Synthetic Turf – A Review of the Current Science

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Pinelands Commission

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Agenda

Exposure Risk to Harmful Chemicals

Contribution to Stormwater Runoff and Flooding

Urban Heat Island Effect

Heat Injury Risk

Athletic Injury Risk

Microplastics

Disposal

Introduction

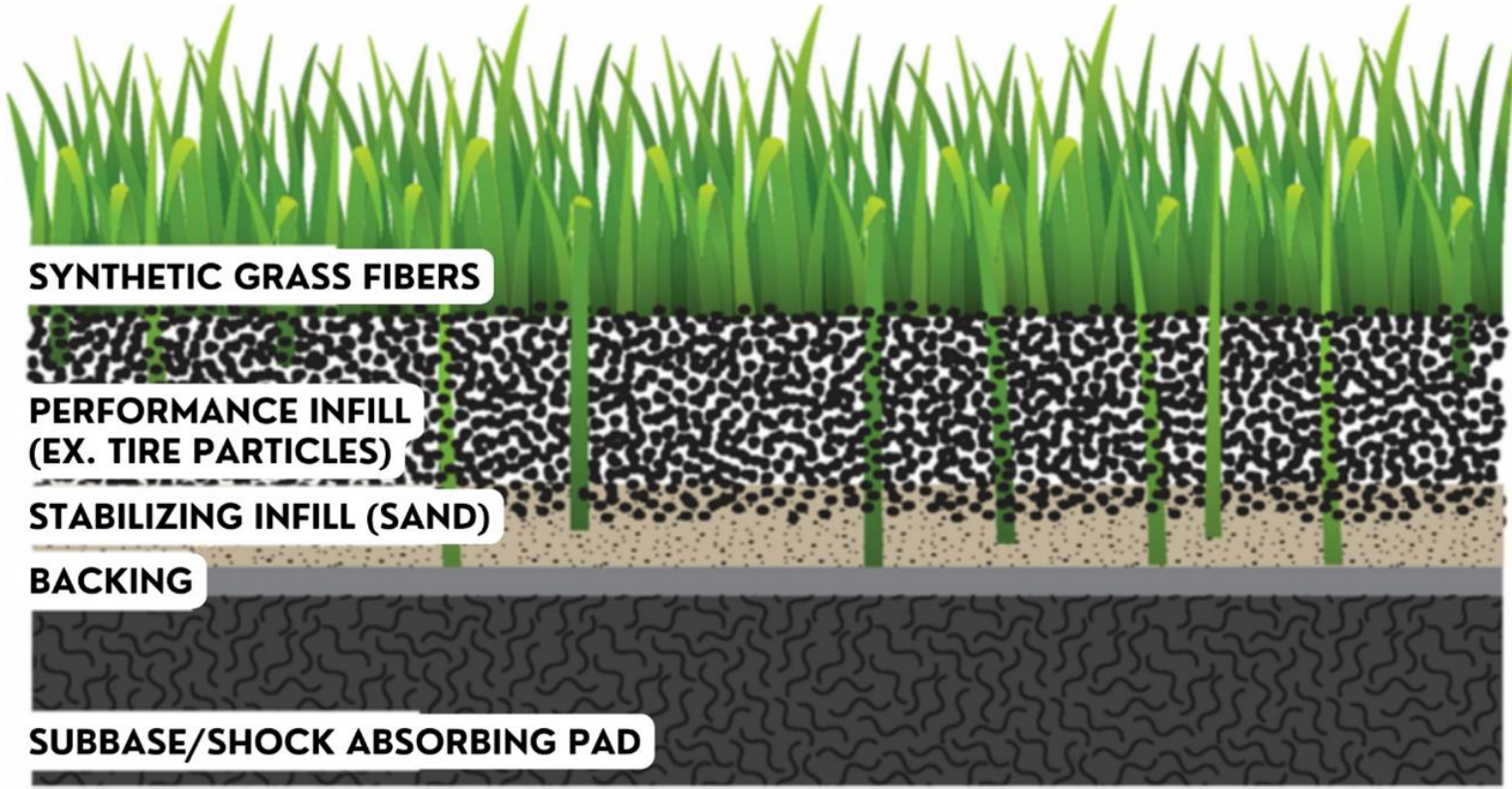
As of 2020, nearly 13,000 synthetic turf fields have been installed, translating into 265 million ft² and 777 million pounds of infill

Generational Progress

First (~1966) -> Second (~1976) -> Third (~1997) -> Fourth (?) -> Fifth (?)

Fibers – polyethylene, nylon, polypropylene

Infill – end of life tires [styrene-butadiene rubber (SBR)], ethylene-propylene diene monomer (EPDM), thermoplastic elastomers, cork, walnut shells, sand, coconut fibers



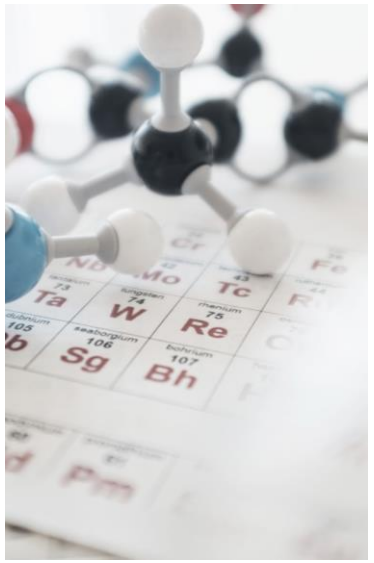
Exposure Risk to Harmful Chemicals

- **Federal Research Action Plan (FRAP) Part 1**

Characterization of Recycled Tire Crumb Rubber (RTCR)*

- Recycled tire crumb rubber (RTCR), the most common type of synthetic turf infill, was found to contain:
  - 20 of 21 metals tested, none of which exceed DEP Non-Residential Ingestion-Dermal Soil standards
  - 37 of 39 SVOCs tested, none of which exceed DEP Non-Residential Ingestion-Dermal Soil standards
  - 24 of 31 VOCs tested at 60° C (140° F), none of which exceed DEP Non-Residential Inhalation Soil standards
  - Bacteria, including *Staphylococcus* and MRSA
- PFAS detected **at levels below** DEP Interim Non-Residential Ingestion Dermal Soil standards in RTCR and turf blades
- Metals and PAHs that **do not exceed** DEP Non-Residential Ingestion-Dermal Soil standards

***Did not consider other infill material, turf blades, or other components of the turf system.**



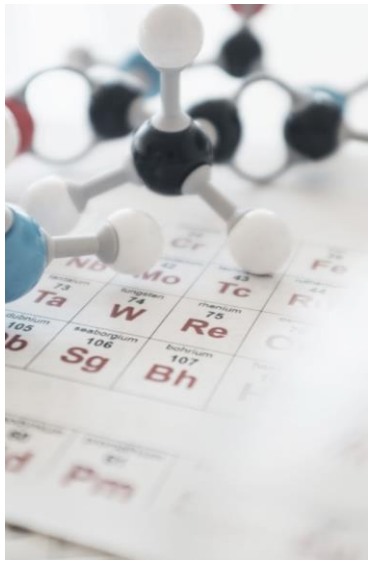
Exposure Risk to Harmful Chemicals

- Federal Research Action Plan (FRAP) Part 2

Tire Crumb Exposure Characterization*

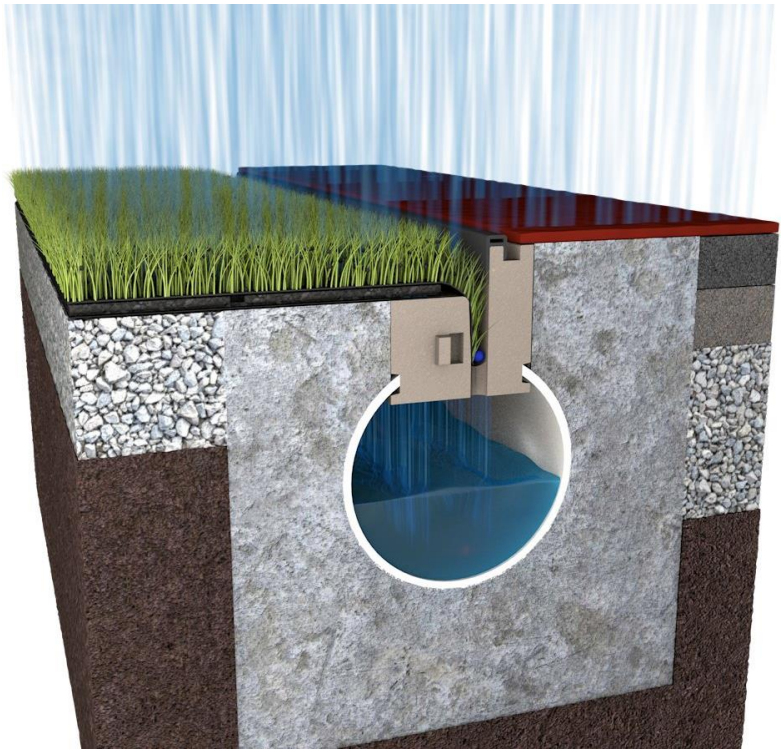
- Measurements of metals in air were similar to background (off-field) levels. Measurements from field dust and field wipe samples were higher, though the difference may be attributed to external sources (cars, industry, construction)
- 15/32 SVOCs & 19/29 VOCs air measurements showed median concentrations higher than background levels, all of which were **below** NJDEP Non-Residential Inhalation Soil Standards
- With one exception (2-hydroxynapthalene), contaminant levels found in bodily fluids did not increase as a result of time spent on a synthetic turf field
- Biologic uptake is very low

