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Supporting Information for

Artificial Turf Fields Act as Point Sources of Metals and Emerging Tire-Derived Contaminants in Stormwater

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SI-1.0 Supplementary methods

SI-1.1 Sample collection and preparation

We collected artificial turf field infill samples into pre-cleaned amber glass jars. Prior to use, all reusable glassware mentioned in this and following sections were triple rinsed with 50/50 acetone/ethanol and allowed to evaporate in a laboratory fume hood.

Simplified schematics of field drainage systems are provided in Figure SI-1. Sampled manholes are indicated with yellow circles. Open drains which drain surrounding grass areas are indicated with gray circles. Full schematics are withheld for confidentiality reasons.

Information on the fields sampled including infill age, infill size distribution, cumulative precipitation since installation, predominant field use, and location are presented in Table SI-1. Due to lapses in historical precipitation data availability from Environment Canada, data was collected from a regional weather aggregation website.[1]

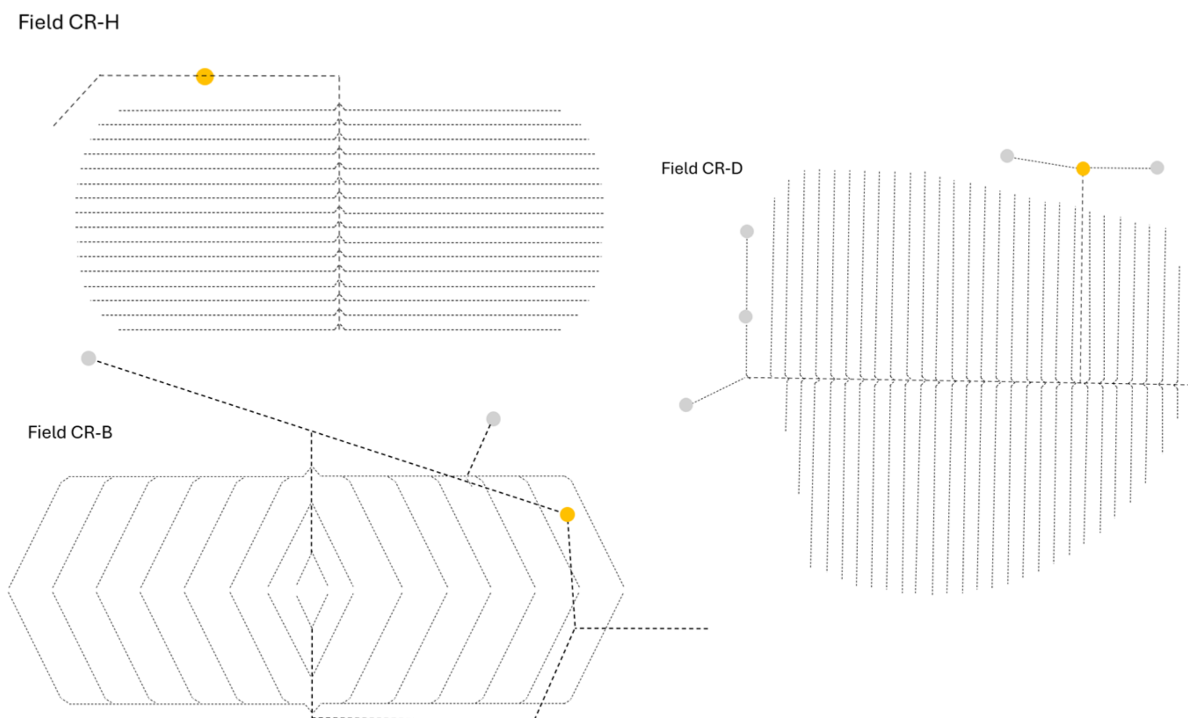


Figure SI-1: Simplified schematics of subsurface drainage for sampled fields

Table SI-1: Information on fields sampled for infill leaching experiments

Field name	Infill age (years)	Infill size (Med. +/- SD) [mm]	Cumulative precipitation since installation [cm]	Predominant field use	Location
TPE-A	1	4 +/- 0.39	136.7	Soccer	North Vancouver
TPE-B	5	10 +/- 6.33	559.1	Soccer	UBC
EPDM-A	7	2.9 +/- 0.76	790.0	Soccer	UBC

CR-A	1	2.65 +/- 0.75	136.7	Soccer	North Vancouver
CR-B	3	3.25 +/- 0.57	329.0	American football	UBC
CR-C	5	2.8 +/- 1.06	559.1	Soccer	Vancouver
CR-D	6	2.4 +/- 0.40	655.6	Baseball	UBC
CR-E	7	3.05 +/- 0.72	790.0	Soccer	North Vancouver
CR-F	9	3 +/- 0.58	1049.6	Soccer	UBC
CR-G	10	2.65 +/- 0.64	1163.8	Soccer	UBC
CR-H	13	3.35 +/- 0.54	1507.0	Soccer	North Vancouver
CR-I	14	2.95 +/- 0.59	1613.8	Soccer	UBC

SI-1.2 Storm event sampling and field details

We prioritized storm events with an anticipated rainfall of >5mm following an antecedent dry-period of 24-hours for sampling. Sample collection began before the start of rainfall and continued throughout rainfall until sampling termination after at least one rise and fall in precipitation rate had occurred.

For Storm Event 1, hourly precipitation data were obtained from the nearest Environment Canada weather station, located approximately 9km from the site. For storm events 2 and 3, 15-minute resolution weather data were obtained from a university weather station, approximately 1km from each site. Cumulative precipitation was calculated by using the hourly or 15-minute precipitation data linearly interpolated to 1-minute resolution. The interpolated values were summed to determine the total precipitation in mm for each storm event and total volume was calculated using this value and field surface area, measured using satellite imagery and "www.calcmaps.com". Cumulative precipitation values are reported along with storm event details below in Table SI-2.

Field blanks are reported throughout the SI but were not subtracted from reported values.

Table SI-2: Storm event sampling details

	Storm Event 1	Storm Event 2	Storm Event 3
Antecedent dry period	19 days	2.5 days	3 days
Start date/time	2025/01/29 14:03 LST	2025/03/08 00:37 UTC	2025/04/05 16:30 LST
End date/time	2025/01/31 10:19 LST	2025/03/08 19:00 UTC	2025/04/07 00:01 LST
Min. temperature (°C)	1.7	5.2	8
Max. temperature (°C)	6	7.8	18
Min. relative humidity (%)	77	80	44
Max. relative humidity (%)	97	98	98
Infill age (years)	13.5	3.5	6.5
Location	North Vancouver, BC, Canada	Greater Vancouver, BC, Canada	Greater Vancouver, BC, Canada
Field surface area (m^2)	10,076	11,116	11,362
Interpolated cumulative precipitation (mm)	29.3	19.07	52
Interpolated cumulative volume (m^3)	295	212	591

SI-1.3 Quantitative ICP-MS analysis of trace organic contaminants

We used an Agilent 7850 Inductively Coupled Plasma-Mass Spectrometer to analyze trace metals concentrations in stormwater and leachate samples. We verified instrument performance during batch tuning, and metals were quantified in helium collision mode. We prepared a seven-point external calibration curve (0–500 μg L^{-1}) using an Environmental Calibration Standard (Agilent 5183-4688). We applied internal standardization using a multi-element internal standard mix (Agilent 5183-4681). For quality assurance and quality control, ultrapure water blanks or field blanks and known concentration spikes were analyzed at minimum every ten samples to assess background contamination, carryover, or instrument drift. We calculated the method detection limit as the lowest calibration curve point detected above background concentrations. Lead concentrations are reported as Pb208. Table SI-3 details information on ICP-MS operating parameters. Calibration points and detection limits are presented below in Table SI-4. Note that values are reported in μg L^{-1} for calibration points, but are presented in mg kg^{-1} of infill material in the main body text.

Table SI-3: ICP-MS instrument operating parameters

Instrument model	Agilent 7850 ICP-MS
Software	Agilent Mass Hunter
Acquisition mode	Spectrum
Peak pattern	1 point
Replicates per sample	3
Sweeps per replicate	100
Integration time per mass (seconds) for Cu, Zn, Pb	0.30
RF power (W)	1550
RF matching (V)	1.80
Nebulizer gas (L min^{-1})	1.09
Nebulizer pump (rps)	0.10
He flow rate (L min^{-1})	4.5
Sample introduction	ISIS discrete sampling

Table SI-4: Calibration curve and quality control data for metals

	Storm event one			Storm event two			Storm event three			Infill leaching		
	63Cu (ug L^{-1})	66Zn (ug L^{-1})	208Pb (ug L^{-1})	63Cu (ug L^{-1})	66Zn (ug L^{-1})	208Pb (ug L^{-1})	63Cu (ug L^{-1})	66Zn (ug L^{-1})	208Pb (ug L^{-1})	63Cu (ug L^{-1})	66Zn (ug L^{-1})	208Pb (ug L^{-1})
MDL	0.184	0.472	0.040	0.200	0.9425	0.132	0.029	0.204	0.014	0.1211	1.3011	0.0931
Blank Max	0.000	0.076	0.002	0.122	0.404	0.017	0.014	0.049	0.013	0.024	0.2076	0.063
0.01 ppb	0.7081	0.4715	0.0404	0.0632	0.9425	0.016	0.031	-0.027	0.0136	0.0008	-0.0048	0.0055
0.1 ppb	0.1844	1.0266	0.1511	0.20	1.3354	0.127	0.107	0.163	0.0936	0.1211	0.0901	0.0931
1 ppb	1.1613	1.3006	1.5917	1.3445	1.7945	1.1836	1.075	1.456	1.0133	0.9877	1.3011	0.9172
10 ppb	12.053	12.0806	11.3176	13.1847	13.9859	11.9421	10.306	10.94	9.3821	9.9551	10.4643	9.0791
100 ppb	102.77	101.3024	99.0258	123.1966	120.027	114.1167	103.15	101.1	96.2899	106.2807	103.8989	98.61
500 ppb	499.4	499.6971	500.1673	495.2963	495.9133	497.1375	499.4	499.8	500.7543	498.7448	499.2103	500.2967

SI-1.4 Quantitative LC-MS/MS analysis of trace organic contaminants

We obtained analytical standards for four organic compounds associated with tire rubber or urban runoff: 6PPD, 6PPD-Q, 1H-benzotriazole (BTZ), and hexamethoxymethylmelamine (HMMM), presented in Table SI-5. We purchased the analytical standards in solid form, dissolved them into LCMS-grade methanol at 1 mg mL^{-1}, vortexed for 30 seconds, and stored samples in amber glass vials at -17 °C until use.

