University at Buffalo The State University of New York

Chemical Leaching from Scrap Tire-Derived Commercial Products

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Auto Heaven

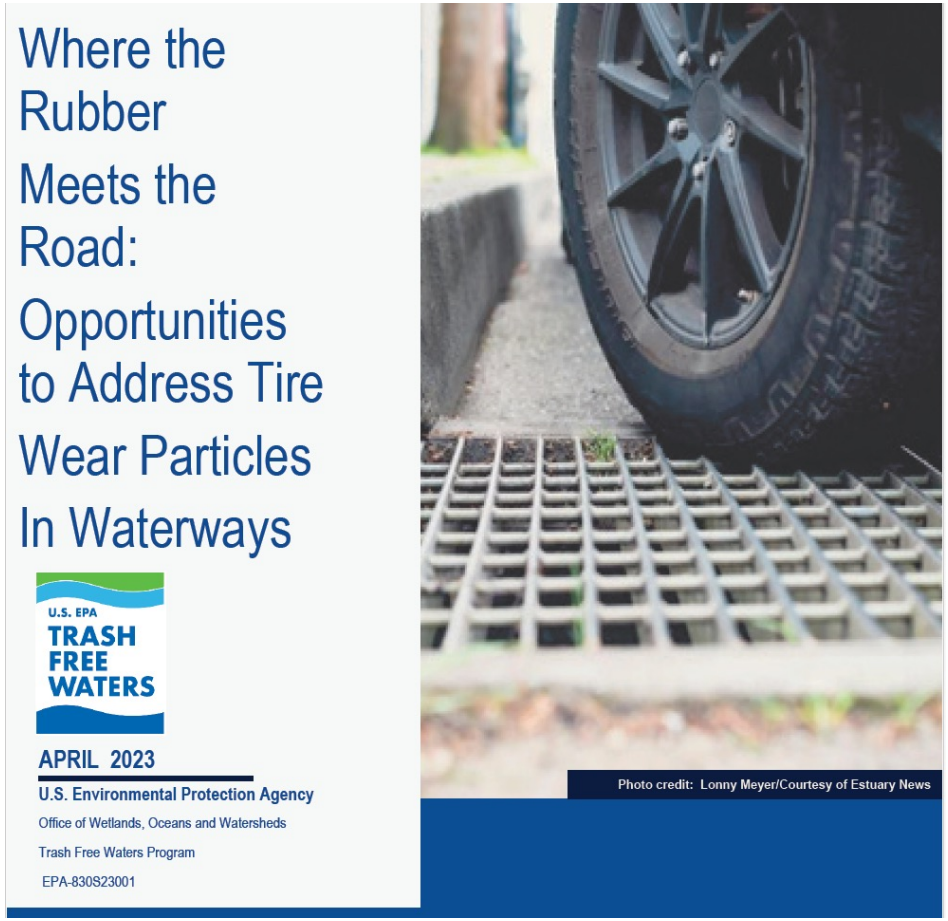

BIGGER, BOLDER, BETTER GARDENS
Vigoro
100% RECYCLED
PREMIUM
RUBBER MULCH
BLACK | 2x coverage of wood mulch per cu ft
helps prevent weeds
eliminates annual mulching
reduces injuries from falls
12-YEAR
COLOR GUARANTEE
COVERS 6.4 SQ FT
TO 1.5 IN DEPTH
PREMIUM RUBBER MULCH
12-YEAR COLOR GUARANTEE
Home Depot


MN DOT


Recycled Rubber Coalition


SportsGrass

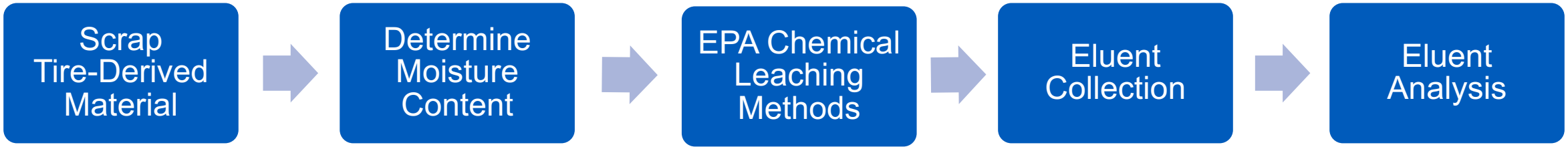
Work builds upon tire wear particle research, specifically considering another group of tire-derived materials