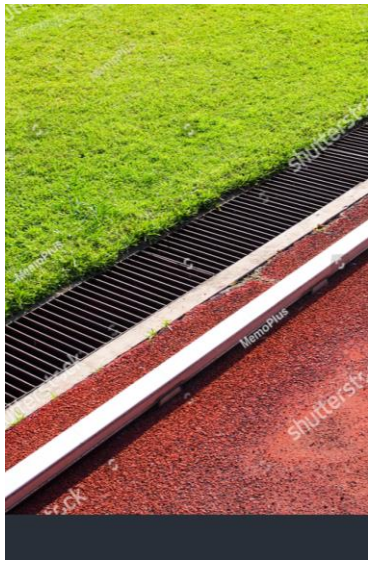
***Did not consider other infill material, turf blades, or other components of the turf system.**



Contribution to Stormwater Runoff and Flooding

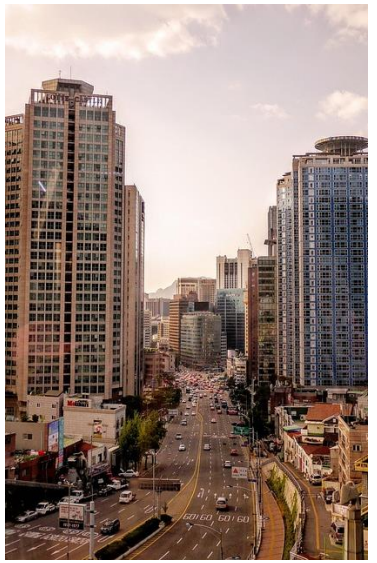
- Synthetic turf fields should be designed to comply with the NJDEP Stormwater Rules
- Proper maintenance of the field's drainage system is critical for ensuring continued good stormwater management
- Synthetic turf fields near or within the 100-year flood zone or in areas adjacent to open ocean are vulnerable to high velocity wave action and storm surge





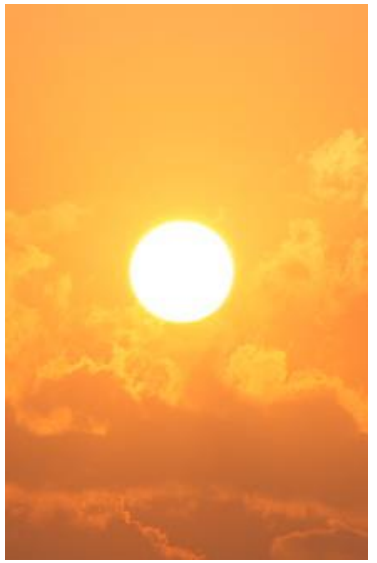
Urban Heat Island Effect

- Studies have consistently found that surface temperatures are higher on synthetic turf than natural turf, some by as much as 59 degrees Fahrenheit.
- Synthetic turf fields are hotter than natural turf fields during the day, but they are cooler than natural turf fields at night.
- Overall, studies demonstrating the impact of synthetic turf on the UHI Effect are inconclusive, but most appear to indicate that the marginal impact is minimal.



Heat Injury Risk

- Children are more susceptible to heat illness
- Studies on the association between playing on synthetic turf fields and heat illness, however, are inconclusive, likely due to the number of variables involved in these studies

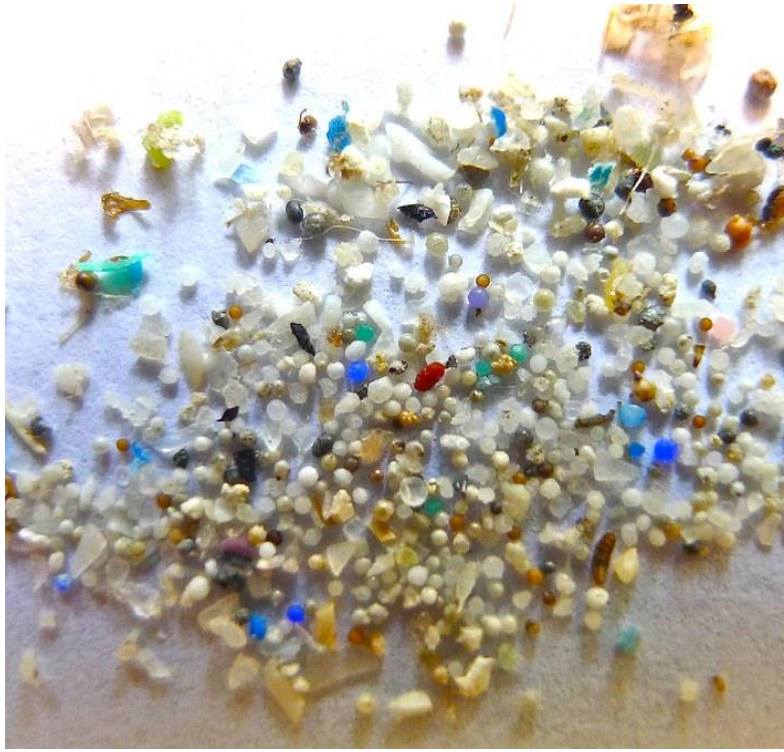


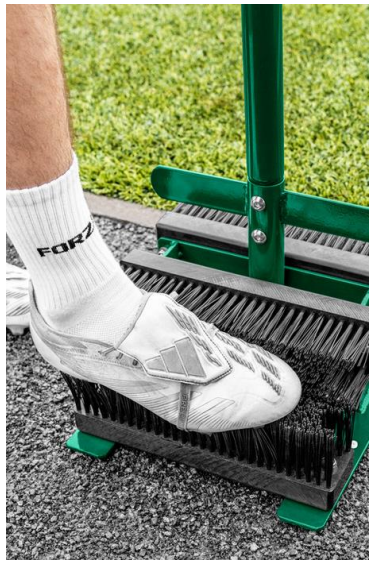
Athletic Injury Risk

- A large majority of the studies on athlete injuries on synthetic turf have examined injuries to adults, primarily professional and collegiate athletes.
- The results of the very few studies on youth and high school athletes have indicated higher injury rates on synthetic turf fields, including overall injury totals and lower extremity injuries.
- Extrapolating the findings from these studies to youth sports is not appropriate, as the field conditions, forces generated, and the level of play is not comparable.

Microplastics

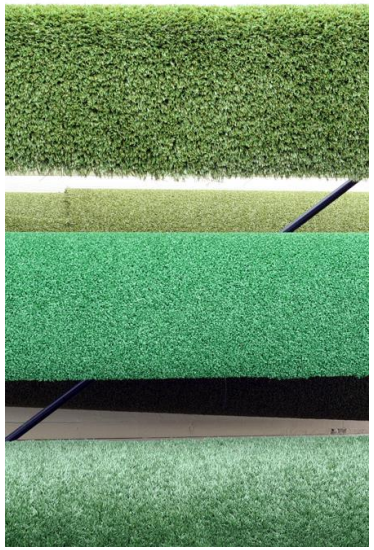
- The plastic components of synthetic turf fields are broken down into small particles known as microplastics.
- RTCR particles when first installed already meet the size definition of microplastics; degradation of RTCR can produce nanoplastics.
- Infill and turf fiber microplastics are dispersed into the environment via different pathways, including wind dispersal; off-site tracking on shoes, clothes, and equipment; stormwater; and maintenance activities.





Disposal

- Synthetic turf field surfacing has a limited useful life, approximately 10-12 years with proper maintenance, after which it must be removed and replaced.
- Emerging technologies may allow for recycling of some synthetic turf components, but issues with quality of the recycled material, high costs, and a lack of recycling facilities have prevented widespread adoption to date.
- Life cycle assessments comparing the environmental impact of synthetic versus natural turf have been inconclusive, in part because not all factors have been evaluated.