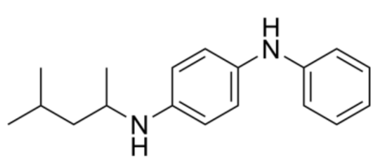
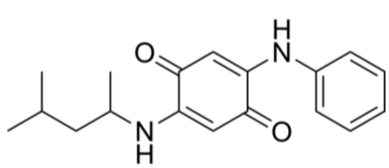
We carried out solid-phase extraction on field samples within seven days of sample collection, with the exception of the first sample from Storm Event 3, which was extracted nine days after collection.

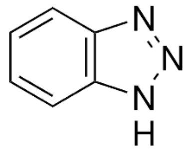
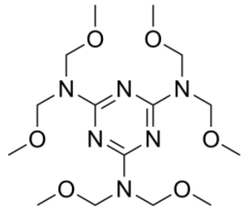
We calculated the method detection limit as the lowest calibration curve point detected above background concentrations. We internal-standard corrected concentrations in samples with internal standard recoveries of 50-150%; samples with internal standard recoveries outside of this range were rejected. 6PPD and 6PPD-Q were corrected using 6PPD-Q-d_5 and BTZ was corrected using BTZ-d4. We quantified HMMM using an external calibration curve due to insufficient retention time similarity and poor SPE recovery of its purchased internal standard. We included a solvent blank in each extraction batch to monitor background contamination and reinjected blanks at a minimum every ten samples to check for contaminant carryover. We reinjected calibration points over the course of each LC-MS run to assess instrument drift. We did not observe substantial instrument drift across analytes, except for 6PPD, which exhibited declining instrument sensitivity over the course of each analytical run. As a result, 6PPD concentrations in later injections may be moderately underestimated.

Table SI-5: Chemical stocks and internal standards

Compound	CAS	Supplier
6PPD	793-24-8	Tokyo Chemical Industry, >98% purity
6PPD-Q	2754428-18-5	Toronto Research Chemicals, >95% purity
BTZ	95-14-7	Toronto Research Chemicals, >95% purity
HMMM	27936-91-0	Toronto Research Chemicals, >95% purity
6PPD-Q-d_5	2750119-14-1	Toronto Research Chemicals, >95 % purity
BTZ-d_4	1185072-03-0	Toronto Research Chemicals, >95% purity

Table SI-6: Chemical structures and properties

Compound	Structure	logKow
6PPD		4.86[2]
6PPD-Q		4.12[3]

Benzotriazole		1.44[4]
HMMM		1.61[5]

We utilized Thermo Fisher TraceFinder software for LC-MS/MS instrument control and data acquisition. Selection of gradient and mobile phase were based on previous work performed in our laboratory. Operating parameters are presented in Table SI-7. SRM parameters are presented in Table SI-8.

Table SI-7: LC-MS/MS instrument operation parameters for quantification of organics

<table>
<tr><th>LC Parameters</th><th></th></tr>
<tr><td>LC Model</td><td>Thermo Scientific Vanquish</td></tr>
<tr><td>Column</td><td>Phenomenox 150 x 3mm, Synergi 4 µm Hydro-RP A</td></tr>
<tr><td>Column temperature (°C)</td><td>40</td></tr>
<tr><td>Mobile phase A</td><td>0.1% formic acid + LC-MS grade water</td></tr>
<tr><td>Mobile phase B</td><td>95/5 LC-MS grade methanol/water</td></tr>
<tr><td>Flow rate (L min^{-1})</td><td>0.350</td></tr>
<tr><td>Run time (minutes)</td><td>16</td></tr>
<tr><td>Needle wash</td><td>50/50 LC-MS grade methanol/water</td></tr>
<tr><td>Needle wash time (seconds)</td><td>15</td></tr>
<tr><td>Injection volume (uL)</td><td>7.5</td></tr>
<tr><td>Gradient details</td><td><table>
<tr><td>Time (mins)</td><td>Flow (mL min^{-1})</td><td>%B</td></tr>
<tr><td>00.00</td><td>0.350</td><td>5</td></tr>
<tr><td>08.00</td><td>0.350</td><td>95</td></tr>
<tr><td>10.00</td><td>0.350</td><td>95</td></tr>
<tr><td>10.10</td><td>0.350</td><td>5</td></tr>
<tr><td>16.00</td><td>0.350</td><td>5</td></tr>
</table></td></tr>
<tr><th>MS Parameters</th><th></th></tr>
<tr><td>MS model</td><td>Thermo Scientific TSQ Altis</td></tr>
<tr><td>Ion source type</td><td>H-ESI</td></tr>
<tr><td>Spray voltage</td><td>Static</td></tr>
<tr><td>Positive ion (V)</td><td>3500</td></tr>
<tr><td>Negative ion (V)</td><td>2500</td></tr>
<tr><td>Sheath gas (arb)</td><td>30</td></tr>
<tr><td>Aux gas (arb)</td><td>8</td></tr>
<tr><td>Sweep gas (arb)</td><td>0</td></tr>
<tr><td>Ion transfer tube temp (°C)</td><td>325</td></tr>
</table>

Vaporizer Temp (°C)	350
Scan mode	SRM

Table SI-8: LC-MS/MS SRM parameters

Compound	Start (mins)	End (mins)	Polarity	Precursor (m/z)	Product (m/z)
BTZ	05.0	08.0	Positive	120.056	064.883
BTZ	05.0	08.0	Positive	120.056	091.883
BTZ-d_4	05.0	08.0	Positive	124.100	068.000
6PPD	08.0	10.0	Positive	269.201	184.083
6PPD	08.0	10.0	Positive	269.201	185.083
HMMM	08.5	10.5	Positive	391.230	177.083
HMMM	08.5	10.5	Positive	391.230	283.083
6PPD-Q	10.0	12.1	Positive	299.175	186.967
6PPD-Q	10.0	12.1	Positive	299.175	240.967
6PPD-Q-d_5	10.0	12.1	Positive	304.200	192.083

<u>SI-1.5 Non-targeted LC-MS/MS analysis of trace organic contaminants</u>

We performed nontarget analysis to better understand the full chemical profile of the sampled infill materials. While it is possible that contaminants were introduced onto artificial turf fields and subsequently incorporated into the infill material through environmental pathways such as stormwater runoff, atmospheric deposition, or carry-over from footwear, we anticipate their impact to be minimal relative to the inherent chemical composition of the turf material.

Full LC-MS/MS operating parameters utilized for non-targeted analysis are presented in Table SI-9.

Table SI-9: LC-MS/MS operation parameters for non-targeted analysis

<table>
<tr><th>LC Parameters</th><th></th></tr>
<tr><td>LC Model</td><td>Thermo Scientific Vanquish</td></tr>
<tr><td>Column</td><td>Phenomenox 150 x 3mm, Synergi 4 µm Hydro-RP A</td></tr>
<tr><td>Column temperature (°C)</td><td>45</td></tr>
<tr><td>Mobile phase A</td><td>0.1% formic acid + LC-MS grade water</td></tr>
<tr><td>Mobile phase B</td><td>95/5 LC-MS grade methanol/water</td></tr>
<tr><td>Flow rate (mL min^{-1})</td><td>0.450</td></tr>
<tr><td>Run time (minutes)</td><td>26.5</td></tr>
<tr><td>Needle wash</td><td>25/25/25/25 IPA/MeOH/H2O/ACN</td></tr>
<tr><td>Needle wash time (seconds)</td><td>10</td></tr>
<tr><td>Injection volume (uL)</td><td>7.5</td></tr>
<tr><td>Gradient details</td><td><table>
<tr><td>Time (mins)</td><td>Flow (mL min^{-1})</td><td>%B</td></tr>
<tr><td>00.00</td><td>0.450</td><td>5</td></tr>
<tr><td>02.66</td><td>0.450</td><td>50</td></tr>
<tr><td>16.00</td><td>0.450</td><td>100</td></tr>
<tr><td>21.33</td><td>0.450</td><td>100</td></tr>
<tr><td>21.66</td><td>0.450</td><td>5</td></tr>
</table></td></tr>
</table>

	26.50	0.450	5
MS Parameters			
MS model	Thermo Scientific Orbitrap Exploris 240		
Ion source type	H-ESI		
Spray voltage	Static		
Positive ion (V)	3500		
Negative ion (V)	3000		
Sheath gas (arb)	25		
Aux gas (arb)	5		
Sweep gas (arb)	0		
Ion transfer tube temp (°C)	325		
Vaporizer Temp (°C)	350		
Full scan parameters:			
Resolution	60,000		
Scan range (m/z)	60-700		
RF Lens (%)	70		
AGC target	Standard		
Polarity	Positive		
Source fragmentation	Disabled		
Dynamic exclusion filter parameters:			
Exclude after n times	n = 1		
Exclusion duration (seconds)	10		
Mass tolerance	3 ppm		
Exclude isotopes	True		
Intensity filter parameters:			
Intensity Threshold	500		
ddMS^2 parameters:			
Data-dependent mode	Number of scans		
Number of dependent scans	10		
Multiplex ions	False		
Isolation window (m/z)	2		
Isolation offset	Off		
Collision energy type	Normalized		
HCD collision energy (%)	20,40,60		
Orbitrap resolution	15,000		
Scan range mode	Auto		

<u>SI-1.6 Non-target data processing</u>

The workflow employed for processing data in Compound Discoverer is presented in . We developed this workflow based on Hamdan et al.[6] who utilized a similar workflow for nontarget analysis of stream surface water samples. Full workflow settings are presented in Table SI-10. Background features were filtered from the data set post-processing via the Compound Discoverer filtering method.