APPENDIX A: PARTICIPATING ORGANIZATIONS

Alliance for Automotive Innovation
Bay Area Clean Water Agencies
Bellingham, Washington, and Washington State 6PPD-quinone Subgroup
Brown & Caldwell
California Association of Sanitation Agencies
California Stormwater Quality Association
Central Contra Costa Sanitary District
City of Seattle
College of Charleston
Goodyear Tire & Rubber Company
Hoopa Valley Tribe
National Asphalt Paving Association
National Association of Clean Water Agencies
New England Interstate Water Pollution Control Commission
New Jersey Department of Environmental Protection
North Carolina Department of Transportation's Highway Stormwater Program
Ocean Conservancy
Oregon Department of Transportation
Oregon State University
Pew Charitable Trusts
Puget Sound Partnership
San Francisco Bay Regional Water Quality Control Board
San Francisco Estuary Institute
Talk Strategies
Texas Commission of Environmental Quality
U.S. Environmental Protection Agency (Office of Wetlands, Oceans and Watersheds, Office of Wastewater Management, Office of Research and Development, regional offices and laboratories)
U.S. Tire Manufacturers Association
Virginia Department of Transportation
Washington State Department of Ecology
Zero Waste Washington

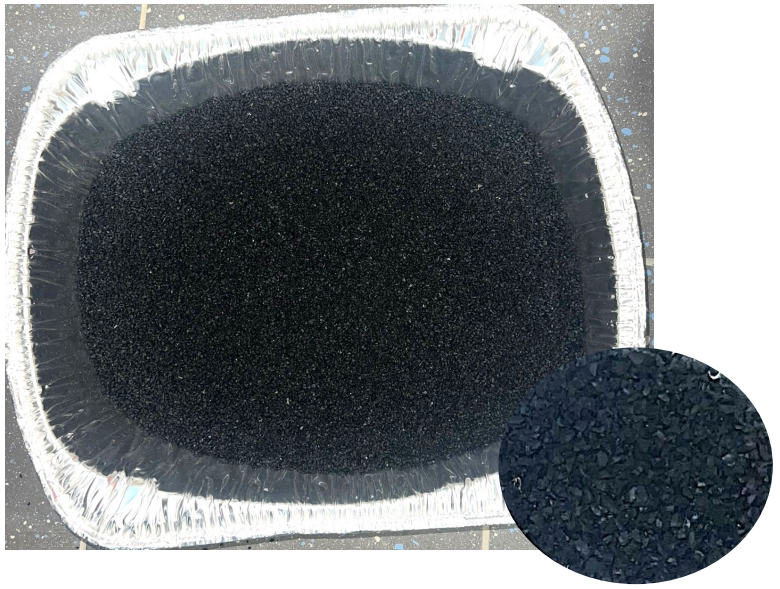
Research Approach



Scrap Tire-Derived Commercial Products