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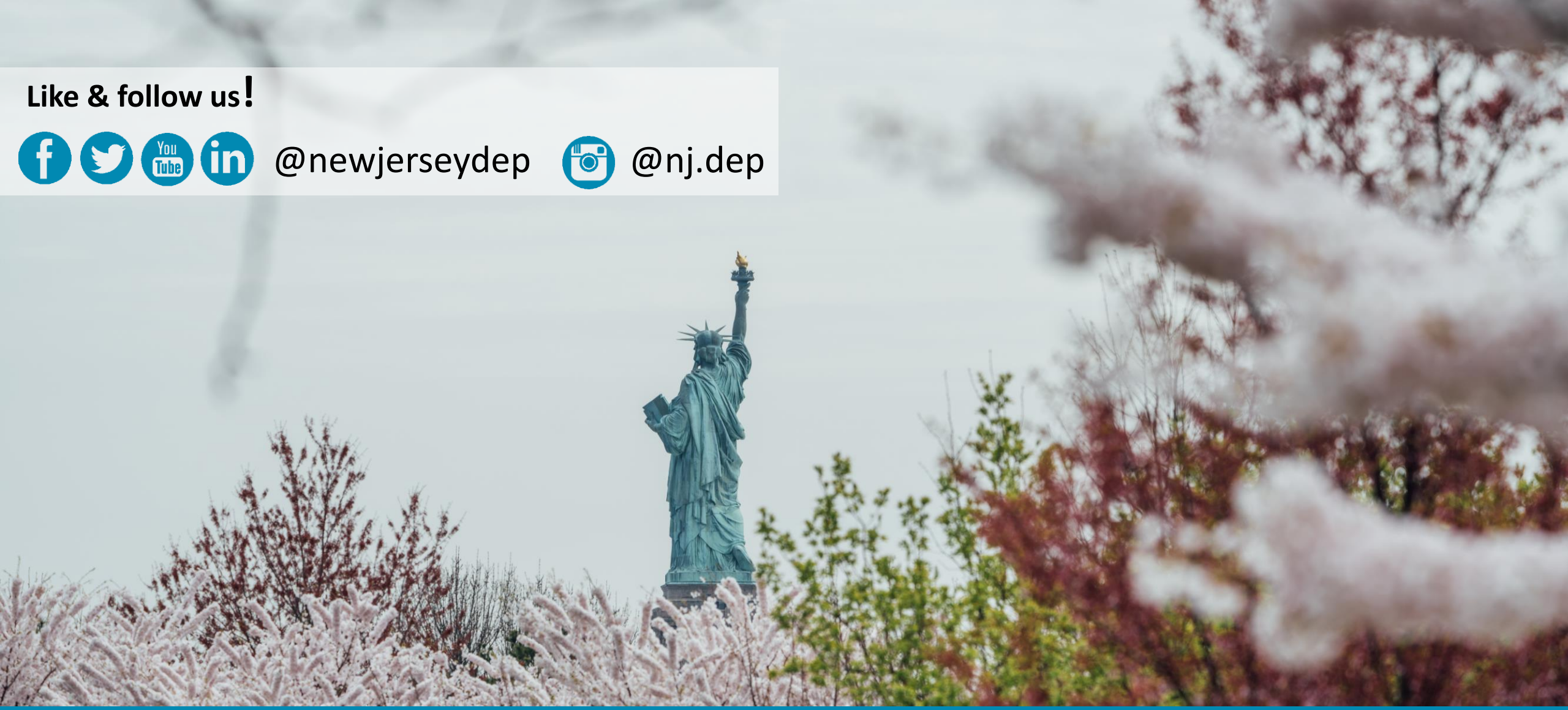

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Back up slides

Ryan-Ndegwa et al. 2024

FRAP Studies

NJDEP DSR Memos

Back up slides – Part 1 V2

Table I-2. Summary Statistics for Metals Analyzed by ICP/MS in Tire Crumb Rubber Infill Samples Collected from Synthetic Turf Fields[a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Arsenic	40	100	0.38	0.20	52	0.19	0.26	0.34	0.45	0.6	1.1
Cadmium	40	100	0.95	0.68	72	0.49	0.57	0.70	1.1	1.7	4.2
Chromium	40	100	1.6	0.84	51	0.97	1.2	1.6	1.9	2.7	3.7
Cobalt	40	100	140	60	44	68	85	120	180	220	290
Lead	40	100	24	26	110	9.3	11	14	25	55	160
Zinc	40	100	15000	3000	20	11000	13000	14000	16000	19000	22000
Aluminum	40	100	1300	740	58	540	670	1100	1600	2500	3400
Antimony	40	100	0.95	0.43	45	0.48	0.66	0.91	1.1	1.6	2.2
Barium	40	100	8.3	5.3	63	3.6	4.8	7.3	10	12	29
Beryllium	40	85	0.008	0.03	380	<LOD	0.0059	0.0098	0.018	0.03	0.068
Copper	40	100	26	12	47	13	16	23	35	42	55
Iron	40	100	610	400	66	280	350	510	620	1200	1800
Magnesium	40	100	330	230	71	210	230	260	330	400	1400
Manganese	40	100	7.7	5.2	67	4.2	4.9	6.2	8.1	12	31
Molybdenum	40	100	0.16	0.064	41	0.076	0.13	0.15	0.18	0.24	0.35
Nickel	40	100	2.7	0.89	33	1.6	2.0	2.7	3.3	3.8	4.6
Rubidium	40	100	1.9	0.58	31	1.3	1.4	1.8	2.1	2.5	3.9
Selenium	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Strontium	40	100	3.4	1.4	42	2.1	2.5	2.9	4.1	5.1	8.3
Tin	40	100	1.6	1.1	70	0.45	0.75	1.5	2.3	3.0	4.3
Vanadium	40	100	1.9	0.87	47	1.2	1.4	1.7	2.3	3.0	4.8

[a] ICP/MS= inductively coupled plasma/mass spectrometry; LOD= limit of detection; Max = maximum

*Values reported only when % >LOD is ≥ 60%

Back up slides – Part 1 V2

Table I-6. Summary Statistics for SVOCs Analyzed by GC/MS/MS in Solvent Extracts for Tire Crumb Rubber Infill Collected from Synthetic Turf Fields[a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Phenanthrene	40	100	2.3	2.6	110	0.26	0.44	1.1	3.3	6.1	10
Fluoranthene	40	100	4.5	2.6	57	2.0	2.4	3.9	6.5	8.1	10
Pyrene	40	100	12	6.2	49	4.2	7.0	13	17	21	25
Benzo[a]pyrene	40	100	0.78	0.52	66	0.38	0.43	0.62	0.91	1.4	3.0
Benzo[ghi]perylene	40	100	1.3	0.64	49	0.47	0.64	1.4	1.8	2.0	2.8
Sum15PAH[b]	40	100	29	15	51	13	17	27	38	49	68
Benzothiazole	40	100	11	13	120	1.1	1.8	7.0	14	31	54
Dibutyl phthalate	40	100	1.5	1.5	100	0.054	0.26	0.97	2.3	3.5	6.6
Bis(2-ethylhexyl) phthalate	40	100	43	42	100	4.9	7.8	28	58	100	170
Aniline	40	100	0.67	0.53	79	0.16	0.27	0.57	0.96	1.2	2.4
4-tert-octylphenol	40	100	9.8	9.7	99	0.90	2.5	5.6	16	27	33
n-Hexadecane	40	100	0.94	1.3	130	0.079	0.1	0.26	1.3	2.6	5.4
Naphthalene	40	100	0.034	0.041	120	0.0058	0.01	0.017	0.039	0.082	0.22
1-Methylnaphthalene	40	100	0.050	0.10	200	0.0024	0.0044	0.0081	0.052	0.13	0.52
2-Methylnaphthalene	40	100	0.083	0.17	200	0.0059	0.010	0.018	0.082	0.19	0.85
Acenaphthylene	40	100	0.046	0.057	120	0.0086	0.011	0.024	0.055	0.11	0.25
Fluorene	40	100	0.18	0.28	150	0.0055	0.012	0.051	0.26	0.47	1.3
Anthracene	40	100	0.52	0.75	140	0.038	0.087	0.17	0.54	1.5	3.1
1-Methylphenanthrene	40	100	1.6	1.3	82	0.33	0.54	1.3	2.1	3.4	5.2
2-Methylphenanthrene	40	100	3.0	4.6	150	0.43	0.58	1.5	3.1	6.3	23
3-Methylphenanthrene	40	100	2.3	2.1	91	0.48	0.69	1.6	3.7	4.8	9.2
Benz(a)anthracene	40	100	2.2	1.4	63	0.71	1.2	1.9	3.1	4.3	6
Chrysene	40	100	2.5	1.8	70	0.73	1.0	2	3.9	5.4	6.2
Benzo(b)fluoranthene	40	100	1.3	0.80	59	0.58	0.72	1.1	1.8	2.2	3.9
Benzo(k)fluoranthene	40	100	0.45	0.31	68	0.18	0.24	0.40	0.58	0.77	1.5
Benzo(e)pyrene	40	100	1.9	0.98	51	0.72	1.1	1.9	2.4	3.5	4.1

Back up slides – Part 1 V2

Table I-6 Continued

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
DBA + ICDP[c]	40	100	0.54	0.31	58	0.19	0.34	0.44	0.78	1.0	1.3
Coronene	40	100	0.54	0.31	58	0.19	0.28	0.49	0.74	1.0	1.4
Dibenzothiophene	40	100	0.31	0.35	110	0.026	0.049	0.16	0.50	0.78	1.4
2-Bromomethylnaphthalene	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
n-Butylbenzene	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Dimethyl phthalate	40	65	0.027	0.061	230	<LOD	<LOD	0.0065	0.019	0.08	0.32
Diethyl phthalate	34	68	0.52	2.4	460	<LOD	<LOD	0.0029	0.19	0.55	14
Diisobutyl phthalate	40	100	1.2	1.8	150	0.04	0.22	0.59	1.4	3.2	9.1
Benzyl butyl phthalate	40	100	1.2	2.0	170	0.049	0.16	0.7	1.4	2.2	12
Di-n-octyl phthalate	40	98	0.25	0.24	96	0.027	0.067	0.19	0.36	0.62	0.99
2,6-Di-tert-butyl-p-cresol	40	20	*	*	*	<LOD	<LOD	<LOD	<LOD	0.56	5.3
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	39	82	0.78	0.89	110	<LOD	0.20	0.37	1.1	2.5	3.0
Cyclohexylisothiocyanate	40	100	0.25	0.18	74	0.016	0.13	0.23	0.32	0.43	0.78

[a] SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry; LOD = limit of detection; Max = maximum

[b] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

*Values reported only when % >LOD is ≥ 60%.