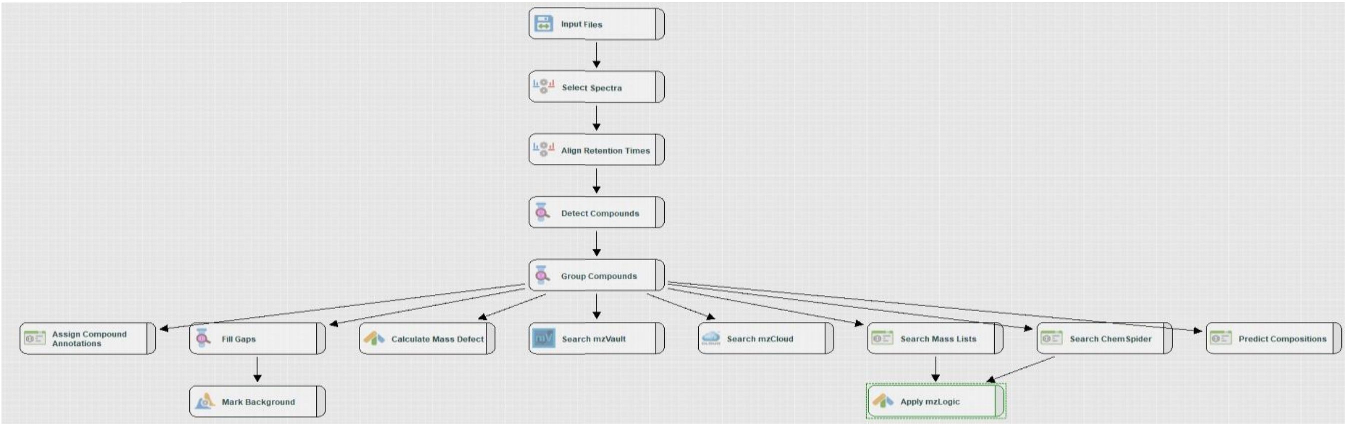


Figure SI-2: Schematic of compound discoverer workflow

Table SI-10: Compound discoverer workflow settings

Node: Select Spectra	
1. Spectrum Properties Filter	
Lower RT Limit	0.3
Upper RT Limit	0 (NA)
2. Scan Event Filters	
Polarity Mode	Any
Node: Align Retention Times	
1. General Settings	
Alignment Model	Adaptive curve
Maximum Shift [min]	0.3
Mass Tolerance	5 ppm
Node: Detect Compounds	
1. General Settings	
Mass Tolerance [ppm]	5 ppm
Min. Peak Intensity	10,000
Use Most Intense Isotope Only	True
Precursor Mass Tolerance	0.025 Da
3.Peak Detection	
Chromatographic S/N Threshold	3
Remove Baseline	True
4.Isotope Pattern Detection	
Group Isotopes for	NA
5. Compound Assembly	
Ions	All ions selected
Node: Group Compounds	
1. General Settings	
Mass Tolerance [ppm]	5 ppm
RT Tolerance [min]	0.1
Minimum Valley [%]	10

Align Peaks	True
Preferred Ions	[M+H]+1; [M-H]-1
Area Integration	Most Common Ion
2. Peak Rating Contributions	
Area Contribution	3
CV Contribution	10
FWHM to Base Contribution	5
Jaggedness Contribution	5
Modality Contribution	5
Zig-zag Index Contribution	5
3. Peak Rating Filter	
Peak Rating Threshold	5
Number of Files	2
Node: Assign Compound Annotations	
1. General Settings	
Mass Tolerance	3 ppm
2. Data Sources	
Data Source #1	mzCloud Search
Data Source #2	mzVault Search
Data Source #3	Predicted Compositions
Data Source #4	ChemSpider Search
Data Source #5	MassList Search
3. Scoring Rules	
Use mzLogic	True
Use spectral distance	True
SFit Threshold	20
SFit Range	20
4. Reprocessing	
Clear Names	False
Node: Fill Gaps	
Node: Search mzVault	
1. Search Settings	
mzVault Library	\GNPS.db|\MassBank.db|\MassBankEU.db
Compound Classes	All
Match Ion Activation Type	False
Match Ion Activation Energy	Any
Ion Activation Energy Tolerance	20
Match Ionization Method	False
Apply Intensity Threshold	False
Precursor Mass Tolerance	5 ppm
Match Analyzer Type	False
Search Algorithm	HighChem High Res
Match Factor Threshold	50
RT Tolerance [min]	10
Use Retention Time	False

Node: Search mzCloud	
1. General Settings	
Compound Classes	All
Library	Autoprocessed; Reference
Search MSn Tree	False
2. DDA Search	
Identity Search	NIST
Match Activation Type	True
Match Activation Energy	Match with Tolerance
Activation Energy Tolerance	20
Apply Intensity Threshold	True
Similarity Search	None
Match Factor Threshold	50
Node: Search Mass Lists	
1. Search Settings	
Mass Lists	EPA CompTox Tire Crumb List[7]
Use Retention Time	False
RT Tolerance [min]	0.1
Mass Tolerance	5 ppm
Node: Search ChemSpider	
1. Search Settings	
Database(s)	ACToR: Aggregated Computational Toxicology Resource; ECHA; EPA DSSTox; EPA Toxcast; EU-OpenScreen; Exposome Explorer; NIST Spectra; SDBS Spectral Database for Organic Compounds
Search Mode	By Formula or Mass
Mass Tolerance	5 ppm
Max # of results per compound	10
Max # of Predicted Compositions to be searched	3
Node: Predict Compositions	
1. Prediction Settings	
Mass Tolerance	3 ppm
Min. Element Counts	C H
Max. Element Counts	C90 H190 Br5Cl4 F5I N10 O18 P3 S5 Si15
Min RDBE	0
Max. RDBE	40
Min. H/C	0.1
Max. H/C	10
Max # Candidates	5
2. Pattern Matching	
Intensity Tolerance [%]	30
Intensity Threshold [%]	0.1
S/N Threshold	3
Use Dynamic Recalibration	True
3. Fragments Matching	

Use Fragments Matching	True
Mass Tolerance	5 ppm
S/N Threshold	3
Node: Mark Background	
1. General Settings	
Max. Sample/Blank	5
Max. Blank/Sample	0
Hide Background	True
Node: Apply mzLogic	
1. Search Settings	
Max. # Compounds	5
Max. # mzCloud Similarity Results to consider per Compound	10
Match Factor Threshold	30

<u>SI-2.0 Supplemental results</u>

<u>SI-2.1: Supplemental results from quantitative infill leaching</u>

Fig SI-3, below, presents a visualization of relative 6PPD and 6PPD-Q from crumb rubber samples used in infill leaching and extraction. The relative abundances were assessed for linear correlation with sample age. No significant trend was found, (p = 0.89, R^2 = 0.003)

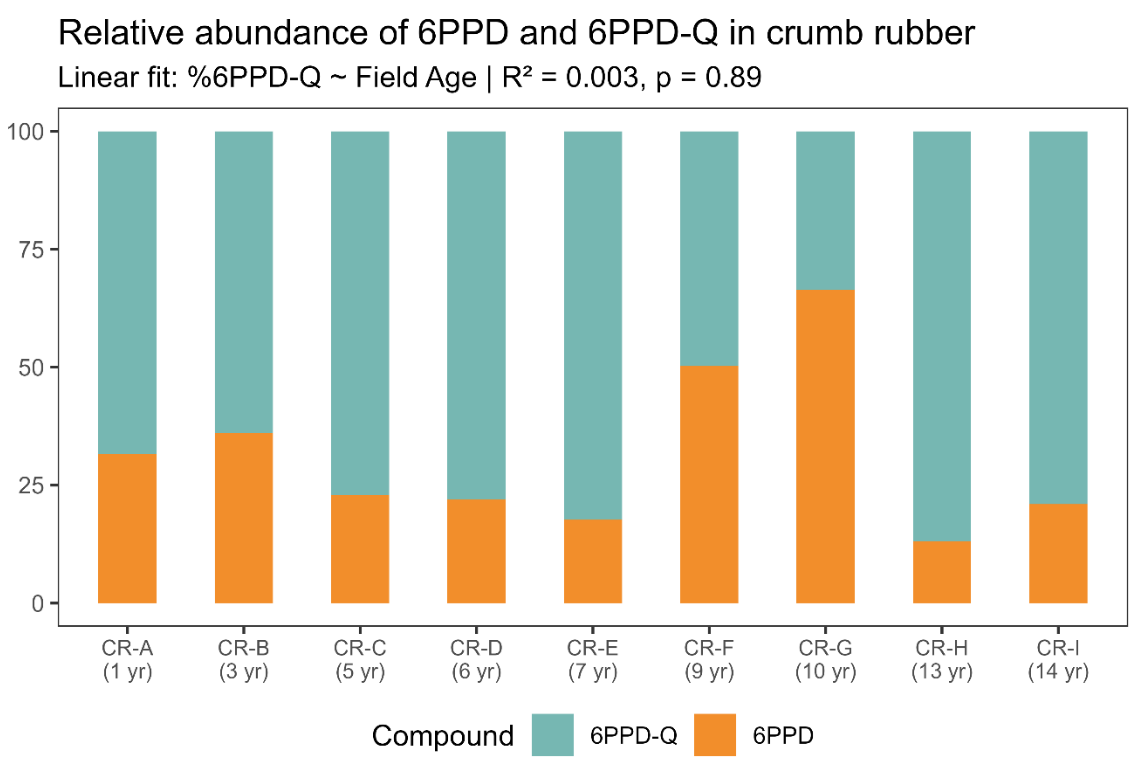


Figure SI-3: Relative abundance of 6PPD and 6PPD-Q in crumb rubber

Processed data for infill leaching are presented in Table SI-12, below.