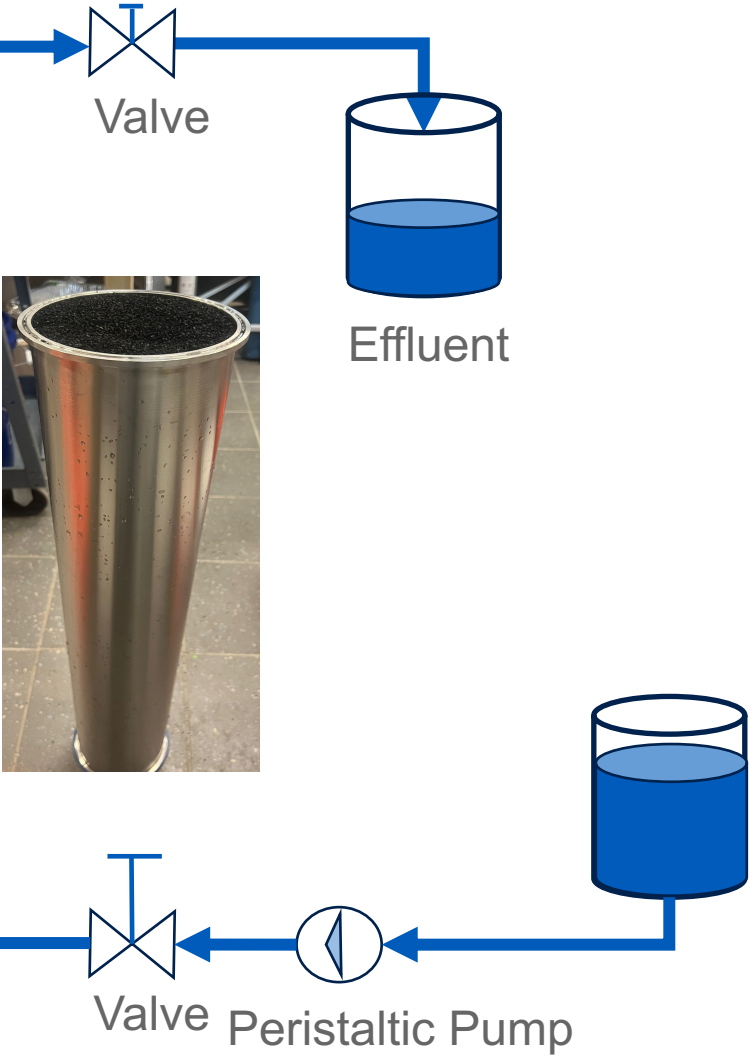
Rubber Aggregate
(with Wire & Fiber)
Avg Length = 5-7 cm
< 1 wt% moisture

Rubber Mulch
(with Fiber)
Avg Length = 2-5 cm
< 1 wt% moisture



Crumb Rubber
Avg Diameter = 0.5 mm
< 1 wt% moisture

Up-Flow Percolation Column Test – EPA Method 1314

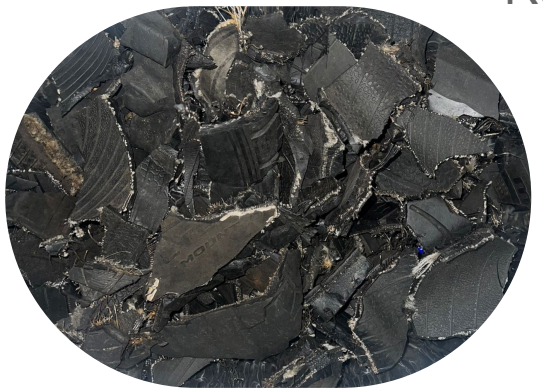


Crumb Rubber

Three Percolation Columns in Parallel

Monolith Test – EPA Method 1315

Rubber Aggregate
or
Rubber Mulch



Stainless Steel
Mesh Cage

Container Holder with
PVC Spacer

Experimental Setup for
Soaking in Type 1 Water

Sampling Intervals for Testing

Fraction Label	End Point ΣL/S	Fraction Volume [mL]	Total Test Time (days)
T01	0.2	1674	0.3
T02	0.5	2527	0.7
T03	1	4211	1.3
T04	1.5	4211	2.0
T05	2	4211	2.7
T06	4.5	21055	6.0
T07	5	4211	6.7
T08	9.5	37899	12.7
T09	10	4211	13.3

Crumb, Percolation, **1314**

Fraction Label	Interval Contact Time [d)	Total Contact Time [d]
T01	0.08	0.08
T02	0.96	1.04
T03	0.96	2.0
T04	5.0	7.0
T05	7.0	14.0
T06	14	28.0
T07	14	42.0
T08	7.0	49.0
T09	14.0	63.0

Aggregate/Mulch, Monolith, **1315**

GC-MS/MS: Gas Chromatography-Tandem Mass Spectrometry
HLB: Hydrophilic-Lipophilic Balance
ICP-MS: Inductively Coupled Plasma-Mass Spectrometry
ICP-OES: Inductively Coupled Plasma – Optical Emission Spectroscopy
LC-MS/MS: Liquid Chromatography-Tandem Mass Spectrometry
ORP: Oxidation-Reduction Potential
SPE: Solid Phase Extraction