Back up slides – Part 1 V2

Table I-10. Summary Statistics for VOC 60 °C Emission Factors for Tire Crumb Rubber Infill Samples Collected from Synthetic Turf Fields[a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Formaldehyde	40	75	16	9.5	58	<LOD	11	15	19	24	48
Metyl isobutyl ketone	37	100	42	26	61	15	22	34	61	87	96
Benzothiazole	37	95	56	39	70	8	14	68	93	100	110
1,3-Butadiene	37	11	*	*	*	<LOD	<LOD	<LOD	<LOD	0.12	0.81
Styrene	37	100	0.45	0.41	91	-0.016	0.092	0.40	0.73	0.96	1.3
Benzene	37	49	*	*	*	<LOD	<LOD	<LOD	0.21	0.55	0.73
Toluene	37	100	0.15	0.31	200	-0.15	-0.048	0.07	0.22	0.72	0.91
Ethylbenzene	37	100	-0.082	0.22	-270	-0.33	-0.27	-0.16	0.14	0.28	0.40
m/p-Xylene	37	100	0.24	1.0	410	-0.96	-0.58	0.16	0.73	1.7	2.5
o-Xylene	37	100	-0.35	0.66	-190	-0.99	-0.88	-0.44	-0.024	0.61	1.5
SumBTEX[b]	37	100	-0.085	2.2	-2600	-2.5	-2.3	-0.4	0.94	3.3	4.6
trans-2-Butene	37	89	-0.25	0.24	-95	<LOD	-0.42	-0.29	-0.12	-0.022	0.33
cis-2-Butene	37	89	-0.23	0.21	-92	<LOD	-0.38	-0.27	-0.1	0.014	0.25
4-Ethyltoluene	37	3	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.22
1,3,5-Trimethylbenzene	37	3	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.78
1,1-Dichloroethene	37	11	*	*	*	<LOD	<LOD	<LOD	<LOD	0.15	0.19
1,1-Dichloroethane	37	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
cis-1,2-Dichloroethene	37	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,2-Dichloroethane	37	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,1,1-Trichloroethane	37	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Carbon Tetrachloride	37	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,2-Dichloropropane	37	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Trichloroethylene	37	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Tetrachloroethylene	37	65	0.0035	0.032	900	<LOD	<LOD	-0.0031	0.011	0.040	0.13
Chlorobenzene	37	68	-0.0028	0.06	-2100	<LOD	<LOD	-0.0057	0.014	0.073	0.19
m-Dichlorobenzene	37	30	*	*	*	<LOD	<LOD	<LOD	0.042	0.14	0.32
p-Dichlorobenzene	37	76	0.079	0.23	290	<LOD	-0.10	0.073	0.22	0.34	0.83
o-Dichlorobenzene	37	38	*	*	*	<LOD	<LOD	<LOD	0.093	0.27	0.52
Trichlorofluoromethane (Freon 11)	37	86	0.079	0.64	810	<LOD	-0.52	0.030	0.66	0.89	1.1
Dichlorodifluoromethane (Freon 12)	37	100	-0.005	0.038	-760	-0.038	-0.018	-0.0077	0.0064	0.027	0.12
Trichlorotrifluoroethane (Freon 113)	37	35	*	*	*	<LOD	<LOD	<LOD	0.0092	0.018	0.12

[a] VOC = volatile organic compound; °C = degrees Celsius; LOD = limit of detection; Max = maximum

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

*Values reported only when % >LOD is ≥ 60%.

Back up slides – Part 1 V2

Table I-12. Summary Statistics for SVOC 60 °C Emission Factors for Tire Crumb Rubber Samples Collected from Tire Recycling Plants [a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Phenanthrene	26	100	0.83	0.34	41	0.4	0.63	0.76	1.0	1.3	1.6
Fluoranthene	26	100	0.16	0.054	33	0.11	0.12	0.15	0.20	0.25	0.27
Pyrene	26	100	0.34	0.072	22	0.23	0.28	0.34	0.40	0.44	0.45
Benzo[a]pyrene	26	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Benzo[ghi]perylene	26	4	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.013
Sum15PAH[b]	26	100	13	7.0	56	4.8	7.6	13	16	18	38
Benzothiazole	26	100	520	340	66	220	290	400	690	950	1500
Dibutyl phthalate	26	100	0.21	0.72	350	-0.49	0.014	0.085	0.34	0.95	3.0
Aniline	26	100	23	7.2	31	18	19	21	25	34	46
4-tert-octylphenol	26	100	20	8.8	43	14	15	18	23	35	47
Naphthalene	26	100	9.5	6.9	73	2.4	4.7	9.3	13	14	35
1-Methylnaphthalene	26	100	7.5	5.9	78	1.3	1.8	6.9	11	16	20
2-Methylnaphthalene	26	100	11	11	94	2.1	2.6	9.3	16	21	48
Acenaphthylene	26	100	0.93	0.34	37	0.59	0.64	0.96	1.1	1.3	2.0
Fluorene	26	100	0.33	0.14	44	0.17	0.23	0.28	0.42	0.53	0.67
Anthracene	26	100	0.12	0.063	55	0.044	0.06	0.10	0.17	0.21	0.26
1-Methylphenanthrene	26	100	0.12	0.052	42	0.074	0.092	0.11	0.15	0.19	0.29
2-Methylphenanthrene	26	92	0.18	0.1	57	0.11	0.11	0.15	0.19	0.31	0.58
3-Methylphenanthrene	26	100	0.28	0.17	61	0.16	0.17	0.24	0.29	0.40	0.96
Benz(a)anthracene	26	4	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.02
Chrysene	26	27	*	*	*	<LOD	<LOD	<LOD	0.0068	0.012	0.017
Benzo(b)fluoranthene	26	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Benzo(k)fluoranthene	26	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Benzo(e)pyrene	26	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
DBA + ICDP[c]	26	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

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Table I-12 Continued

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Coronene	26	4	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.010
Dibenzothiophene	26	100	0.11	0.043	38	0.073	0.090	0.095	0.13	0.17	0.25
2-Bromomethylnaphthalene	26	23	*	*	*	<LOD	<LOD	<LOD	<LOD	0.39	0.93
n-Butylbenzene	26	100	1.1	1.0	94	0.11	0.34	0.79	1.3	2.7	4.4
Dimethyl phthalate	26	85	0.037	0.058	160	<LOD	0.0078	0.02	0.032	0.15	0.24
Diisobutyl phthalate	26	100	0.15	0.4	270	-0.2	-0.034	0.11	0.28	0.33	1.8
Di-n-octyl phthalate	26	69	0.019	0.19	1000	<LOD	<LOD	-0.016	0.018	0.044	0.86
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	25	4	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.56

[a] SVOC = semivolatile organic compound; °C = degrees Celsius; LOD = limit of detection; Max = maximum

[b] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

*Values reported only when % >LOD is ≥ 60%.

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Table K-1. Comparison of Metal ICP/MS Analysis Results Between Tire Rubber Collected from Tire Recycling Plants and Tire Crumb Rubber Infill Composite Samples from Synthetic Turf Fields[a,b,c]

Analyte	Recycling Plants Mean (mg/kg)	Recycling Plants Standard Deviation (mg/kg)	Synthetic Turf Fields Mean (mg/kg)	Synthetic Turf Fields Standard Deviation (mg/kg)	t-test p-value[d]
Arsenic	0.30	0.088	0.38	0.20	0.2261
Cadmium	0.55	0.13	0.95	0.68	0.0002
Chromium	1.8	0.70	1.6	0.84	NR
Cobalt	190	87	140	60	0.0056
Lead	13	10	24	26	0.0060
Zinc	17000	3500	15000	3000	0.0063
Aluminum	1000	510	1300	740	0.1907
Antimony	1.2	0.41	0.95	0.43	0.0097
Barium	7.4	7.9	8.3	5.3	0.0923
Beryllium	0.015	0.0071	0.008	0.03	NR
Copper	42	22	26	12	0.0003
Iron	490	290	610	400	0.2118
Magnesium	290	78	330	230	0.7467
Manganese	5.7	2.1	7.7	5.2	0.0403
Molybdenum	0.22	0.09	0.16	0.064	0.0013
Nickel	3.2	1.0	2.7	0.89	0.0397
Rubidium	1.8	0.46	1.9	0.58	0.5729
Strontium	2.9	0.68	3.4	1.4	0.1584
Tin	1.8	0.64	1.6	1.1	NR
Vanadium	1.7	0.64	1.9	0.87	NR

[a] ICP/MS= inductive coupled plasma/mass spectrometry

[b] Recycling Plants (n=27); Synthetic Turf Fields (n=40)

[c] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[d] Statistical tests performed using ln-transformed measurement values

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Table K-3. Comparison of SVOC GC/MS/MS Analysis Results Between Tire Rubber Solvent Extracts for Samples Collected from Tire Recycling Plants and Synthetic Turf Fields[a,b]