Table SI-11: Concentrations of contaminants in infill leachate in mg/kg

Sample	6PPD-Q	BTZ	6PPD	HMMM	Copper	Zinc
TPE-A (1 yr)	BDL(<0.0197)	BDL(<0.00313)	0	BDL(<0.0084)	0.013	BDL(<0.13)
TPE-A (1 yr)	BDL(<0.0197)	BDL(<0.00313)	0	BDL(<0.0084)		
TPE-A (1 yr)	BDL(<0.0197)	0.027	0	BDL(<0.0084)		
EPDM-A (7 yr)	BDL(<0.0197)	BDL(<0.00313)	0	0.009	0.054	1.911
EPDM-A (7 yr)	0.077	BDL(<0.00313)	0.183		0.1	2.385
EPDM-A (7 yr)	0.033	0.005	0.067	BDL(<0.0084)		
TPE-B (5 yr)	BDL(<0.0197)	9.582	0	BDL(<0.0084)	0.03	BDL(<0.13)
TPE-B (5 yr)	0.023	8.673	0	BDL(<0.0084)	BDL(<0.0121)	BDL(<0.13)
TPE-B (5 yr)	BDL(<0.0197)	5.762	0	BDL(<0.0084)		
CR-I (14 yr)	1.754	0.05	0.342	BDL(<0.0168)	0.029	14.554
CR-I (14 yr)	0.815	0.016	0.223	BDL(<0.0084)	0.013	24.257
CR-I (14 yr)	0.84	0.013	0.182	BDL(<0.0084)		
CR-C (5 yr)	5.474	0.016	1.08	0.122	0.053	48.814
CR-C (5 yr)	2.864	0.007	0.852	0.024	0.056	32.678
CR-C (5 yr)	2.068	0.007	0.45	0.018		

CR-B (3 yr)	*2.954*	*0.014*	*0.884*	*0.046*	*0.27*	*10.885*
CR-B (3 yr)	*1.392*	*BDL(<0.00313)*	*0.648*	*0.011*	*0.326*	*11.228*
CR-B (3 yr)	*0.912*	*BDL(<0.00313)*	*0.785*	*0.015*		
CR-D (6 yr)	*6.56*	*0.016*	*2.124*	*0.032*	*0.128*	*26.277*
CR-D (6 yr)	*6.942*	*BDL(<0.00626)*	*1.79*	*0.04*	*0.172*	*35.057*
CR-D (6 yr)	*7.874*	*BDL(<0.00626)*	*1.962*	*0.054*		
CR-H (13 yr)	*1.262*	*BDL(<0.00626)*	*0.358*	*0.018*	*0.048*	*3.766*
CR-H (13 yr)	*0.728*	*0.006*	*0.11*	*BDL(<0.0084)*	*0.034*	*2.752*
CR-H (13 yr)	*0.642*	*BDL(<0.00313)*	*0.109*	*BDL(<0.0084)*		
CR-E (7 yr)	*5.094*	*BDL(<0.00626)*	*1.348*	*0.022*	*BDL(<0.0121)*	*2.738*
CR-E (7 yr)	*6.278*	*BDL(<0.00626)*	*0.628*	*0.03*	*0.017*	*3.319*
CR-E (7 yr)	*6.58*	*BDL(<0.00626)*	*1.646*	*0.02*		
CR-G (10 yr)	*2.142*	*BDL(<0.00626)*	*5.006*	*0.036*	*0.051*	*13.887*
CR-G (10 yr)	*1.554*	*BDL(<0.00626)*	*2.616*	*0.024*	*0.074*	*20.041*
CR-G (10 yr)	*1.734*	*BDL(<0.00626)*	*3.44*	*0.02*		
CR-F (9 yr)	*1.436*	*BDL(<0.00626)*	*0.928*	*BDL(<0.0168)*	*BDL(<0.0121)*	*8.553*
CR-F (9 yr)	*0.92*	*BDL(<0.00313)*	*0.943*	*0.016*	*0.016*	*6.856*
CR-F (9 yr)	*0.547*	*BDL(<0.00313)*	*0.451*	*BDL(<0.0084)*		

CR-A (1 yr)	*3.485*	*BDL(<0.0157)*	*1.615*	*0.055*	*0.025*	*12.141*
CR-A (1 yr)	*2.645*	*BDL(<0.0157)*	*0.615*	*0.07*	*0.014*	*10.813*
CR-A (1 yr)	*5.335*	*BDL(<0.0157)*	*9.065*	*0.065*		

To understand if cumulative precipitation is related to mean contaminant release, we assessed total precipitation since year of installation against mean concentration of contaminant release, calculating compound-specific Spearman's correlations, presented below.

Table SI-12: Spearman's correlation for cumulative precipitation and mean contaminant release

Compound	n	R2	p-value
6PPD-Q	9	0.321	0.1206
6PPD	9	0.267	0.1618
HMMM	9	0.632	0.0104
BTZ	9	0.034	0.6354

<u>SI-2.2: Supplemental results from non-target infill leaching</u>

All compounds putatively identified at level 2 confidence and the number of detections per infill type are presented below in Table SI-13: Level 2 predicted compounds, use class, and detection countTable SI-13. Further data from the nontargeted analysis, including peak area abundance and library matching information, is available in the additional SI excel file.

Table SI-13: Level 2 predicted compounds, use class, and detection count

		Number of detections			
Predicted compound	**Use**	CR (X/27)	TPE (X/6)	EPDM (X/3)	CMTT (X/ 3)
3-Phenyl-2,3-dihydro-1,3-benzothiazol-2-imine	Various	23	0	0	3
4-Methoxychalcone	Naturally occurring	0	3	0	0
7-methyl-3-nitroimidazo[1,2-a]pyridine	Drug	0	3	0	0
acridine-9(10H)-thione	Rubber	23	0	0	2
Alpha-pyrrolidinovalerophenone	Drug	7	0	1	0
Betaine	Drug	3	1	0	1
Chalcone	Naturally occurring	0	2	0	0
DEET	Pesticide	17	5	2	2
Dipropylene glycol dimethyl ether	Various	3	0	0	0
Leucomalachite green	Dye	16	0	0	3
Desipramine	Drug	3	0	0	3

Lauramidopropyl betaine	Personal care product	15	4	0	2
Nordeprenyl	Drug	24	0	0	3
Diphenylphosphate	Plasticizer	9	0	1	1
4-Hydroxy-1-(2-hydroxyethyl)-2,2,6,6-tetramethylpiperidine	UV-stabilizer	22	5	3	2
N-Cyclohexyl-2-benzothiazol-amine	Rubber	25	0	0	3
Hydrocinchonine	Drug	3	0	0	3
Galaxolidone	Personal care product	7	3	1	1
Dextromethorphan	Drug	3	0	0	3
Praziquantel	Drug	0	0	0	3
N,N-Diethyl-3-methoxybenzamide	Pesticide	9	1	3	3
N,N-Diethyl-4-hydroxybenzamide	Laboratory	0	1	0	1
Lauryldiethanolamine	Personal care product	4	3	0	0
Dibutyl phthalate	Plasticizer	6	3	0	0
Cinchophen	Drug	21	6	3	1
4-(Dimethylamino)phenylthiocyanate	Drug	15	2	1	1
Diisobutyl phthalate	Plasticizer	3	0	0	0
Sempervirine	Drug	6	0	0	3
Harmine	Drug	4	0	0	3
Di(2-ethylhexyl)phthalate (DEHP)	Plasticizer	27	6	3	3
Cyclohexylamine	Rubber	7	1	0	0
N,N'-Diphenylguanidine	Rubber	27	6	3	3
Neocuproine	Laboratory	20	0	0	3
Octrizole	UV-stabilizer	0	3	2	0
Stearoyl Ethanolamide	Naturally occurring	3	0	0	3
Triphenylphosphine oxide	Laboratory	10	5	0	2
Tris(2-ethylhexyl) phosphate	Flame retardant	7	0	0	3
Uric acid	Naturally occurring	4	0	3	0
UROCANATE - 20.0 eV	Naturally occurring	4	1	0	1

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Spectra examples for the fifteen level 2 compounds are presented below. Recorded data are presented as positive intensity (top) while reference spectra, acquired from mzVault or mzCloud, are presented as negative intensity (bottom).

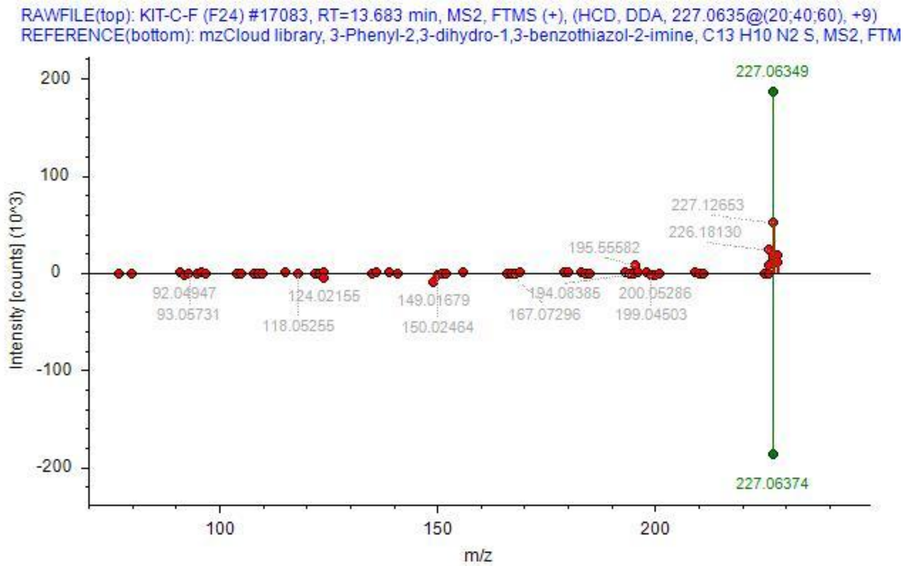

Figure SI-4: MS2 spectra matching for 3-phenyl-2,4-dihydro-1,3-benzothiazol-2-imine

