. Assuming playground use from 1 through 12 years of age, an increased cancer risk of 2.9×10^{-6} was calculated, due to the chronic hand-to-mouth ingestion of chrysene. This risk is slightly lower than the *di minimis* risk level of 1×10^{-6}, generally considered an acceptable cancer risk because of its small magnitude compared to the overall cancer rate (OEHHA, 2007). Therefore, none of the chemical exposures from hand-to-mouth contact from recycled tire playground surfacing raised concerns about health effects in children. The authors acknowledge that many of the uncertainties in the assumptions used in their modeling could overestimate or underestimate actual health risk.

OEHHA (2007) also exposed shredded tire rubber to simulated gastric fluid to simulate the release of constituent chemicals that would occur in the stomach after a child swallowed a rubber nugget or buffing. Twenty-two chemicals, including metals and organic compounds, were released from tire shreds during a 21-hour incubation period at 37˚C. The researchers used an exposure model for a 15-kg child ingesting 10 g of tire rubber to estimate the bioavailable oral dose. All of the calculated exposure-dose levels were at or below the corresponding screening value, suggesting a low risk of adverse non-cancer health effects. Five of the leaching chemicals were currently listed by California as carcinogens by the oral route, but the experimental concentrations applied to the model were associated with a 3.7×10^{-8} increased risk of cancer, lower than the *di minimis* risk level of 1×10^{-6}. Therefore, a low risk adverse health effects was predicted from this model of a 15-kg child ingesting 10 g of tire rubber.

CPSC staff identified six literature reviews and other assessments of the health and ecological risks associated with the use of recycled tire rubber in consumer applications and that specifically address recycled rubber on playgrounds. These reviews and assessments do not report any original data or specific exposure modeling, and the references cited in these reports that would be of interest to the Federal Research Action Plan have been captured in the LRGA document in Appendix B of this status report. The conclusion of these reviews varies; some support the relative safety of tire crumb rubber playground surfaces (Simon, 2010; Cardno Chem Risk, 2013; LeDoux, 2007; Anderson, et al., 2006), while others expressed concerns about hazards to children's health (Sullivan, 2006; Environmental and Human Health, Inc., 2007). The authors of many of these reviews discuss the limitations of the available data and indicate that additional studies are needed to support the safety of recycled tire rubber in playground surfacing.

The LRGA report notes that data gaps were more pronounced for recycled tire crumb rubber on playgrounds and indoor fields than for outdoor synthetic turf fields. CPSC staff and the interagency LRGA team did not identify any epidemiological studies on any of the topics included in the Federal Research Action Plan.

Exposure Characterization for Recycled Tire Materials on Playgrounds

The Federal Research Action Plan includes an objective that the federal partners will "characterize exposures, or how people are exposed to these chemical compounds based on their activities on the fields." CPSC staff interprets this objective also to include activities on playgrounds.

No studies identified by CPSC staff or the LRGA team have measured children's exposure to chemicals from playing on recycled tire rubber playground surfaces. The OEHHA (2007) studies used exposure models to estimate children's oral exposure to selected substances in rubber playground surfaces from hand-to-mouth contact and direct ingestion of rubber pieces. These appear to be quality laboratory studies, and the modeling methods used may be useful for CPSC's work, but they are limited in scope because the studies assessed only oral exposures. Children on playgrounds can be exposed to playground surfacing materials by oral, dermal, and inhalation routes. Oral exposure can occur by directly mouthing the surface materials, ingestion/swallowing of loose materials, hand-to-mouth contact, object-to-mouth contact, and by eating food or drinking beverages while on the playground surface. Direct dermal contact with surface materials can lead to transdermal absorption of certain substances while children touch or carry surfacing with their hands, walk barefoot, or wear short pants or sleeves that allow a larger surface area of exposed skin. Some activities, such as burying in or throwing loose-fill materials can add to dermal exposure. Volatile compounds released from rubber and fine particles suspended in the air by disturbing the surface can be inhaled.