Sample Processing and Preparation

Split, Filter, pH, Conductivity, ORP

Tire Materials

- Spike $^{13}C/^{2}H$ surrogates
- Concentrate (HLB SPE)
- Elute analytes, evaporate
- Reconstitute, spike internal standards
- LC-MS/MS Analysis

PAHs & Phthalates

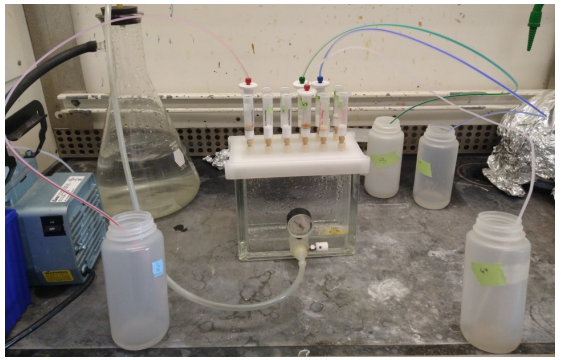
- Acidify, dechlorinate
- Spike $^{13}C/^{2}H$ surrogates
- Concentrate (C_{18} SPE)
- Elute, dry, evaporate
- Reconstitute, spike internal standards
- GC-MS/MS Analysis

Chlorinated Paraffins

- Spike ^{13}C-labelled surrogates
- Direct-inject high-resolution MS analysis

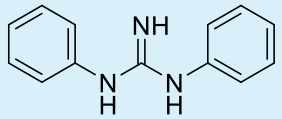
Metals

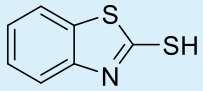
- Acidify to 2% HNO_3
- Spike 10 ppb ^{103}Rh
- ICP-MS/ICP-OES Analysis

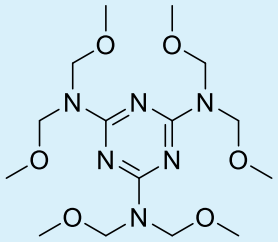


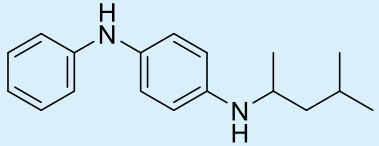
Target Analytes and Methods

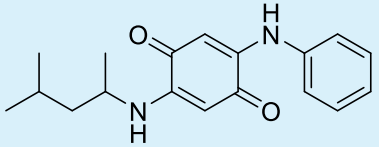
Tire Materials


1,3-diphenylguanidine


2-mercaptobenzothiazole


hexamethoxymethylmelamine


N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine (6PPD)


6PPD-quinone (6PPD-Q)


LC-MS/MS


GC-MS/MS


HR-MS

Chlorinated Paraffins

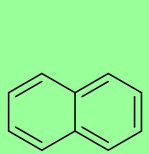
Total mass
(C_{10}-C_{13}), (C_{14}-C_{17})