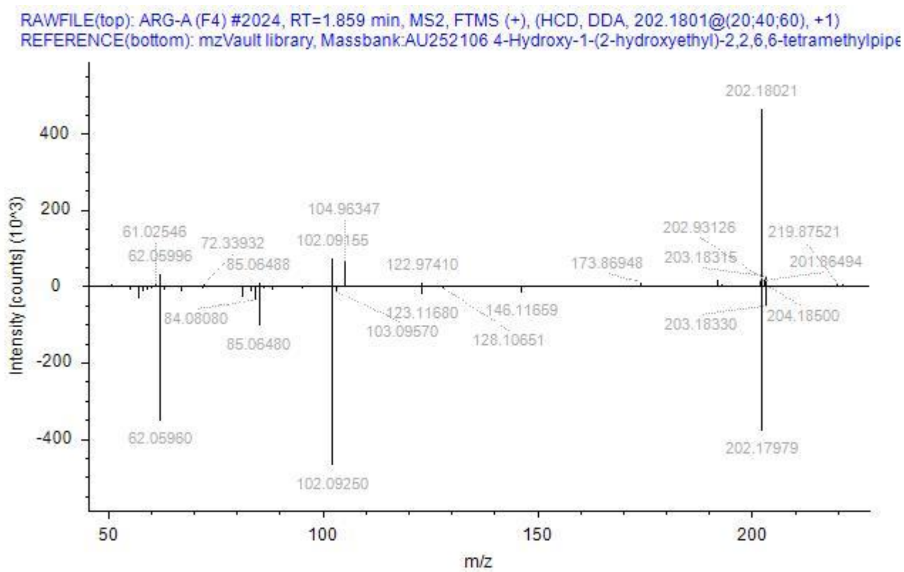

Figure SI-5: MS2 spectra matching for 4-Hydroxy-1-(2-hydroxyethyl)-2,2,6,6-tetramethylpiperidine

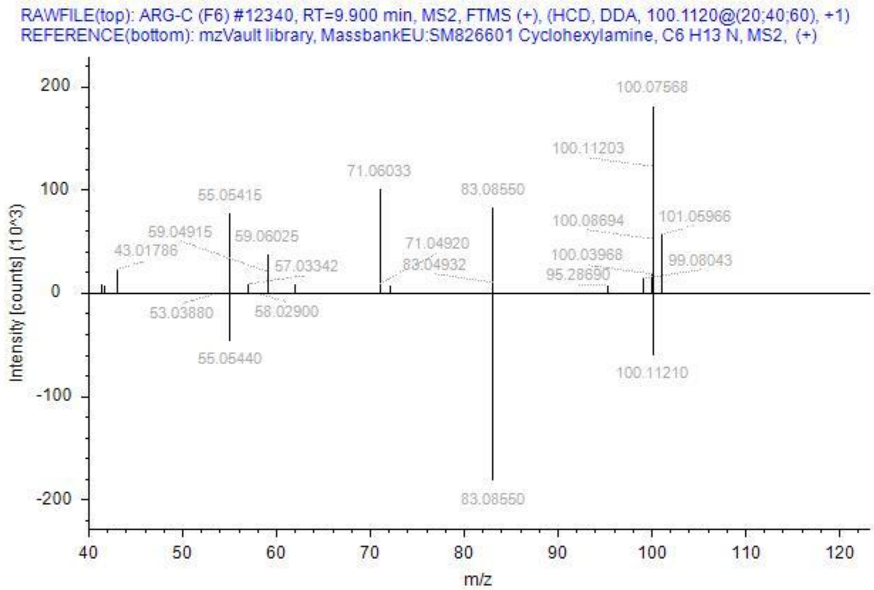

Figure SI-6: MS2 spectra matching for cyclohexylamine

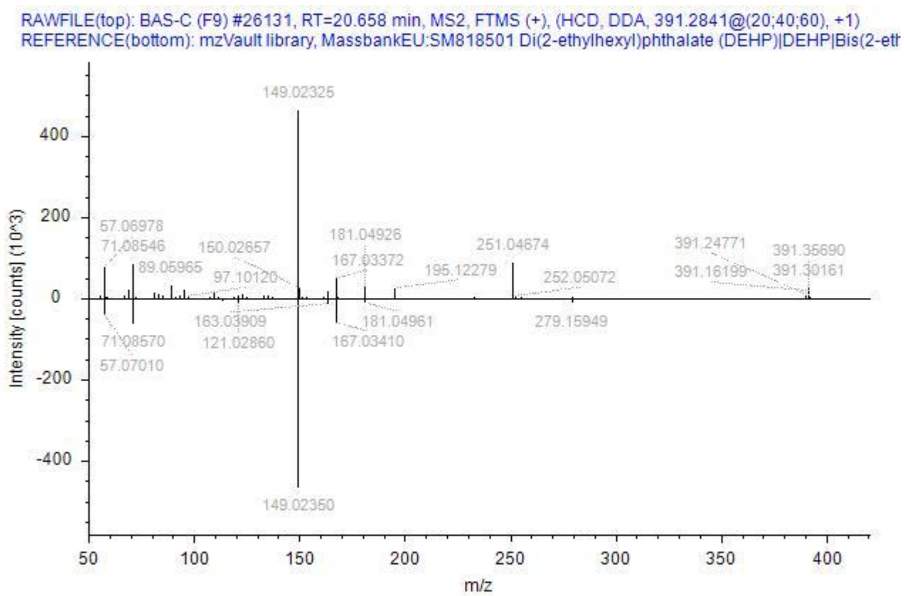

Figure SI-7: MS2 spectra matching for di(2-ethylhexyl)phthalate (DEHP)Di(2-ethylhexyl)phthalate (DEHP)