Performing experimental studies of children's exposure to chemicals would be complicated by ethical and practical challenges. No epidemiological or bio-monitoring studies of children on rubber playground surfaces are available. The next best method to estimate exposure, without doing direct measurements in children, is to use mathematical models. Modeling allows researchers to estimate chemical exposure by using quantitative exposure factors and activity patterns in combination with experimentally measured chemical concentration and bioavailability data. For example, OEHHA (2007) used a simple hand-to-mouth exposure model to estimate oral mass exposure rate (using zinc as an example):

Hand-loaded zinc concentration (μg/cm^2) × hand surface area transferring zinc to mouth (cm^2/hand-to-mouth event) × total events (hand-to-mouth events/day) × hand-to-mouth transfer efficiency (dimensionless) = oral mass exposure rate (μg/day)

In this model, the hand-loaded zinc concentration was determined by analysis of wipe samples collected at a playground. The other variables are examples of exposure factors and represent behavioral (hand-to-mouth events/day), anatomical (hand surface area), and physico-chemical (hand-to-mouth transfer efficiency) factors found in the literature to develop its exposure estimates (OEHHA, 2007). Dividing the daily oral mass exposure rate by the child's body weight (in kg) will provide a daily oral dose of the chemical in units of μg/kg-day. An oral dose value can then be compared to a toxicological reference value, such as a reference dose (RfD) or cancer slope factor (CSF), to predict the risk of specific health effects.

Exposure models can be simple or complex, depending on the variables the modelers have available and/or the specific questions being addressed by the model. Modeling can also demonstrate the impact of changes to a single variable on the output figure. Some exposure factor data can be found in the scientific literature, but the scenarios of children playing on each of the types of playground surfacing are too specific to be represented accurately by generic playground activity data. At a minimum, CPSC staff will need certain data describing children's behaviors and activities on playground surfaces, frequency and duration of playground visits, how children are dressed on playgrounds, and more. Certain anatomic and physiological factors, such as skin surface area of hands, body weights at various ages, and respiratory rates during active play can be acquired from the literature.

To estimate the exposure of children to recycled tire rubber constituents on playgrounds, the CPSC will require the chemical characterization and bioavailability results that are currently being collected by the EPA and ATSDR under the Federal Research Action Plan. No exposure modeling for playgrounds can be completed until these data are available. Meanwhile, the CPSC is gathering data that will inform the behavioral exposure factors and activity patterns.

National Survey of Parents and Supporting Data Collection Activities

The Federal Research Action Plan notes that the "CPSC is exploring conducting a survey of parents to get first-hand perspectives on potential exposures from playground surface materials." A survey of parents could provide valuable information on the behavioral exposure factors that will be specific to the playground surface types of interest. However, to ensure that the survey conducted with parents asks the correct questions and asks the questions in an efficient manner that is not too burdensome on those being surveyed, CPSC initiated preliminary data collection activities that will inform development of the survey. These activities included field observations of children at a limited number of public playgrounds and focus groups of people who visit and work at playgrounds. The subsections below describe the CPSC's data collection activities.

Playground Field Observations

CPSC staff conducted limited scoping playground field observations of children playing on playgrounds with different types of surfacing. The purpose of the scoping observations was to gain first-hand observations of how toddlers and young children interact with unitary and loose-fill playground surfacing. The behaviors observed will be considered while developing the national survey to be distributed to parents and child caretakers. This observational activity is very limited in scope and is not intended to produce statistically representative data on any population.

CPSC staff gained permission from local public parks officials in a limited region of Maryland to conduct the observations. The agreement with the playground owners included anonymity of the playground sites in reporting.

The playgrounds to which CPSC staff was granted permission to make observations included playgrounds with PIP, bonded rubber, loose-fill rubber, and engineered wood fiber (EWF) surfaces. Although EWF is not made from recycled tires, it was included for reference as a non-tire surface and as a surrogate for loose-fill rubber because permission was granted for only one loose-fill rubber playground. The playground owners who agreed to the field observations do not have playgrounds with rubber tile or synthetic turf surfaces. Therefore, these surface types are not represented in this data collection activity. However, the PIP and bonded rubber can serve as surrogates for all of the unitary surface types.

The behaviors of interest were:

- hand contact with surface material;
- picking up or throwing surface material;
- playing with surface material for more than 30 seconds;
- playing with a toy on the playground surface for more than 30 seconds;
- barefoot contact with surface;
- face or mouth contact with surface material
- contact of other exposed body parts with surface material;
- falling onto surface;
- crawling on surface for more than 30 seconds;
- eating food or drinking a beverage while on playground surface.

Playing with toys or other objects and eating food or drinking a beverage while on the playground surface is considered secondary contact, while the remaining behaviors listed above describe primary contacts with the surfacing materials.

Other information recorded for each 20-minute observation session included the number of children on the playground who appear to be? 6 months to 5 years old; the playground surfacing type; the names of the observers (two or three observers per session); date, starting time, ambient temperature in ˚F; and whether the playground surface was wet or dry.