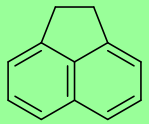
Metals

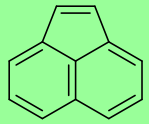
Ag, As, Ba, Cd, Cr, Co, Hg, Pb, Se, Zn

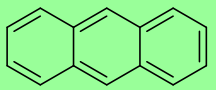

ICP-MS

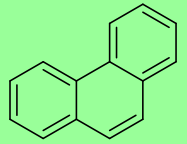
PAHs and Phthalate Esters

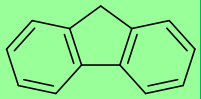

naphthalene

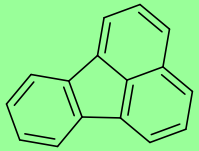

acenapthene

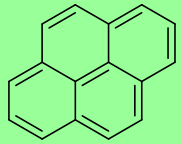

acenaphthalene

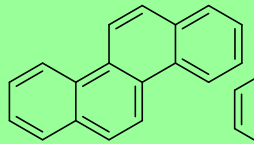

anthracene

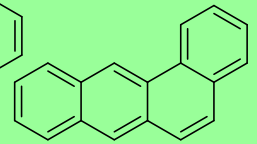

phenanthrene

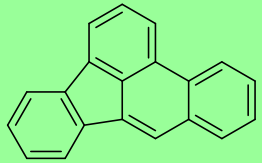

fluorene

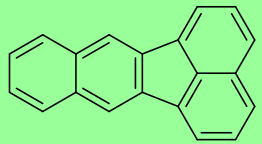

fluoranthene

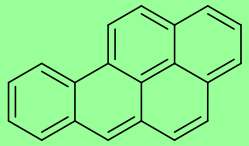

pyrene

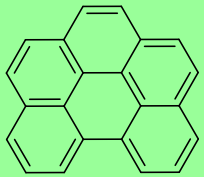

chrysene

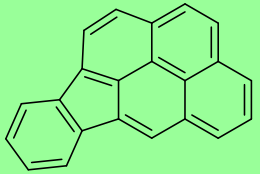

benzo[a]anthracene

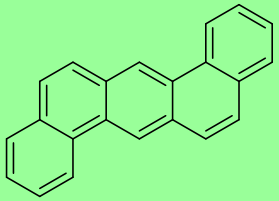

benzo(b)fluoranthene