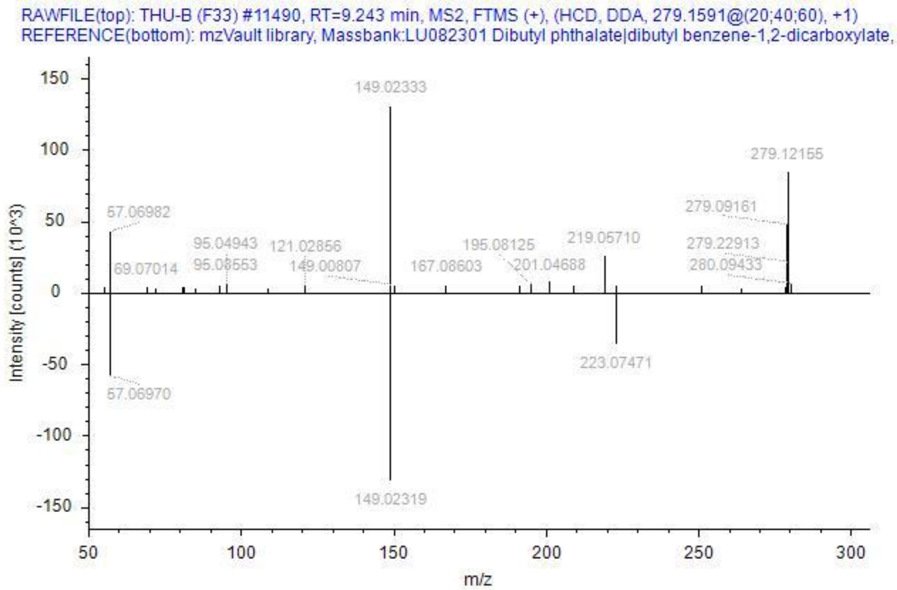

Figure SI-8: MS2 spectra matching for dibutyl phthalate

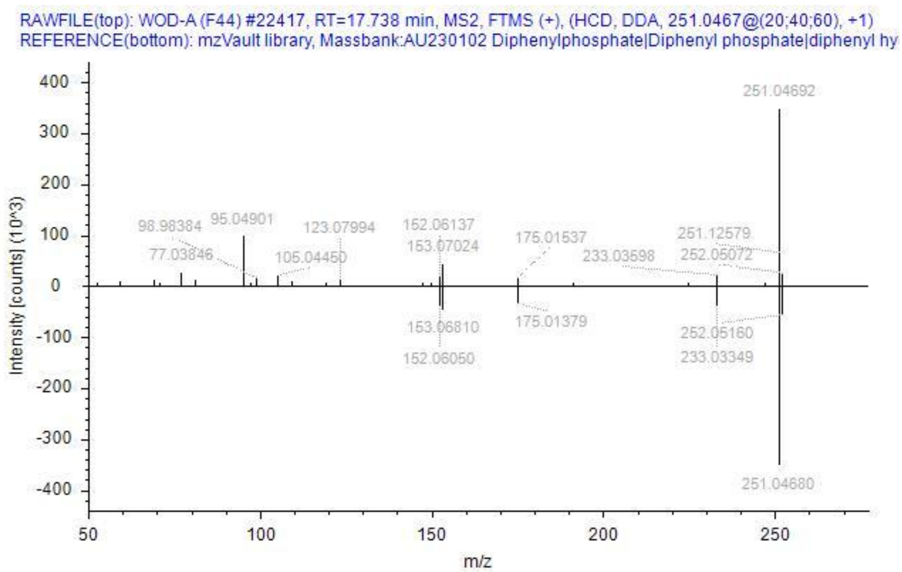

Figure SI-9: MS2 spectra matching for diphenylphosphate

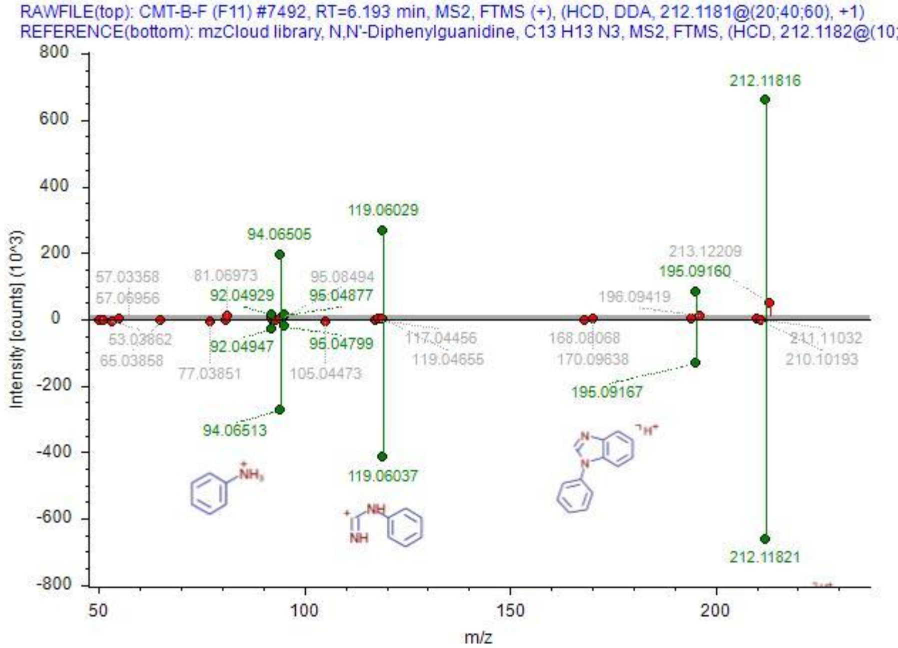

Figure SI-10: MS2 spectra matching for N,N'-diphenylguanidine

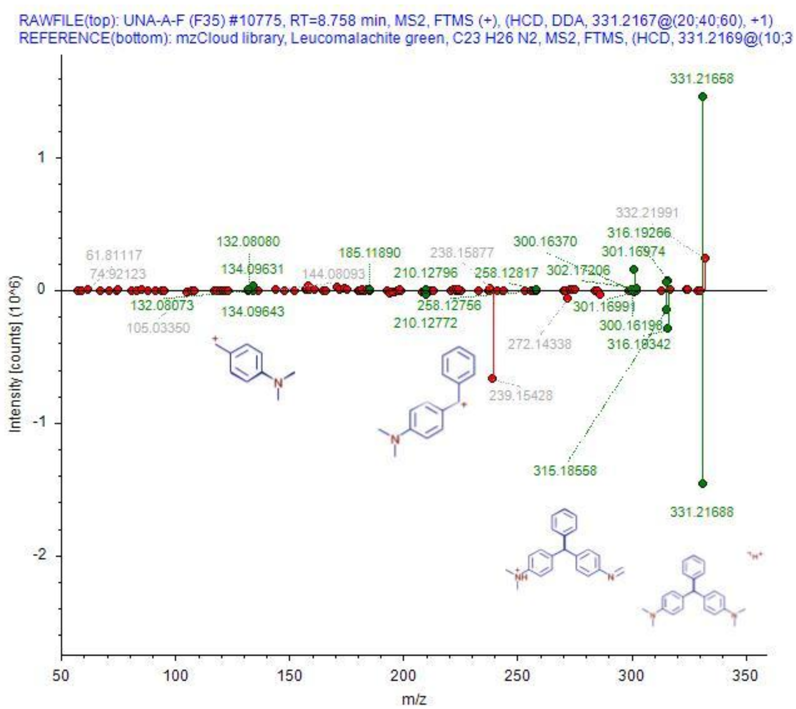

Figure SI-11: MS2 spectra matching for leucomalachite green

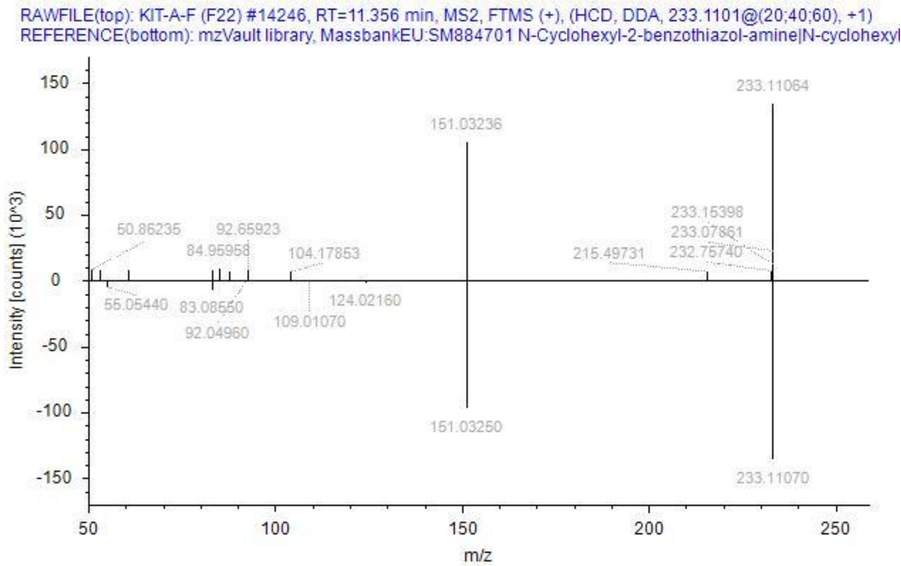

Figure SI-12: MS2 spectra matching for N-cyclohexyl-2-benzothiazol-amine (NCBA)