Observations were made passively with two or three CPSC staff members sitting at a bench or picnic table near the playground and with a clear view of most of the playground area. One or two observers reported when the behaviors of interest were observed; and one recorded making a mark next to that behavior on the data collection form. Notations were made each time a child arrived or exited the playground during the 20-minute observation period. No photos or videos or any identifying information about the children was collected. Observers did not interact with the children or anyone else at the playgrounds. Knowing that parents and child care providers are sensitive to strangers at a playground, observers were prepared to explain what they were doing, if approached and asked; no one approached the observers with questions. Children who were estimated to be between 6 months and 5 years old were included in the study. Children's ages were estimated by appearances for inclusion, based on observers' experience; however, information on individual children was not recorded. No contact was made with anyone to verify age estimations.

Observations were made at one playground per surface type (PIP, bonded rubber, loose-fill rubber, and EWF); and 20-minute observation sessions were conducted at each playground four times. Observation sessions occurred over approximately 2 weeks in October 2016, and the sessions included different times of the day between 10:00 a.m. and 5:00 p.m. to observe different children.

Each of the behaviors of interest listed above was observed at least once for unitary and once for loose-fill surfaces. A more thorough analysis of data collected during the scoping observations was not completed by the writing of this status report. The behaviors observed will be considered while developing the national survey planned for distribution to parents and child caretakers in different regions of the U.S. in 2017.

Focus Groups

A focus group is a collection of people assembled for a "carefully planned series of discussions designed to obtain perceptions on a defined area of interest in a permissive, nonthreatening environment" (Krueger & Casey, 2015). It is a method for gathering qualitative information on a topic, using a semi-structured discussion among a small group of participants. The discussion is guided by a moderator to keep the conversation on topic and to ensure specific questions are addressed by the group. This method is used to gather information about participants' experiences and thoughts on the topic of interest. The CPSC chose focus groups to collect information to develop the national survey of parents. CPSC contracted with an Arlington, VA-based contractor with experience in conducting behavioral research for government agencies to

execute the focus groups and subsequently, the national survey (Contract No. CPSC-D-16-0002; Solicitation No. CPSC-Q-16-0031).
CPSC staff worked with the contractor to develop the focus group plan and instructions for moderators. CPSC staff and the contractor have prepared the necessary paperwork for Office of Management and Budget (OMB) review package, as required under the Paperwork Reduction Act. The contractor has arranged for review of the survey plan by an institutional review board (IRB), to ensure that the proposed methods are appropriate and ethical. The IRB service selected is experienced in performing reviews for healthcare and government research efforts. No recruitment of survey participants will begin until IRB and OMB are obtained.

The focus groups will include three sets of participants: 1) parents of children between 1 and 3 years of age; 2) childcare providers of children between 1 and 3 years of age, and 3) playground inspectors. Participants of the first two groups (10 parents and 10 childcare providers) will have or care for at least one child who is over one year of age and under three years of age and who supervises this child or children in playgrounds at least three times a week. The contractor will attempt to recruit an accurate representation of the U.S. population and to include a range of demographic and socioeconomic groups. The participants of the third group will be 10 parks professionals who hold a current Certified Playground Safety Inspector (CPSI) certification and who inspect and maintain playgrounds regularly at least once per month. The park personnel will be employed at a diverse range of playgrounds in terms of playground size, materials, and equipment, and who also work in a diverse range of neighborhoods (*i.e.*, urban vs. rural, socioeconomic attributes of the area).

To recruit parents and childcare givers, the contractor will send an e-mail to an existing pool of participants asking for parents and childcare providers of toddlers in the Washington, D.C., metropolitan area for participation in a focus group. If the e-mails to parents do not yield enough responses, the contractor will then reach out to local parent groups online and through message boards in common areas where these parents are likely to frequent. Similarly, if the e-mails to childcare providers do not yield enough responses, the contractor will reach out to local childcare provider groups or businesses, either online, or through message boards in common areas where these childcare providers are likely to frequent. To recruit parks and recreation employees, the contractor will initially send invitations to the focus group to the e-mail addresses of CPSI certified individuals located within a 25-mile radius of the contractor's offices in Arlington, VA. Potential participants will be identified by a public CPSI registry maintained by the National Recreation and Park Association.

Focus groups will take place at the contractor's offices in Arlington, VA. Because participants often have competing demands for their time, incentives are used to encourage participation in research. Participants will receive nominal compensation for participating. This compensation value will be determined per IRB and OMB recommendations, after these organizations' review of the research plan.