Analyte	Recycling Plants – n	Recycling Plants Mean (mg/kg)	Recycling Plants Standard Deviation (mg/kg)	Synthetic Turf Fields – n	Synthetic Turf Fields Mean (mg/kg)	Synthetic Turf Fields Standard Deviation (mg/kg)	t-test p-value[c]
Phenanthrene	27	3.6	1.3	40	2.3	2.6	<0.0001
Fluoranthene	27	6.1	1.7	40	4.5	2.6	0.001
Pyrene	27	18	2.4	40	12	6.2	<0.0001
Benzo[a]pyrene	27	0.74	0.39	40	0.78	0.52	0.9556
Benzo[ghi]perylene	27	1.3	0.59	40	1.3	0.64	0.5983
Sum15PAH[d]	27	41	8.9	40	29	15	<0.0001
Benzothiazole	27	79	19	40	11	13	<0.0001
Dibutyl phthalate	27	0.68	0.44	40	1.5	1.5	0.6508
Bis(2-ethylhexyl) phthalate	27	12	14	40	43	42	<0.0001
Aniline	27	3.8	1.8	40	0.67	0.53	<0.0001
4-tert-octylphenol	27	30	6.2	40	9.8	9.7	<0.0001
n-Hexadecane	27	3.6	1.8	40	0.94	1.3	<0.0001
Naphthalene	27	1.4	0.75	40	0.034	0.041	<0.0001
1-Methylnaphthalene	27	1.6	1.3	40	0.05	0.10	<0.0001
2-Methylnaphthalene	27	1.8	1.3	40	0.083	0.17	<0.0001
Acenaphthylene	27	0.37	0.085	40	0.046	0.057	<0.0001
Fluorene	27	0.37	0.14	40	0.18	0.28	<0.0001
Anthracene	27	0.59	0.40	40	0.52	0.75	0.0041

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Table K-3 Continued

Analyte	Recycling Plants n	Recycling Plants Mean (mg/kg)	Recycling Plants Standard Deviation (mg/kg)	Synthetic Turf Fields n	Synthetic Turf Fields Mean (mg/kg)	Synthetic Turf Fields Standard Deviation (mg/kg)	t-test p-value[c]
1-Methylphenanthrene	27	1.4	0.53	40	1.6	1.3	0.4311
2-Methylphenanthrene	27	1.4	0.8	40	3.0	4.6	0.3292
3-Methylphenanthrene	27	2.1	1.1	40	2.3	2.1	0.3725
Benz(a)anthracene	27	1.1	0.57	40	2.2	1.4	0.0002
Chrysene	27	4.3	1.7	40	2.5	1.8	<0.0001
Benzo(b)fluoranthene	27	1.6	1.0	40	1.3	0.8	0.147
Benzo(k)fluoranthene	27	0.44	0.19	40	0.45	0.31	0.6553
Benzo(e)pyrene	27	1.7	1.1	40	1.9	0.98	0.2047
DBA + ICDP[e]	27	0.35	0.21	40	0.54	0.31	0.0076
Coronene	27	0.82	0.48	40	0.54	0.31	0.0014
Dibenzothiophene	27	0.42	0.13	40	0.31	0.35	0.0004
Dimethyl phthalate	27	0.040	0.022	40	0.027	0.061	NR
Diethyl phthalate	27	0.091	0.17	34	0.52	2.4	NR
Diisobutyl phthalate	27	0.50	0.39	40	1.2	1.8	0.568
Benzyl butyl phthalate	27	0.64	0.37	40	1.2	2.0	0.757
Di-n-octyl phthalate	27	0.32	0.19	40	0.25	0.24	NR
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	21	0.44	0.30	39	0.78	0.89	NR
Cyclohexylisothiocyanate	27	0.98	0.33	40	0.25	0.18	NR

[a] SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry

[b] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set.

[c] Statistical tests performed using ln-transformed measurement values.

[d] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[e] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

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Table K-5. Comparison of VOC 60 °C Emission Factor Results Between Tire Rubber Collected from Tire Recycling Plants and Tire Crumb Rubber Infill Composite Samples from Synthetic Turf Fields [a,b]

Analyte	Recycling Plants – n	Recycling Plants Mean (mg/kg)	Recycling Plants Standard Deviation (mg/kg)	Synthetic Turf Fields – n	Synthetic Turf Fields Mean (mg/kg)	Synthetic Turf Fields Standard Deviation (mg/kg)	t-test p-value[c]
Formaldehyde	27	40	16	40	16	9.5	NR
Metyl isobutyl ketone	27	140	15	37	42	26	<0.0001
Benzothiazole	27	220	8.3	37	56	39	<0.0001
Styrene	27	1.1	0.58	37	0.45	0.41	NR
Toluene	27	1.1	0.95	37	0.15	0.31	NR
Ethylbenzene	27	-0.0055	0.26	37	-0.082	0.22	NR
m/p-Xylene	27	1.2	0.71	37	0.24	1.0	NR
o-Xylene	27	-0.4	0.43	37	-0.35	0.66	NR
SumBTEX[d]	27	2.1	2.2	37	-0.085	2.2	NR
trans-2-Butene	27	-0.22	0.25	37	-0.25	0.24	NR
cis-2-Butene	27	-0.2	0.21	37	-0.23	0.21	NR
Tetrachloroethylene	27	0.14	0.23	37	0.0035	0.032	NR
p-Dichlorobenzene	27	0.019	0.12	37	0.079	0.23	NR
Trichlorofluoromethane (Freon 11)	27	0.23	0.58	37	0.079	0.64	NR
Dichlorodifluoromethane (Freon 12)	27	0.041	0.047	37	-0.0050	0.038	NR

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set.

[c] Statistical tests performed using ln-transformed measurement values.

[d] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

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Table K-7. Comparison of SVOC 60 °C Emission Factor Results Between Tire Rubber Collected from Tire Recycling Plants and Tire Crumb Rubber Infill Composite Samples from Synthetic Turf Fields[a,b]

Analyte	Recycling Plants – n	Recycling Plants Mean (mg/kg)	Recycling Plants Standard Deviation (mg/kg)	Synthetic Turf Fields – n	Synthetic Turf Fields Mean (mg/kg)	Synthetic Turf Fields Standard Deviation (mg/kg)	t-test p-value[c]
Phenanthrene	26	0.83	0.34	40	0.58	0.71	NR
Fluoranthene	26	0.16	0.054	40	0.16	0.11	NR
Pyrene	26	0.34	0.072	40	0.29	0.21	NR
Sum15PAH[d]	26	13	7.0	40	2.0	1.9	<0.0001
Benzothiazole	26	520	340	40	34	50	NR
Dibutyl phthalate	26	0.21	0.72	40	0.14	0.41	NR
Aniline	26	23	7.2	40	3.5	5.1	NR
4-tert-octylphenol	26	20	8.8	40	5.8	5.5	NR
Naphthalene	26	9.5	6.9	40	-0.14	0.56	NR
1-Methylnaphthalene	26	7.5	5.9	40	0.24	0.63	NR
2-Methylnaphthalene	26	11	11	40	0.46	1.3	NR
Acenaphthylene	26	0.93	0.34	40	0.10	0.18	NR
Fluorene	26	0.33	0.14	40	0.19	0.35	NR
1-Methylphenanthrene	26	0.12	0.052	40	0.14	0.13	NR
2-Methylphenanthrene	26	0.18	0.10	40	0.23	0.28	NR
3-Methylphenanthrene	26	0.28	0.17	40	0.37	0.44	NR
Dibenzothiophene	26	0.11	0.043	40	0.087	0.12	NR
n-Butylbenzene	26	1.1	1.0	40	-0.0037	0.027	NR
Dimethyl phthalate	26	0.037	0.058	40	0.016	0.027	NR
Diisobutyl phthalate	26	0.15	0.40	40	0.11	0.31	NR

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set.

[c] Statistical tests performed using ln-transformed measurement values.

[d] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

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Table O-1. Comparison of Metals Analyzed by ICP/MS in Tire Crumb Rubber Infill Collected at Outdoor and Indoor Synthetic Turf Fields[a,b]

Analyte	Outdoor Fields Mean (mg/kg)	Outdoor Fields Standard Deviation (mg/kg)	Indoor Fields Mean (mg/kg)	Indoor Fields Standard Deviation (mg/kg)	F-test p-value[c,d]
Arsenic	0.39	0.18	0.37	0.23	0.488
Cadmium	0.86	0.45	1.1	0.96	0.3997
Chromium	1.7	0.88	1.5	0.8	NR
Cobalt	140	60	140	63	0.8128
Lead	20	14	31	39	0.4709
Zinc	15000	3300	15000	2600	0.6996
Aluminum	1400	810	1100	590	0.3431
Antimony	0.91	0.43	1.0	0.42	0.2828
Barium	8.6	5.5	7.8	5.1	0.631
Beryllium	0.011	0.033	0.0035	0.025	NR
Copper	26	11	25	15	0.3715
Iron	710	460	430	170	0.0129
Magnesium	320	190	340	300	0.9777
Manganese	8.5	6.3	6.3	2.0	0.2704
Molybdenum	0.15	0.067	0.16	0.061	0.7457
Nickel	2.5	0.78	3.1	0.96	0.0754
Rubidium	2.0	0.62	1.6	0.42	0.0287
Strontium	3.4	1.6	3.4	1.2	0.7799
Tin	1.6	1.1	1.6	1.0	NR
Vanadium	2.0	1.0	1.7	0.43	NR

[a] ICP/MS = inductively coupled plasma/mass spectrometry

[b] Outdoor Fields (n=25); Indoor Fields (n=15)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

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Table O-3. Comparison of SVOCs in Extracts Analyzed by GC/MS/MS for Tire Crumb Rubber Infill Collected at Outdoor and Indoor Synthetic Turf Fields[a,b]