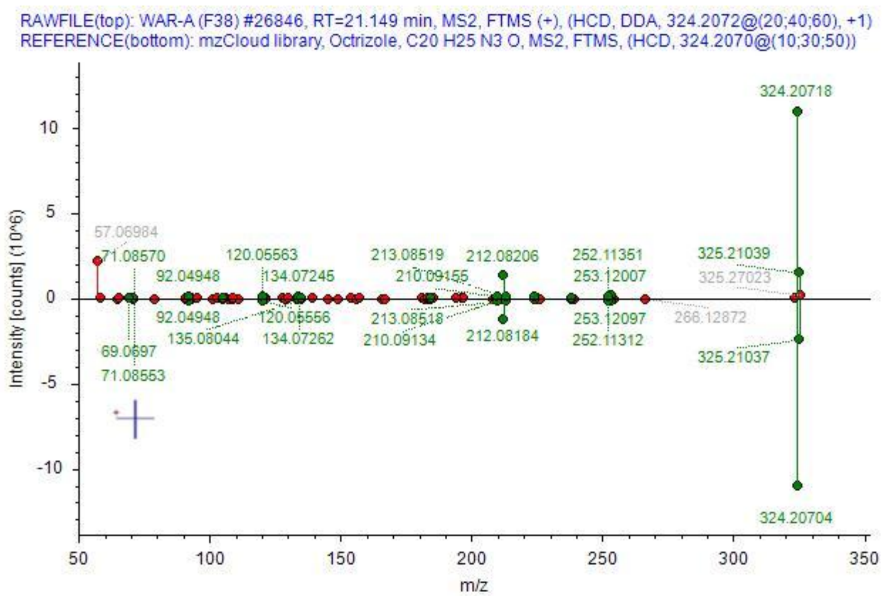

Figure SI-13: MS2 spectra matching for octrizole

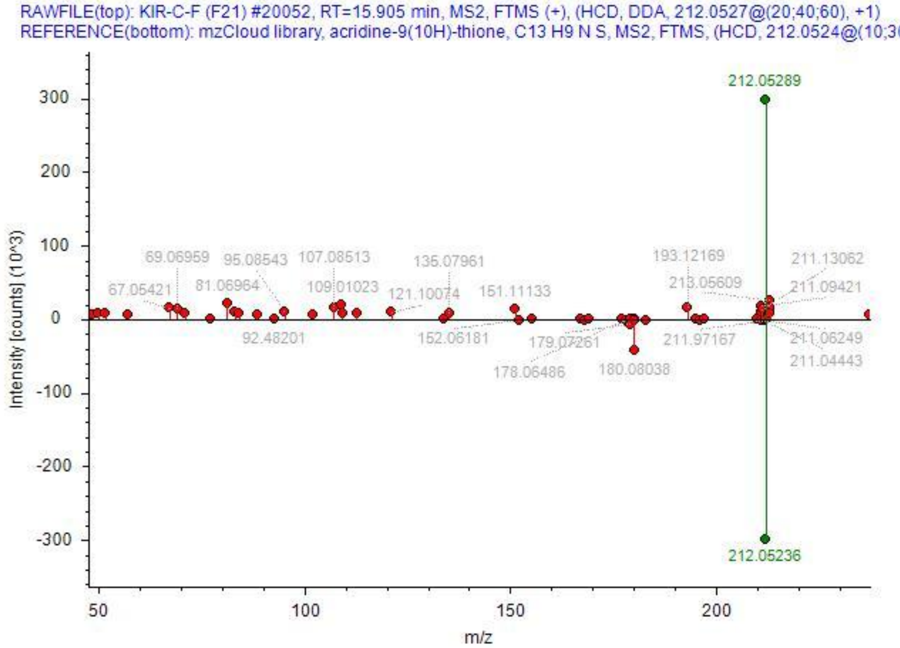

Figure SI-14: MS2 spectra matching for acridine-9(10H)-thione

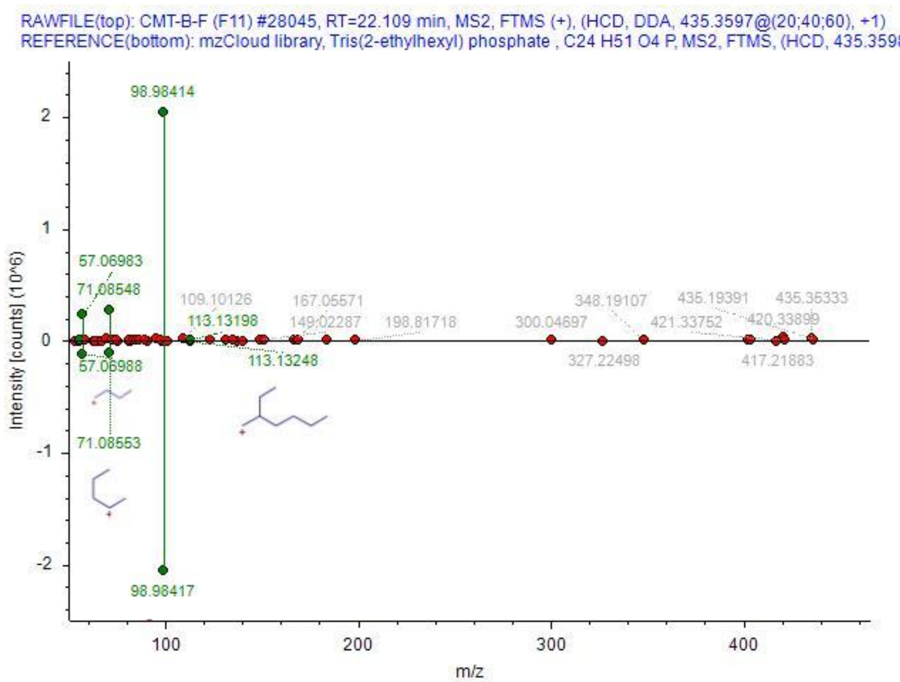

Figure SI-15: MS2 spectra matching for tris(2-ethylhexyl) phosphate

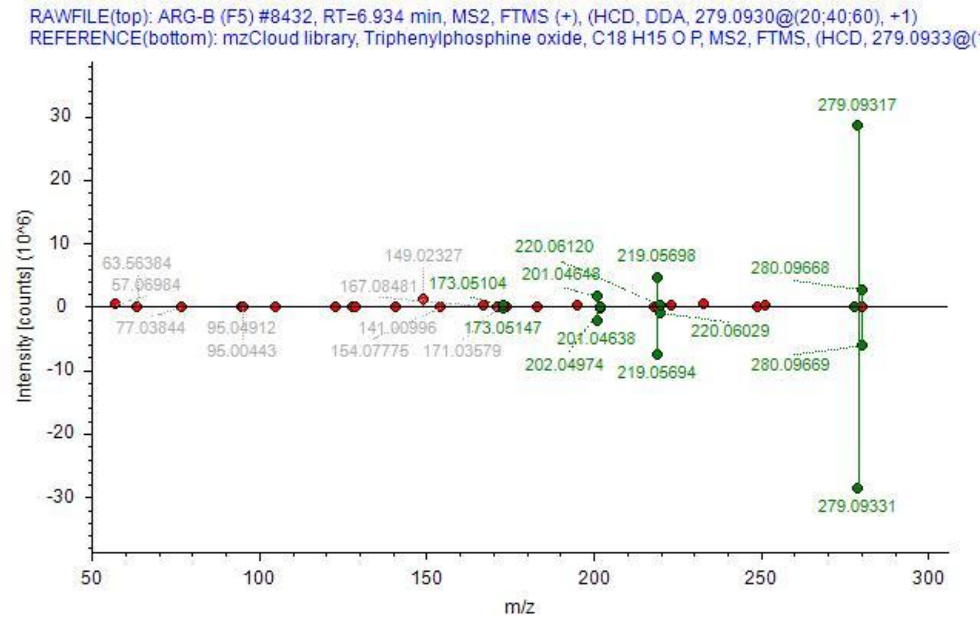

Figure SI-16: MS2 spectra matching for triphenylphosphine oxide

Figure SI-17 below, visually represents the abundance of putatively identified (Levels 2 and 3) compounds. The top ten most abundant compounds are plotted in a stacked bar plot, with each color representing mean abundance within an infill material group. Results demonstrate that the most abundant compounds detected exhibited notable variability among infill types, with several compounds appearing predominantly in specific infills. Octrizole was largely associated with TPE infill, whereas 6PPD, N,N'-diphenylguanidine, tris(2-ethylhexyl)phosphate, and desipramine were primarily concentrated in CMT samples. Isovaleraldehyde, a rubber vulcanization agent, displayed the highest mean abundance in CMT but was present across all infill types, suggesting widespread use during production and potential persistence under environmental conditions. Di(2-ethylhexyl)phthalate and diethylamine exhibited the greatest mean abundance in EPDM infill, while urea and 1H-1,2,4-triazole-3-sulfonamide showed relatively uniform mean peak areas across all four infill materials, indicating broader use or their presence as background contaminants.

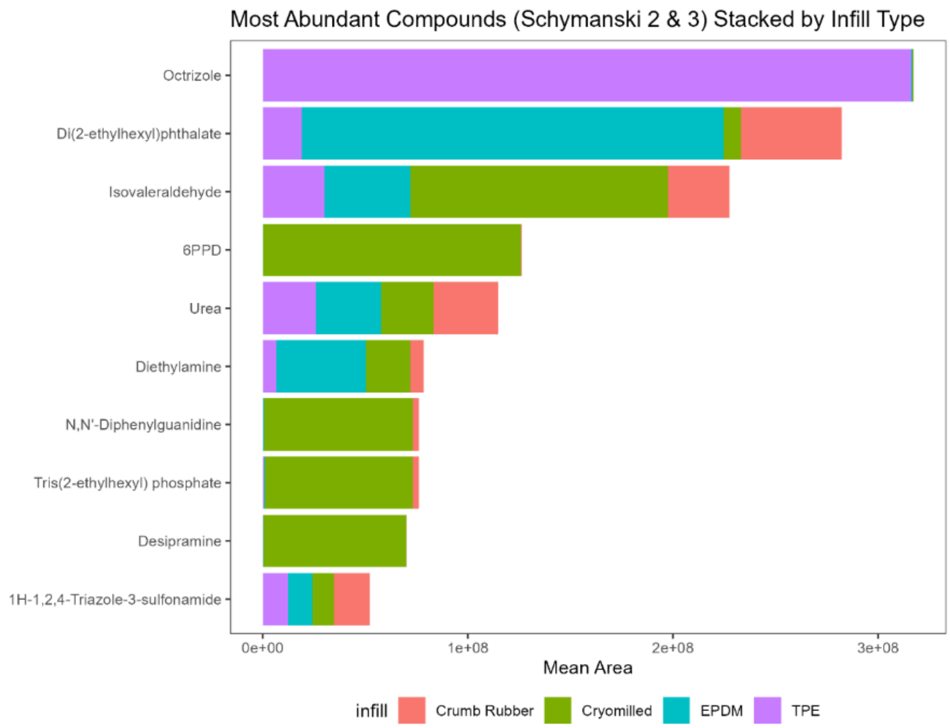

Figure SI-17: Highest abundance compounds by peak area within Schymanski level 2 and 3

Annual 6PPD and 6PPD-Q depletion estimates are provided below. These values likely represent an upper bound, as they are based on the maximum observed emissions. Calculations assume an annual precipitation of 146 cm and an average artificial turf field size of 7,140 m^2.

$$Annual\ 6PPD\ Loss = \frac{146\frac{cm}{year}\ x\ \frac{1\ m}{100\ cm}\ x\ 7140\ m^2\ x\ 0.1756\frac{ug}{L}}{10^6\frac{ug}{g}\ x\ \frac{m^3}{1000\ L}} = 1.83\frac{g}{year}$$

$$Annual\ 6PPDQ\ Loss = \frac{146 \frac{cm}{year}\ x\ \frac{1\ m}{100\ cm}\ x\ 7140\ m^2\ x\ 0.1302 \frac{ug}{L}}{10^6 \frac{ug}{g}\ x\ \frac{m^3}{1000\ L}} = 1.36 \frac{g}{year}$$

Equation 1: Estimate of maximum annual contaminant loss

SI-2.3: Supplemental results from stormwater sampling

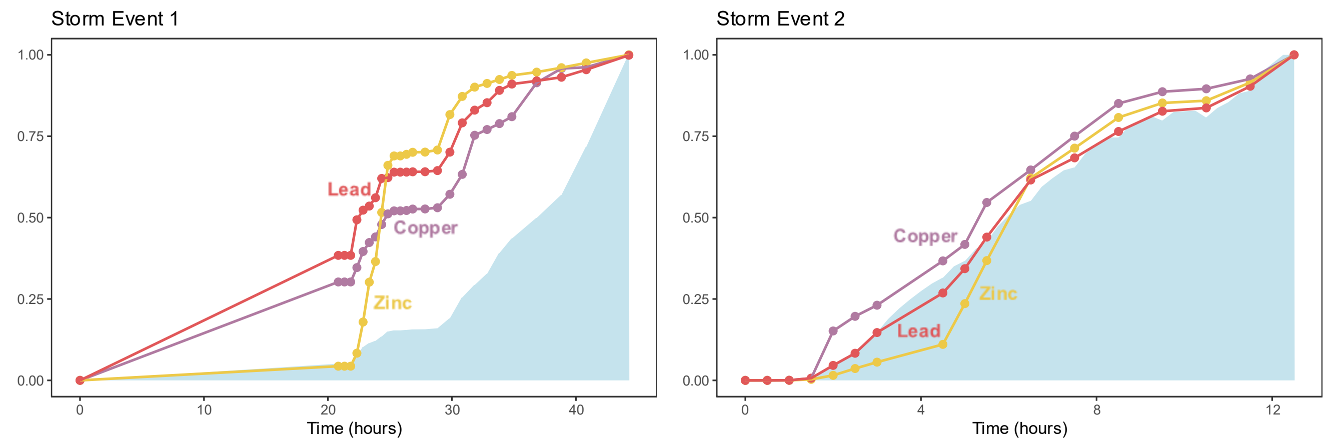

Figure SI-18: Cumulative metals release from storm events 1 and 2

A summary of instantaneous and cumulative data from the three stormwater sampling events is presented below.