After participants have been identified, but before they report to the contractor's office for scheduled focus groups, the participants will be asked to take a picture of the playground surface(s) at the playground(s) they visit most regularly, and e-mail it to the contractor. The

photographs will not be a prerequisite for participation, but they will help with identifying the playground surface types (*e.g*., loose-fill rubber, PIP, bonded rubber).
The three focus groups (parents, caregivers, parks employees) will be conducted separately. When participants report to the contractor's offices for the focus group, the moderator will introduce him/herself and have brief introductions among the participants. The moderator will then lead an informal, but structured, discussion within each group, to address a list of questions regarding playground visitation habits, children's activities and behaviors observed on playgrounds, clothing worn by children on playgrounds, snacks and refreshments consumed at playgrounds, hand-washing habits, and more. Visual aids will be provided to clarify understanding of the different types of playground surfaces. Each focus group is expected to take up to 120 minutes, including opportunities for breaks and refreshments.

The focus group discussions will be video and audio recorded and observed by a one-way glass window by contractor personnel and CPSC staff for data-collection purposes. A data coding scheme will be developed by the contractor and CPSC staff to emphasize organization of qualitative data. The contractor will assign a data manager to maintain quality control of the data collected. The contractor will provide to CPSC a written summary of the data collected in each focus group. Participant confidentiality will be protected by the contractor, and no personally identifiable information will be permanently recorded or reported to the CPSC.

National Survey

CPSC staff will work with the contractor to develop a national survey that will be distributed to parents and child caregivers in various regions of the U.S. The survey questions will be developed based on information collected in the focus groups, playground field observations, and other research studies. The contractor will ensure that the survey promotes comprehension and thoughtful responding, and meanwhile, reduce survey fatigue and its consequences (*e.g*., non-response, invariant responding).

The contractor will develop and propose sampling and data collection plan options necessary to obtain a nationally representative sample of households with children of ages 0–5. The contractors will outline tradeoffs between the different approaches and will address key sources of survey error, including coverage, nonresponse, sampling, and/or measurement error. CPSC staff will review the options for recruiting strategies and inform the contractor of the choice selected.

The contractor will arrange for review of the survey plan by an IRB to ensure that the proposed methods are ethical. The IRB service selected is experienced in performing reviews for healthcare and government research efforts. CPSC staff and the contractor will prepare the necessary paperwork for internal CPSC clearance and OMB review package, as required under the Paperwork Reduction Act.
The contractor will begin recruitment of survey participants following the finalization of the questionnaire and after receiving OMB and IRB approval to administer the survey. Participants will be recruited by re-contacting and interviewing respondents of the Social Sciences Research Solutions (SSRS) Omnibus, which is a national, weekly, dual-frame bilingual RDD (random digit dialing) telephone survey designed to meet standards of quality associated with custom research studies. The contractor will use this sample source to pre-screen individuals in the target

population (*i.e.*, individuals with children ages 0-5). The targeted households will be re-contacted to administer the full survey.

The time of delivery of survey results will depend on the preceding steps required before recruitment of participants can begin. CPSC staff intends to submit the OMB package for approval in early calendar year 2017. Because this survey will require a full OMB review and the publication of *Federal Register* notices, it could take 12 months or more to obtain approval. Data collection will be completed within 12 weeks of receipt of OMB approval. A draft report will be submitted by the contractor to CPSC for review and approval within four (4) weeks of conclusion of data collection.

Findings of the national survey will be used to clarify and improve the CPSC's understanding of how children less than 5 years of age interact with various types of playground surfacing. Qualitative and quantitative data obtained in the survey will be used to inform development of exposure scenarios and exposure factors that can be used to estimate children's exposure to substances of concern in playground surfaces made with recycles tires.

Subsequent Research Considerations

The CPSC's strategy for understanding the chemical composition of rubber products derived from recycled tires is to review the results of the tire crumb rubber characterization and exposure characterization studies conducted by the US EPA and ATSDR conducted under the Federal Research Action Plan when those data are available. These new data will be considered with published scientific literature on tire rubber composition, bioavailability, and exposure. The CPSC will use exposure modeling to determine whether any of the bioavailable substances may pose a health hazard to children using playgrounds. Oral, dermal, and inhalation routes of exposure will be considered individually and in combination. Specific risk assessment strategies will be determined based on review of the new data and will likely focus on substances of highest concern.

CPSC staff might find that the data for tire crumb rubber and its use on synthetic turf fields cannot be used to estimate adequately exposure for children on playgrounds. In this case, the CPSC staff will explore initiating collection of samples at playgrounds with recycled tire surfaces for chemical analysis and bioavailability characterization. This type of data collection endeavor will be contingent on overcoming several challenges, including (1) acquiring funding (CPSC has requested FY 2017 funding for this and related work); (2) identification of playgrounds across the country with each of the different types of recycled tire rubber surfacing; and (3) gaining permission from playground owners to collect samples. A previous attempt by the EPA to collect samples of rubber playground surfacing was hindered by denial of permissions for access to collect samples (Highsmith, et al., 2009).

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