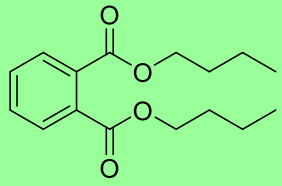

benzo(k)fluoranthene

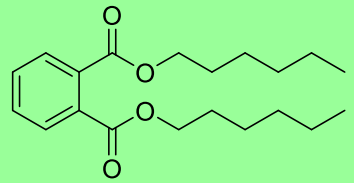

benzo(a)pyrene

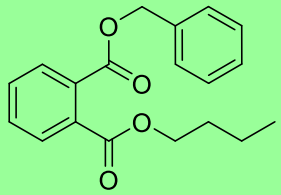

benzo[g,h,i]perylene

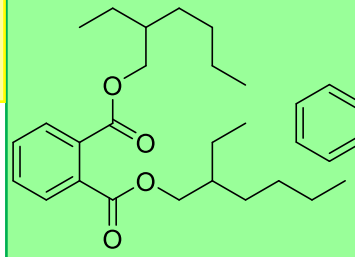

indeno[1,2,3-cd]pyrene

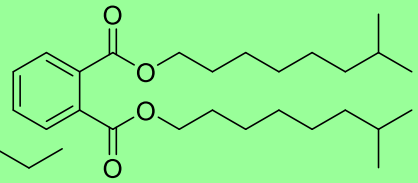

dibenz[a,h]anthracene

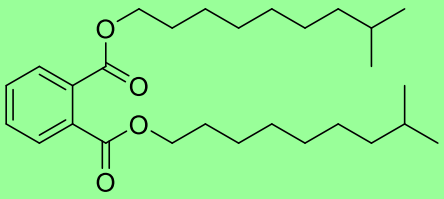

di-n-butyl phthalate


di-n-hexyl phthalate

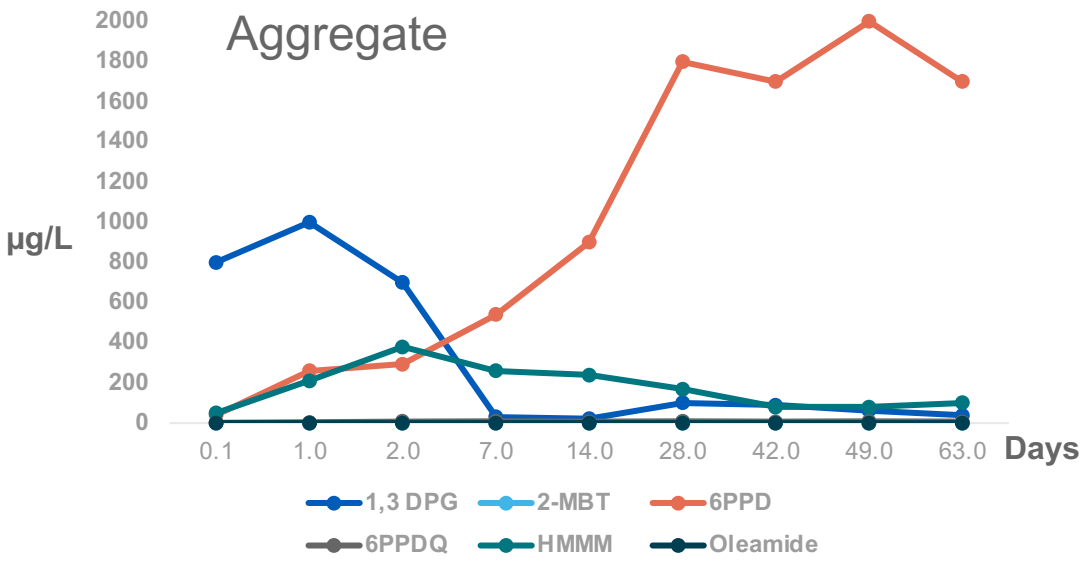