Analyte	Outdoor Fields Mean (mg/kg)	Outdoor Fields Standard Deviation (mg/kg)	Indoor Fields Mean (mg/kg)	Indoor Fields Standard Deviation (mg/kg)	F-test p-value[c,d]
Phenanthrene	0.76	0.71	4.8	2.6	<0.0001
Fluoranthene	3.5	2.3	6.2	2.2	0.0004
Pyrene	8.8	3.9	19	3.7	<0.0001
Benzo[a]pyrene	0.66	0.37	0.98	0.67	0.0375
Benzo[ghi]perylene	1.1	0.54	1.6	0.68	0.0315
Sum15PAH[e]	21	9.4	42	12	<0.0001
Benzothiazole	5.6	9.2	19	14	<0.0001
Dibutyl phthalate	0.63	0.70	2.9	1.4	<0.0001
Bis(2-ethylhexyl) phthalate	29	27	65	53	0.0185
Aniline	0.38	0.24	1.2	0.54	<0.0001
4-tert-octylphenol	3.5	2.2	20	7.9	<0.0001
n-Hexadecane	0.20	0.2	2.2	1.3	<0.0001
Naphthalene	0.014	0.0082	0.067	0.053	<0.0001
1-Methylnaphthalene	0.0085	0.011	0.12	0.14	<0.0001
2-Methylnaphthalene	0.016	0.016	0.20	0.24	<0.0001
Acenaphthylene	0.020	0.017	0.090	0.072	<0.0001
Fluorene	0.036	0.054	0.43	0.34	<0.0001
Anthracene	0.13	0.13	1.2	0.91	<0.0001
1-Methylphenanthrene	0.87	0.63	2.8	1.2	<0.0001
2-Methylphenanthrene	1.2	1.4	5.9	6.4	<0.0001
3-Methylphenanthrene	1.2	1.1	4.2	2.2	<0.0001
Benz(a)anthracene	2.2	1.3	2.3	1.6	0.8612

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Table O-3 Continued

Analyte	Outdoor Fields Mean (mg/kg)	Outdoor Fields Standard Deviation (mg/kg)	Indoor Fields Mean (mg/kg)	Indoor Fields Standard Deviation (mg/kg)	F-test p-value[c,d]
Chrysene	2.0	1.7	3.4	1.6	0.0033
Benzo(b)fluoranthene	1.2	0.74	1.6	0.82	0.0237
Benzo(k)fluoranthene	0.38	0.29	0.58	0.31	0.0113
Benzo(e)pyrene	1.6	0.92	2.4	0.91	0.0088
DBA + ICDP[f]	0.48	0.30	0.65	0.31	0.0564
Coronene	0.45	0.28	0.69	0.31	0.0085
Dibenzothiophene	0.096	0.092	0.66	0.33	<0.0001
Dimethyl phthalate	0.0043	0.0069	0.065	0.09	NR
Diethyl phthalate	-0.0055	0.010	1.5	4.0	NR
Diisobutyl phthalate	0.36	0.34	2.7	2.3	<0.0001
Benzyl butyl phthalate	0.44	0.40	2.4	2.8	<0.0001
Di-n-octyl phthalate	0.13	0.12	0.44	0.26	NR
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	0.96	1.0	0.49	0.62	NR
Cyclohexylisothiocyanate	0.16	0.10	0.40	0.19	NR

[a] SVOC = semivolatile organic compound; GC/MS/MS= gas chromatography/tandem mass spectrometry

[b] Outdoor Fields (n=25); Indoor Fields (n=15)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[f] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

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Table O-5. Comparison of VOC 60 °C Emission Factors for Tire Crumb Rubber Infill Collected at Outdoor and Indoor Synthetic Turf Fields[a,b]

Analyte	Outdoor Fields Mean (ng/g/h)	Outdoor Fields Standard Deviation (ng/g/h)	Indoor Fields Mean (ng/g/h)	Indoor Fields Standard Deviation (ng/g/h)	F-test p-value[c,d]
Formaldehyde	12	5.7	23	10	NR
Metyl isobutyl ketone	28	16	68	20	<0.0001
Benzothiazole	35	31	95	9.6	<0.0001
Styrene	0.24	0.29	0.84	0.29	NR
Toluene	0.11	0.33	0.24	0.24	NR
Ethylbenzene	-0.12	0.20	-0.0059	0.26	NR
m/p-Xylene	0.043	0.97	0.61	0.97	NR
o-Xylene	-0.39	0.70	-0.27	0.60	NR
SumBTEX[e]	-0.44	2.2	0.58	2.1	NR
trans-2-Butene	-0.25	0.28	-0.26	0.16	NR
cis-2-Butene	-0.23	0.25	-0.24	0.15	NR
Tetrachloroethylene	-0.0013	0.033	0.012	0.027	NR
Chlorobenzene	0.0036	0.038	-0.015	0.088	NR
p-Dichlorobenzene	0.028	0.17	0.17	0.29	NR
Trichlorofluoromethane (Freon 11)	-0.12	0.60	0.44	0.57	NR
Dichlorodifluoromethane (Freon 12)	-0.0029	0.033	-0.009	0.047	NR

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] Outdoor Fields (n=24–25); Indoor Fields (n=13–15)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

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Table O-7. Comparison of SVOC 60 °C Emission Factors for Tire Crumb Rubber Infill Collected at Outdoor and Indoor Synthetic Turf Fields[a,b]

Analyte	Outdoor Fields Mean (ng/g/h)	Outdoor Fields Standard Deviation (ng/g/h)	Indoor Fields Mean (ng/g/h)	Indoor Fields Standard Deviation (ng/g/h)	F-test p-value [c,d]
Phenanthrene	0.17	0.22	1.2	0.75	NR
Fluoranthene	0.11	0.085	0.23	0.11	NR
Pyrene	0.20	0.14	0.44	0.24	NR
Sum15PAH[e]	1.0	0.65	3.6	2.1	<0.0001
Benzothiazole	9.7	11	74	64	NR
Dibutyl phthalate	0.11	0.43	0.2	0.39	NR
Aniline	0.79	1.0	8.0	6.1	NR
4-tert-octylphenol	2.9	3.1	11	5.0	NR
Naphthalene	-0.23	0.50	0.022	0.63	NR
1-Methylnaphthalene	0.0092	0.053	0.62	0.92	NR
2-Methylnaphthalene	0.0081	0.084	1.2	1.9	NR
Acenaphthylene	0.026	0.034	0.23	0.25	NR
Fluorene	0.026	0.041	0.46	0.47	NR
1-Methylphenanthrene	0.074	0.063	0.26	0.13	NR
2-Methylphenanthrene	0.092	0.10	0.46	0.32	NR
3-Methylphenanthrene	0.17	0.19	0.71	0.52	NR
Dibenzothiophene	0.020	0.025	0.20	0.12	NR
n-Butylbenzene	-0.010	0.015	0.0075	0.038	NR
Dimethyl phthalate	0.0011	0.0097	0.040	0.030	NR
Diisobutyl phthalate	0.022	0.28	0.25	0.30	NR

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] Outdoor Fields (n=25); Indoor Fields (n=15)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Back up slides – Part 2 V2

Figure 3. Comparison of Urinary PAH Concentrations Across Biomonitoring Study Participants and NHANES 2007–2008 and 2016–2017 Participants Overall, by Adjustment Method

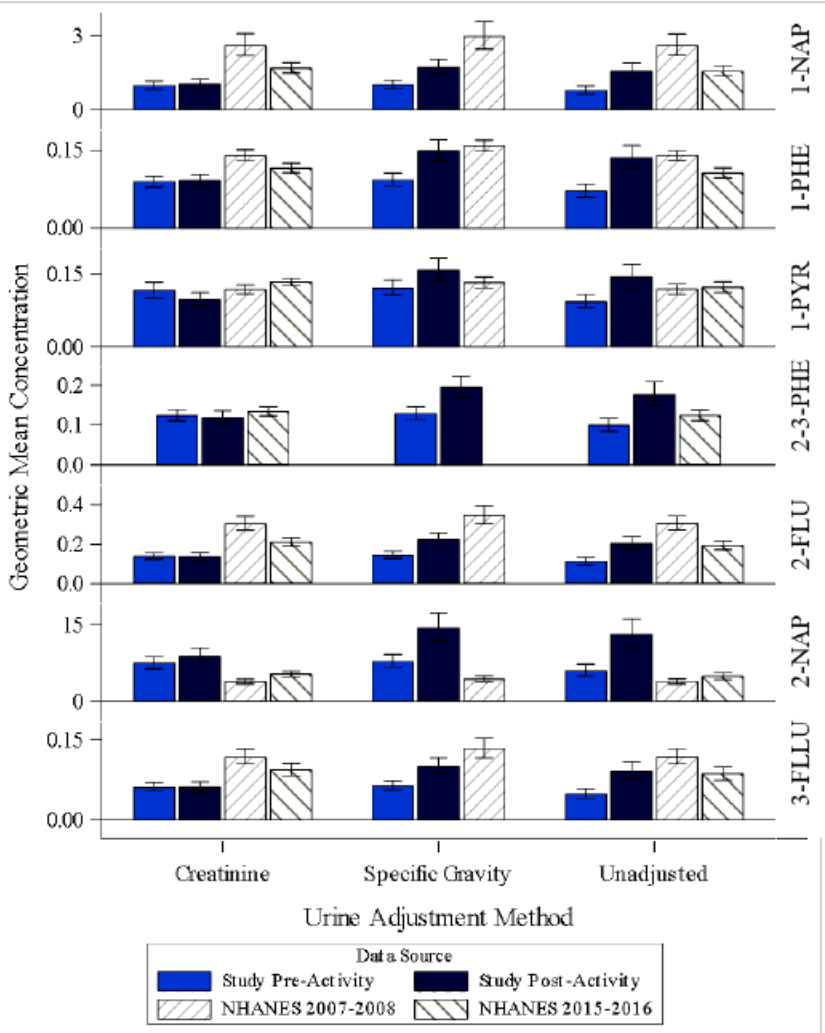

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Table 4-33. Exposure Pilot Study Field Air Sampling SVOC Measurements[a,b,c]