Table SI-14: Summary of instantaneous and cumulative contaminant release for each storm event

Storm Event 1		*Instantaneous Sampling*			*Cumulative Values*	
Compound and Source		*n*	*Median ± SD*	*Maximum*	*Total Mass*	*Event Mean*
Copper	Brake pads	26	5.22 (±4.62) µg/L	20.59 µg/L	1.03 g	3.48 µg/L
Zinc	Tire additive	26	73 (± 236.16) µg/L	726.42 µg/L	19.00 g	64.40 µg/L
Lead	Tire wear	26	0.11 (± 0.25) µg/L	0.966 µg/L	0.04 g	0.13 µg/L
Storm Event 2		*Instantaneous Sampling*			*Cumulative Values*	
Compound and Source		*n*	*Median ± SD*	*Maximum*	*Total Mass*	*Event Mean*
Copper	Brake pads	46	5.54 (± 6.41) µg/L	30.27 µg/L	1.45 g	6.82 µg/L
Zinc	Tire additive	46	18.04 (± 18.46) µg/L	64.17 µg/L	5.58 g	26.32 µg/L
Lead	Tire wear	46	0.20 (± 0.07) µg/L	0.37 µg/L	0.049 g	0.229 µg/L
Storm Event 3		*Instantaneous Sampling*			*Cumulative Values*	
Compound and Source		*n*	*Median ± SD*	*Maximum*	*Total Mass*	*Event Mean*
Copper	Brake pads	26	5.45 (±2.39) µg/L	11.51 µg/L	2.773 g	4.691 µg/L
Zinc	Tire additive	26	45.98 (± 25.85) µg/L	97.37 µg/L	19.641 g	33.234 µg/L
Lead	Tire wear	25	0.0185 (± 0.0403) µg/L	0.1686 µg/L	0.024 g	0.041 µg/L
6PPD-Q	6PPD	24	0.0385 (± 0.035) µg/L	0.1302 µg/L	0.022 g	0.038 µg/L
6PPD	Antiozonant	24	0.0626 (± 0.0383) µg/L	0.1756 µg/L	0.038 g	0.064 µg/L
HMMM	Crosslinking agent	26	0.2493 (± 0.203) µg/L	0.8834 µg/L	0.232 g	0.392 µg/L

BTZ	Corrosion inhibitor	25	0.0334 (± 0.0218) µg/L	0.0801 µg/L	0.019 g	0.033 µg/L

Post-processing data for each of the three stormwater sampling events is presented below. MDLs for organics vary as a result of differences in sample volume before solid-phase extraction.

Table SI-15: Concentrations of metals in stormwater samples from storm event one

Sample	**DateTime**	**Copper**	**Zinc**	**Lead**
0A	2025-01-29 22:03:00 UTC	0.887	10.607	0.093
1	2025-01-30 18:53:00 UTC	20.588	54.737	0.966
2	2025-01-30 19:23:00 UTC	3.11	29.9	0.229
3	2025-01-30 19:53:00 UTC	11.034	34.729	0.442
4	2025-01-30 20:23:00 UTC	6.904	115.555	0.633
5	2025-01-30 20:53:00 UTC	5.943	212.511	0.131
6	2025-01-30 21:23:00 UTC	8.021	656.013	0.135
7	2025-01-30 21:53:00 UTC	8.783	597.73	0.482
8	2025-01-30 22:23:00 UTC	9.917	726.419	0.571
9	2025-01-30 22:53:00 UTC	7.454	605.888	BDL(<0.04)
10	2025-01-30 23:23:00 UTC	8.91	520.198	0.609
11	2025-01-30 23:53:00 UTC	9.524	430.454	BDL(<0.04)
12	2025-01-31 00:23:00 UTC	2.945	240.452	BDL(<0.04)
13	2025-01-31 00:53:00 UTC	9.066	237.52	0.071
14	2025-01-31 01:53:00 UTC	2.438	90.13	0.054
15	2025-01-31 02:53:00 UTC	4.321	137.274	0.149
16	2025-01-31 03:53:00 UTC	4.714	229.228	0.239
17	2025-01-31 04:53:00 UTC	3.317	55.879	0.18
18	2025-01-31 05:53:00 UTC	10.988	48.213	0.132
19	2025-01-31 06:53:00 UTC	1.8	21.4	0.086
20	2025-01-31 07:53:00 UTC	0.99	12.085	0.076
21	2025-01-31 08:53:00 UTC	1.676	18.287	0.056
22	2025-01-31 10:53:00 UTC	5.728	10.232	BDL(<0.04)
23	2025-01-31 12:53:00 UTC	2.16	12.489	BDL(<0.04)
24	2025-01-31 14:53:00 UTC	BDL(<0.18)	6.395	BDL(<0.04)
25A	2025-01-31 18:19:00 UTC	0.467	5.621	BDL(<0.04)

BDL: Below detection limit

Table SI-16: Concentrations of metals in stormwater samples from storm event two

Sample	**DateTime**	**Copper**	**Zinc**	**Lead**
1.03	2025-03-08 06:30:00 UTC	7.082	10.278	0.153
1.04	2025-03-08 07:00:00 UTC	4.626	7.107	0.157
1.05	2025-03-08 07:30:00 UTC	5.069	8.516	0.2
1.06	2025-03-08 08:00:00 UTC	4.479	8.474	0.158
1.07	2025-03-08 08:30:00 UTC	30.267	9.812	0.274

1.08	2025-03-08 09:00:00 UTC	6.46	11.663	0.18
1.09	2025-03-08 09:30:00 UTC	4.047	8.952	0.253
1.10	2025-03-08 11:00:00 UTC	5.542	8.572	0.166
1.11	2025-03-08 11:30:00 UTC	6.712	64.169	0.333
1.12	2025-03-08 12:00:00 UTC	14.639	57.946	0.37
1.13	2025-03-08 13:00:00 UTC	5.481	53.664	0.323
1.14	2025-03-08 14:00:00 UTC	6.872	23.424	0.151
1.15	2025-03-08 15:00:00 UTC	7.425	26.896	0.201
1.16	2025-03-08 16:00:00 UTC	4.711	22.476	0.273
1.17	2025-03-08 17:00:00 UTC	6.38	19.223	0.245
1.18	2025-03-08 18:00:00 UTC	2.547	18.042	0.186
1.19	2025-03-08 19:00:00 UTC	4.564	20.246	0.2

BDL: Below detection limit;

Table SI-17: Concentrations of metals and organics in stormwater samples from storm event three

Sample	DateTime	6PPD-Q	BTZ	6PPD	HMMM	Copper	Zinc	Lead
0A	2025-04-05 23:30:00 UTC	BDL(<0.011)	BDL(<0.016)	BDL(<0.097)	0.008	4.556	7.257	0.015
01	2025-04-06 10:00:00 UTC	0.008	0.015	BDL(<0.062)	0.009	10.437	19.255	0.026
02	2025-04-06 11:00:00 UTC	0.014	0.017	BDL(<0.052)	0.01	10.431	9.195	BDL(<0.014)
03	2025-04-06 11:30:00 UTC	BDL(<0.008)	0.014	BDL(<0.067)	0.009	5.451	13.938	0.043
04	2025-04-06 12:00:00 UTC	0.044	0.028	BDL(<0.063)	0.504	11.505	49.254	0.169
05	2025-04-06 12:30:00 UTC	0.13	0.08	0.115	0.883	9.149	62.239	0.076
06	2025-04-06 13:00:00 UTC	0.102	0.071	0.116	0.582	8.134	69.786	BDL(<0.014)
07	2025-04-06 13:30:00 UTC	0.052	**	0.076	0.198	5.994	39.702	0.018
08	2025-04-06 14:00:00 UTC	0.063	0.068	0.082	0.323	7.364	97.372	0.028
09	2025-04-06 14:30:00 UTC	0.049	0.057	0.102	0.294	6.866	56.393	0.015
10	2025-04-06 15:00:00 UTC	0.039	0.045	BDL(<0.058)	0.196	5.444	57.277	BDL(<0.014)
11	2025-04-06 15:30:00 UTC	0.036	0.042	0.074	0.181	6.144	64.973	0.024
12	2025-04-06 16:00:00 UTC	0.038	0.037	0.063	0.22	5.447	48.335	BDL(<0.014)
13	2025-04-06 16:30:00 UTC	NQ	0.033	NQ	0.151	4.961	48.199	BDL(<0.014)
14	2025-04-06 17:00:00 UTC	0.024	0.024	BDL(<0.057)	0.116	4.705	45.981	0.038
15	2025-04-06 17:30:00 UTC	0.034	0.028	BDL(<0.05)	0.213	7.119	35.692	BDL(<0.014)
16	2025-04-06 18:00:00 UTC	0.054	0.035	0.069	0.286	5.755	37.743	0.04
17	2025-04-06 18:30:00 UTC	0.053	0.055	0.13	0.391	5.59	69.43	0.061
18	2025-04-06 19:00:00 UTC	0.042	0.051	0.079	0.389	4.796	75.363	0.018
19	2025-04-06 20:00:00 UTC	0.13	0.072	0.176	0.249	4.758	90.501	0.092
20	2025-04-06 21:00:00 UTC	0.033	0.034	0.092	0.264	5.142	39.158	0.019
21	2025-04-06 22:00:00 UTC	NQ	0.021	NQ	0.236	2.558	19.021	BDL(<0.014)
22	2025-04-06 23:00:00 UTC	0.011	0.016	BDL(<0.046)	0.453	3.783	14.014	BDL(<0.014)
23	2025-04-07 00:42:00 UTC	0.014	0.017	BDL(<0.054)	0.47	4.85	24.37	0.115

**: Data point removed due to possible presence of particle; NQ: Not quantified; BDL: below detection limit

SI-3.0: Citations

1 Total Precipitation - Annual data for Vancouver, https://vancouver.weatherstats.ca/charts/precipitation-yearly.html, (accessed 3 February 2026).

2 UNEP Publications, *SIDS Initial Assessment Report For SIAM 18*, 2004.

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4 PubChem, 1H-Benzotriazole, https://pubchem.ncbi.nlm.nih.gov/compound/7220, (accessed 30 January 2026).

5 *Screening assessment: Triazines and Triazole group : Chemical Abstracts Service Registry Numbers 61-82-5, 2893-78-9, 3089-11-0*, Government of Canada = Gouvernement du Canada, Ottawa, 2021.

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7 CompTox Chemicals Dashboard, https://comptox.epa.gov/dashboard/chemical-lists/TIRECRUMB, (accessed 1 October 2025).