Semivolatile Organic Compound (SVOC)	> Minimum Quantifiable Limit (%)	Background Air Sample Median (ng/m³)	Field Air Sample Location 1 Median (ng/m³)	Field Air Sample Location 2 Median (ng/m³)	Field Air Sample Max (ng/m³)
Phenanthrene	100	2.0	4.5	5.7	35
Fluoranthene	100	0.37	0.90	1.3	9.9
Pyrene	17	0.15	0.54	0.89	15
Benzo[a]pyrene	0	0	0	0	0.030
Benzo[ghi]perylene	33	0.013	0	0	0.23
Sum15PAH[d]	N/A*	3.2	8.4	10	70
Benzothiazole	100	-3.9	6.5	15	214
Dibutyl phthalate	100	12	7.4	19	102
Bis(2-ethylhexyl) phthalate	100	7.5	15	11	77
4-tert-octylphenol	100	1.7	5.4	11	68
n-Hexadecane	100	-0.13	-14	-5.5	14
1-Methylnaphthalene	100	-0.16	-0.0965	-0.11	0.70
2-Methylnaphthalene	100	-0.46	-0.25	-0.34	0.58
Acenaphthylene	58	-0.013	0.19	0.16	0.46
Fluorene	100	0.98	2.1	1.9	4.6
Anthracene	17	0.059	0.053	0.30	4.7
1-Methylphenanthrene	92	0.12	0.45	0.57	6.8
2-Methylphenanthrene	25	0.16	0.64	0.74	7.0
3-Methylphenanthrene	83	0.21	0.81	0.94	8.9
Benz[a]anthracene	0	0.022	0.013	0.015	0.18
Chrysene	17	0.013	0.034	0.047	0.26
Benzo(b)fluoranthene	0	0	0	0	0.29
Benzo(k)fluoranthene	0	0	0	0	0
Benzo(e)pyrene	0	0.022	0	0.015	0.21
DBA + ICDP	0	0	0	0	0
Coronene	0	0	0	0	0.26
Dibenzothiophene	100	0.26	0.44	0.52	6.1
Dimethyl phthalate	100	0.43	0.40	0.32	1.4
Diethyl phthalate	100	-11	-3.2	3.0	38
Benzyl butyl phthalate	100	6.4	4.8	11	75
Di-n-octyl phthalate	42	0.46	-0.58	-0.41	7.9
2,6-Di-tert-butyl-p-cresol	100	0.93	0.31	-0.003	10
Cyclohexylisothiocyanate	0	0	0	0	0

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Table 4-34. Exposure Pilot Study Field Air Sampling VOC Measurements[a,b]

Volatile Organic Compound (VOC)	> Method Detection Limit (%)	Background Air Sample Median (ng/m³)	Field Air Sample Location 1 Median (ng/m³)	Field Air Sample Location 2 Median (ng/m³)	Field Air Sample Max (ng/m³)
Methyl isobutyl ketone	83	160	430	820	1900
Benzothiazole	17	41	69	96	1600
1,3-Butadiene	100	24	28	13	50
Styrene	100	92	92	200	670
Benzene	100	500	400	360	590
Toluene	100	2100	1400	1300	5300
Ethylbenzene	100	200	160	170	740
m/p-Xylene	100	650	500	510	2400
o-Xylene	100	150	140	190	520
SumBTEX[c]	N/A[d]	3700	2700	2500	9500
trans-2-Butene	100	14	17	9.8	31
cis-2-Butene	100	12	15	10	33
4-Ethyltoluene	75	42	42	40	52
1,3,5-Trimethylbenzene	83	24	22	25	45
1,1-Dichloroethene	0	0.72	13	6.7	17
1,1-Dichloroethane	58	9.8	11	20	23
cis-1,2-Dichloroethene	0	0	0	0	0
1,2-Dichloroethane	67	26	55	60	95
1,1,1-Trichloroethane	50	43	43	42	59
Carbon tetrachloride	100	720	760	730	1200
1,2-Dichloropropane	0	0	0	0	0
Trichloroethylene	0	12	13	12	41
Tetrachloroethylene	100	53	52	64	150
Chlorobenzene	100	20	22	22	37
m-Dichlorobenzene	75	10	23	11	30
p-Dichlorobenzene	100	30	32	31	34
o-Dichlorobenzene	100	1.8	5.0	2.3	23
Trichlorofluoromethane (Freon™ 11)	100	1300	1300	1300	1400
Dichlorodifluoromethane (Freon™ 12)	100	330	340	370	520
1,1,2-Trichlorotrifluoroethane (Freon™ 113)	100	570	560	540	620

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Table 4-40. Comparison of Average Tire Crumb Rubber Infill, Field Dust, and Field Surface Wipe Metal Measurement Results from the Three Exposure Pilot Study Fields[a]

Metal	Tire Crumb Rubber Infill Average (mg/kg)	Field Dust Average (mg/kg)	Field Surface Wipe Average (ng/cm^2)
Arsenic	0.12	0.5	0.016
Cadmium	0.63	0.044	0.0061
Chromium	1.1	13[b]	0.62
Cobalt	118	45	0.81
Lead	16	38	1.7
Zinc	13900	9400	130
Aluminum	1200	4700	120
Antimony	0.80	1.9	0.11
Barium	69	93	1.4
Beryllium	0.066	0.14	0.0003
Copper	14	140	0.93
Iron	500	7700[b]	160
Magnesium	270	1700	24
Manganese	6.3	170[b]	2
Molybdenum	0.15	0.99[b]	0.031
Nickel	2.3	8.9[b]	0.14
Rubidium	1.9	10	0.16
Strontium	4.1	26	0.38
Tin	1.6	1.8	0.33
Vanadium	1.9	7.4	0.31

[a] Average results from samples collected across the three exposure pilot study synthetic turf fields.

[b] These metals may be components of stainless steel 316; a stainless-steel sieve was used to collect dust samples.

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Table 4-41. Comparison of Average Tire Crumb Rubber Infill, Field Dust, Field Wipe, and Drag Sled SVOC Measurement Results from the Three Exposure Pilot Study Fields[a,b]

Semivolatile Organic Compound (SVOC)	Tire Crumb Infill Average (mg/kg)	Field Dust Average (mg/kg)	Field Surface Wipe Average (ng/cm^2)	Field Drag Sled Average (ng/cm^2)
Phenanthrene	1.6	0.85	0.0049	0.0016
Fluoranthene	4.1	2.2	0.013	0.0036
Pyrene	12	5.5	0.028	0.0070
Benzo[a]pyrene[c]	0.93	0.71	0.0039	0.0014
Benzo[ghi]perylene[c]	1.9	3.7	0.018	0.0038
Sum15PAH[c]	28	19	0.096	0.026
Benzothiazole	5.5	4.3	0.16	0.015
Dibutyl phthalate	1.2	0.33	NR	0.00051
Bis(2-ethylhexyl) phthalate	73	24	0.15	NR
4-tert-octylphenol	15	5.2	0.11	0.012
n-Hexadecane	0.47	0.14	NR	0.0012
1-Methylnaphthalene	0.0057	0.0063	0.00056	0.00007
2-Methylnaphthalene	0.011	0.014	0.0011	0.00009
Acenaphthylene	0.022	0.012	0.00025	0.00003
Fluorene	0.062	0.034	0.00009	0.00006
Anthracene	0.24	0.15	0.0006	0.00019
1-Methylphenanthrene	1.2	0.52	0.0033	0.00087
2-Methylphenanthrene	1.2	0.63	0.0031	0.0012
3-Methylphenanthrene	1.7	0.71	0.0035	0.00129
Benz[a]anthracene	0.76	0.38	0.0025	0.00078
Chrysene	4.1	3.0	0.016	0.0045
Benzo(b)fluoranthene[c]	1.4	1.4	0.0045	0.001
Benzo(k)fluoranthene[c]	0.50	0.32	0.0011	0.0014
Benzo(e)pyrene[c]	2.2	1.5	0.0060	0.0035
DBA + ICDP[c,e]	0.68	0.65	0.0026	0.00047
Coronene[c]	0.74	1.9	0.014	0.0018

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Table 4-41. Continued

Semivolatile Organic Compound (SVOC)	Tire Crumb Infill Average (mg/kg)	Field Dust Average (mg/kg)	Field Surface Wipe Average (ng/cm2)	Field Drag Sled Average (ng/cm2)
Dibenzothiophene	0.21	0.10	0.00025	0.00009
Dimethyl phthalate	0.0031	0.029	0.00020	0.00009
Diethyl phthalate	0.13	0.10	NR	0.0011
Diisobutyl phthalate	0.71	0.29	NR	0.0012
Benzyl butyl phthalate	0.70	15	NR	0.013
Di-n-octyl phthalate	0.51	0.14	0.00097	0.0014
Bis(2-ethylhexyl) adipate	2.4	NR	0.035	0.0029
2,6-Di-tert-butyl-p-cresol	0.097	0.11	0.0086	0.00059
2-Hydroxybenzothiazole	15	9.4	NR	0.045

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Table 4-45. Exposure Pilot Study Pre- and Post-Activity Creatinine-Adjusted Urinary PAH Measurements, by Sport[a, b]

PAH	Sport	Pre-Activity Mean	Pre-Activity Standard Deviation	Pre-Activity Geo Mean	Pre-Activity 95% CI	Post-Activity Mean	Post-Activity Standard Deviation	Post-Activity Geo Mean	Post-Activity 95% CI
1-Hydroxynaphthalene (µg/g)	Soccer	1.66	2.06	0.943	0.428 – 2.08	1.79	2.42	0.974	0.439 – 2.16
1-Hydroxynaphthalene (µg/g)	Football	0.987	0.645	0.850	0.571 – 1.26	1.01	0.816	0.829	0.532 – 1.29
2-Hydroxynaphthalene (µg/g)	Soccer	8.26	4.42	6.91	4.20 – 11.4	10.4	6.41	8.73	5.46 – 13.9
2-Hydroxynaphthalene (µg/g)	Football	7.45	4.86	6.17	3.84 – 9.91	10.2	5.65	8.76	5.68 – 13.5
1-Hydroxyphenanthrene (ng/g)	Soccer	128	121	97.4	58.1 – 164	142	156	101	57.3 – 177
1-Hydroxyphenanthrene (ng/g)	Football	75.1	35.3	67.1	46.1 – 97.8	86.2	26.9	82.5	65.5 – 104
2- & 3-Hydroxyphenanthrene (ng/g)	Soccer	188	241	123	67.1 – 225	207	307	121	62.3 – 233
2- & 3-Hydroxyphenanthrene (ng/g)	Football	102	22.3	100	85.0 – 118	102	17.2	101	88.8 – 115
2-Hydroxyfluorene (ng/g)	Soccer	220	173	179	114 – 282	225	206	177	110 – 285
2-Hydroxyfluorene (ng/g)	Football	156	58.3	147	114 – 190	160	61.5	151	118 – 194
3-Hydroxyfluorene (ng/g)	Soccer	85.3	91.0	63.8	38.7 – 105	95.3	123	61.9	33.4 – 115
3-Hydroxyfluorene (ng/g)	Football	52.6	18.9	49.7	38.4 – 64.3	50.7	19.6	47.4	35.8 – 62.8
1-Hydroxypyrene (ng/g)	Soccer	115	111	87.6	53.0 – 145	109	101	82.5	48.5 – 140
1-Hydroxypyrene (ng/g)	Football	92.9	55.1	81.7	56.6 – 118	71.3	28.7	66.0	48.4 – 89.9

[a] PAH = Polycyclic aromatic hydrocarbon; Geo = Geometric; CI = Confidence interval

[b] Number of soccer player samples = 7; Number of football player samples = 7

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Table 4-47. Statistical Analysis of Differences in Exposure Pilot Study Pre- and Post-Activity Creatinine-Adjusted Urinary PAH Measurements

PAH	Minimum Difference[a]	Maximum Difference [a]	Median	Mean	Standard Deviation	Skewness	Kurtosis	ProbN[b]	Probt[c]	Probsr[d]
1-Hydroxynaphthalene (µg/g)	-1.25	1.05	0.00	0.08	0.54	-0.43	2.78	0.023	0.596	0.618
2-Hydroxynaphthalene (µg/g)	-5.75	13.9	1.28	2.45	4.32	1.00	3.79	0.048	0.053	0.041
1-Hydroxyphenanthrene (ng/g)	-59.6	95.7	1.78	12.4	43.11	0.94	0.70	0.006	0.301	0.463
2- & 3-Hydroxyphenanthrene (ng/g)	-120	172	0.63	9.12	62.4	0.95	4.42	0.001	0.594	0.820
2-Hydroxyfluorene (ng/g)	-148	105	4.13	4.88	54.7	-1.25	5.44	0.001	0.744	0.153
3-Hydroxyfluorene (ng/g)	-41.1	81.4	-2.75	4.08	28.6	1.51	3.78	0.018	0.603	0.715
1-Hydroxypyrene (ng/g)	-113	75.1	-9.60	-13.6	42.2	-0.28	2.76	0.068	0.249	0.078

[a] These values represent the difference in the pre- and post-activity polycyclic aromatic hydrocarbon (PAH) concentrations. Number of samples = 14.

[b] Shapiro-Wilk test for normality *p*-value

[c] T-test *p*-value

[d] Wilcoxon Signed-Rank test *p*-value

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Table 4-52. Statistical Analysis of Differences in Exposure Pilot Study Pre- and Post-Activity Whole Blood Metals and Serum Metals Measurements

Metal	Minimum Difference[a]	Maximum Difference[a]	Median	Mean	Standard Deviation	Skewness	Kurtosis	ProbN[b]	Probt[c]	Probsr[d]
Blood cadmium (µg/L)	-0.15	0.20	0.00	-0.01	0.08	1.31	4.72	0.004	0.724	0.563
Blood manganese (µg/L)	-3.70	3.90	-0.20	0.15	2.09	0.13	0.71	0.567	0.822	0.902
Blood lead (µg/dL)	-0.10	0.15	0.00	0.01	0.06	0.45	1.82	0.229	0.493	0.656
Blood mercury, total (µg/L)	-0.25	0.40	0.00	0.04	0.19	0.94	0.82	0.065	0.537	0.703
Blood selenium (µg/L)	-20.0	50.00	0.00	5.45	20.7	1.08	0.79	0.200	0.402	0.555
Serum copper (µg/dL)	-8.00	10.00	0.00	0.18	4.45	0.38	2.65	0.049	0.895	0.813
Serum selenium (µg/L)	-10.0	10.00	0.00	1.82	8.74	-0.41	-1.62	0.006	0.506	0.727
Serum zinc (µg/dL)	-9.00	13.00	-1.00	-1.45	6.74	0.75	0.72	0.243	0.491	0.492

[a] These values represent the difference in the pre- and post-activity whole blood and serum metals concentrations. Number of samples = 11.

[b] Shapiro-Wilk test for normality *p*-value

[c] T-test *p*-value

[d] Wilcoxon Signed-Rank test *p*-value

Back up slides – Part 2 V1

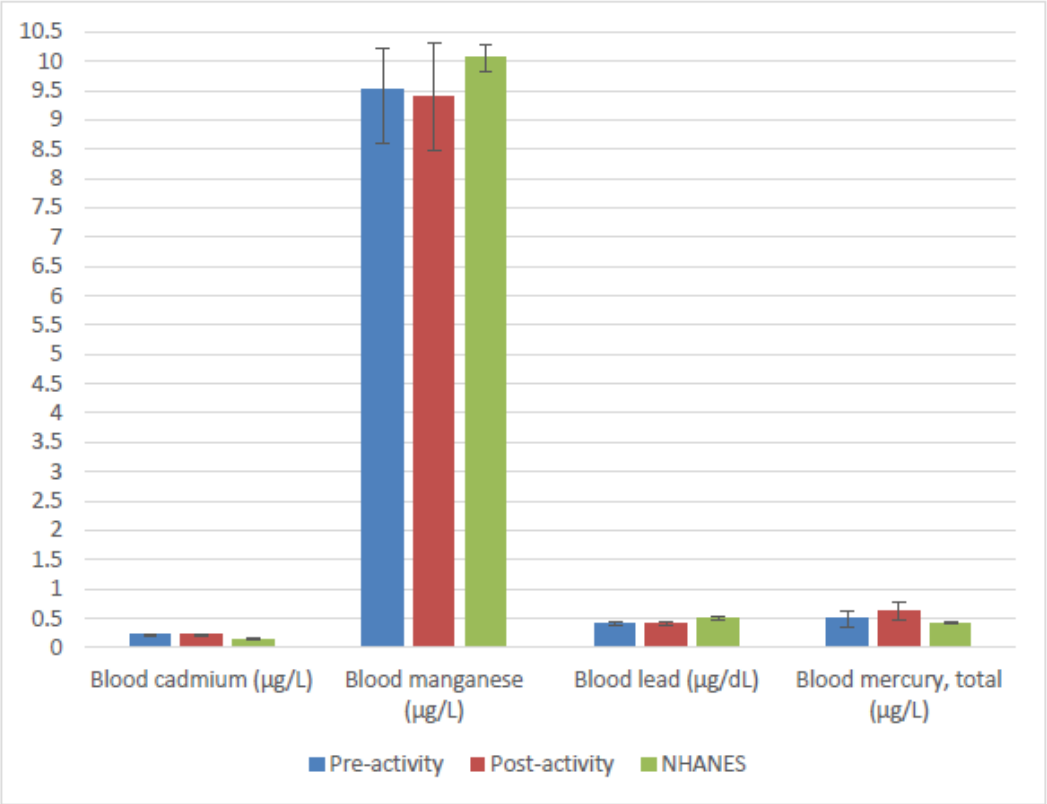

Figure 4-33. Exposure pilot study pre-activity and post-activity blood cadmium, blood manganese, blood lead and total blood mercury geometric mean levels compared to NHANES (2013-2014) weighted and design-adjusted values for Ages 11-21.

[NHANES = National Health and Nutrition Examination Survey]