benzyl butyl phthalate

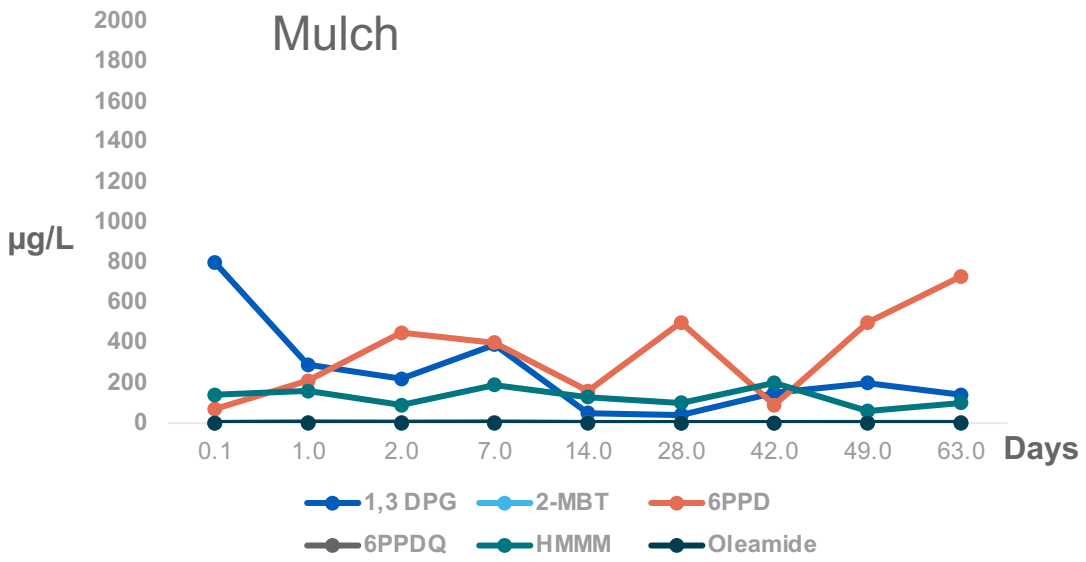

di(2-ethylhexyl) phthalate


di-isononyl phthalate

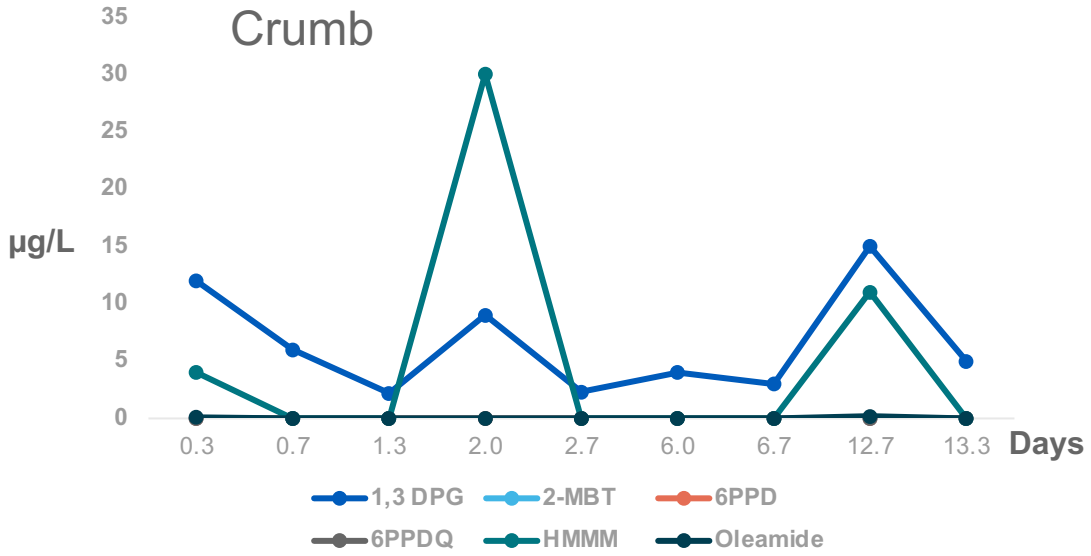

di-isodecyl phthalate

Tire Derived Materials

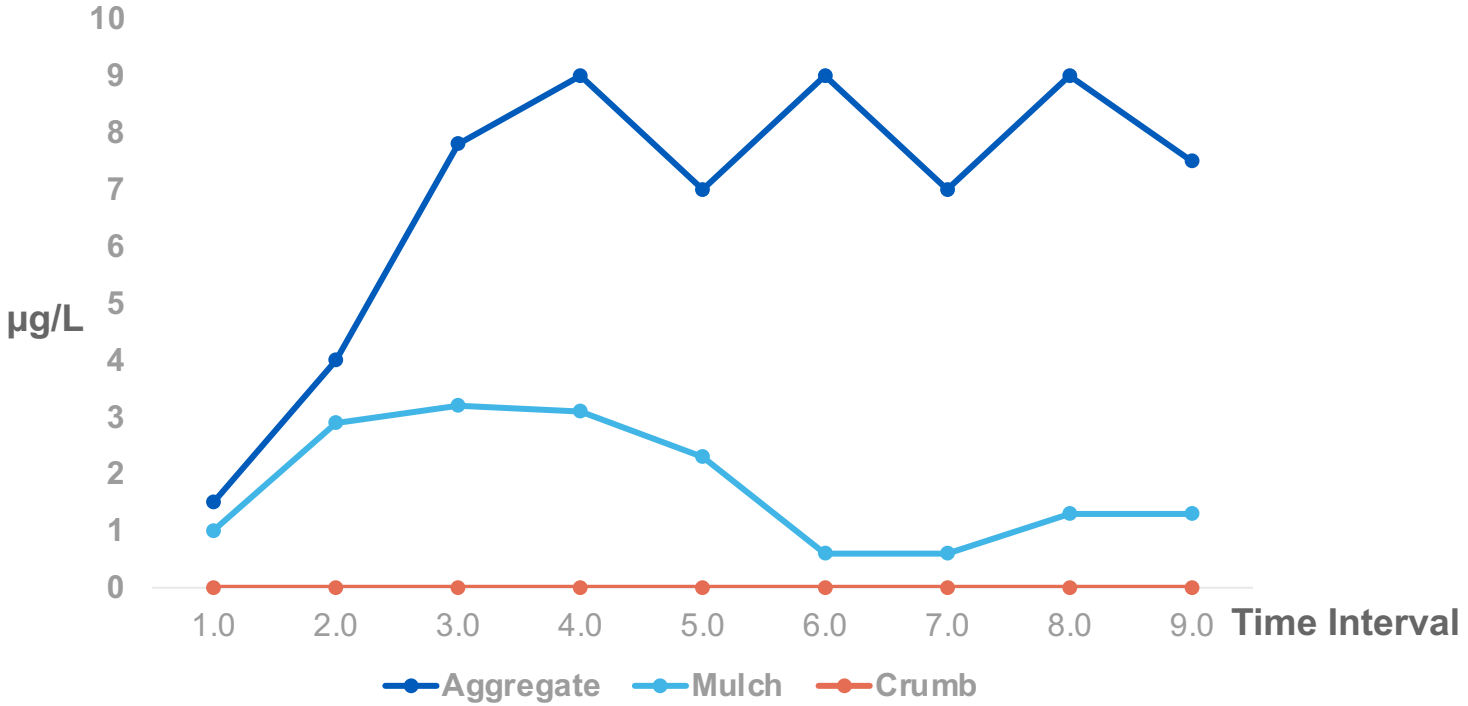




Note:
Crumb has different scales;
Tested with different method



Tire Derived Materials – 6PPDQ

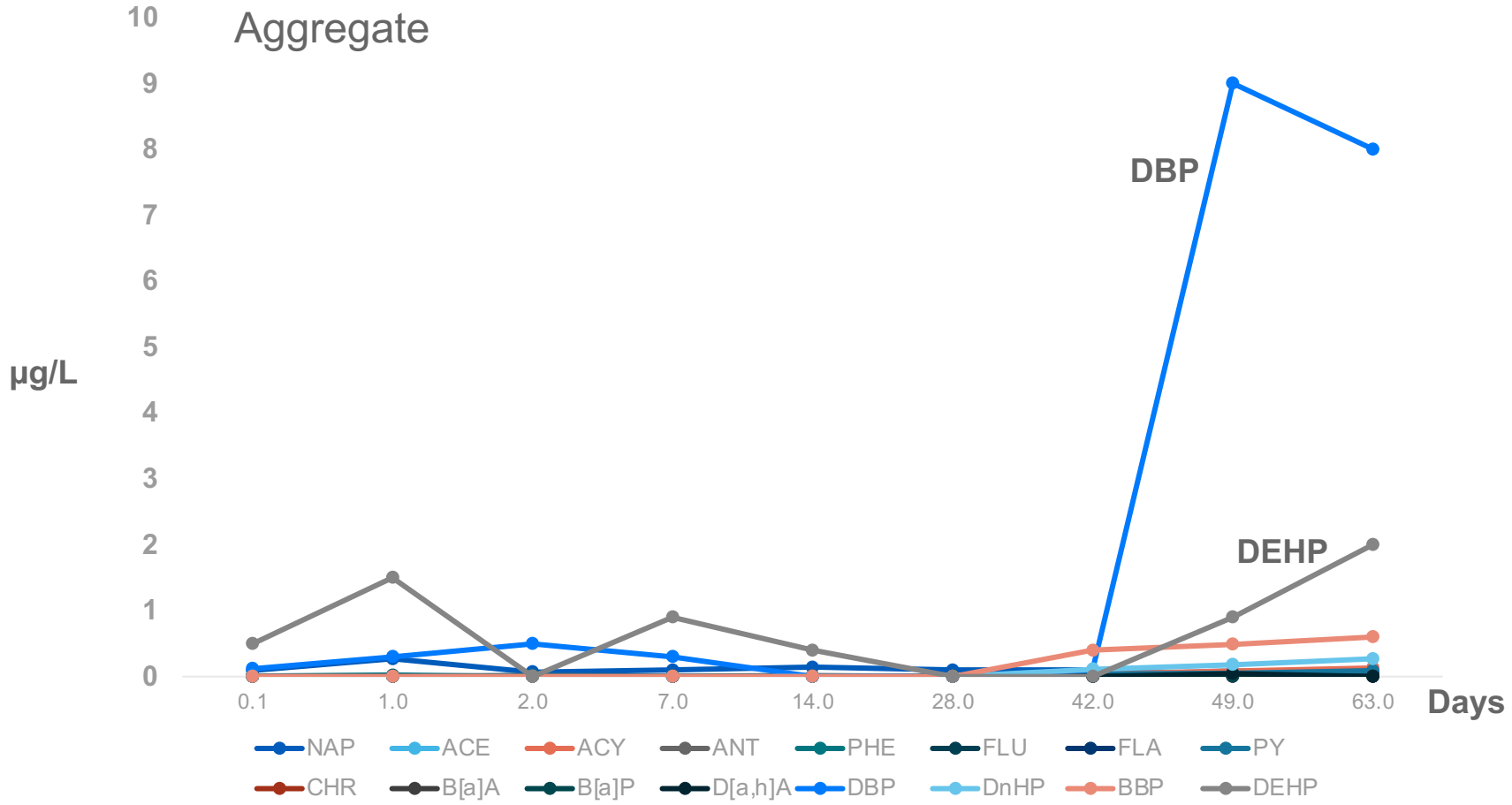


PAHs & Phthalate Esters

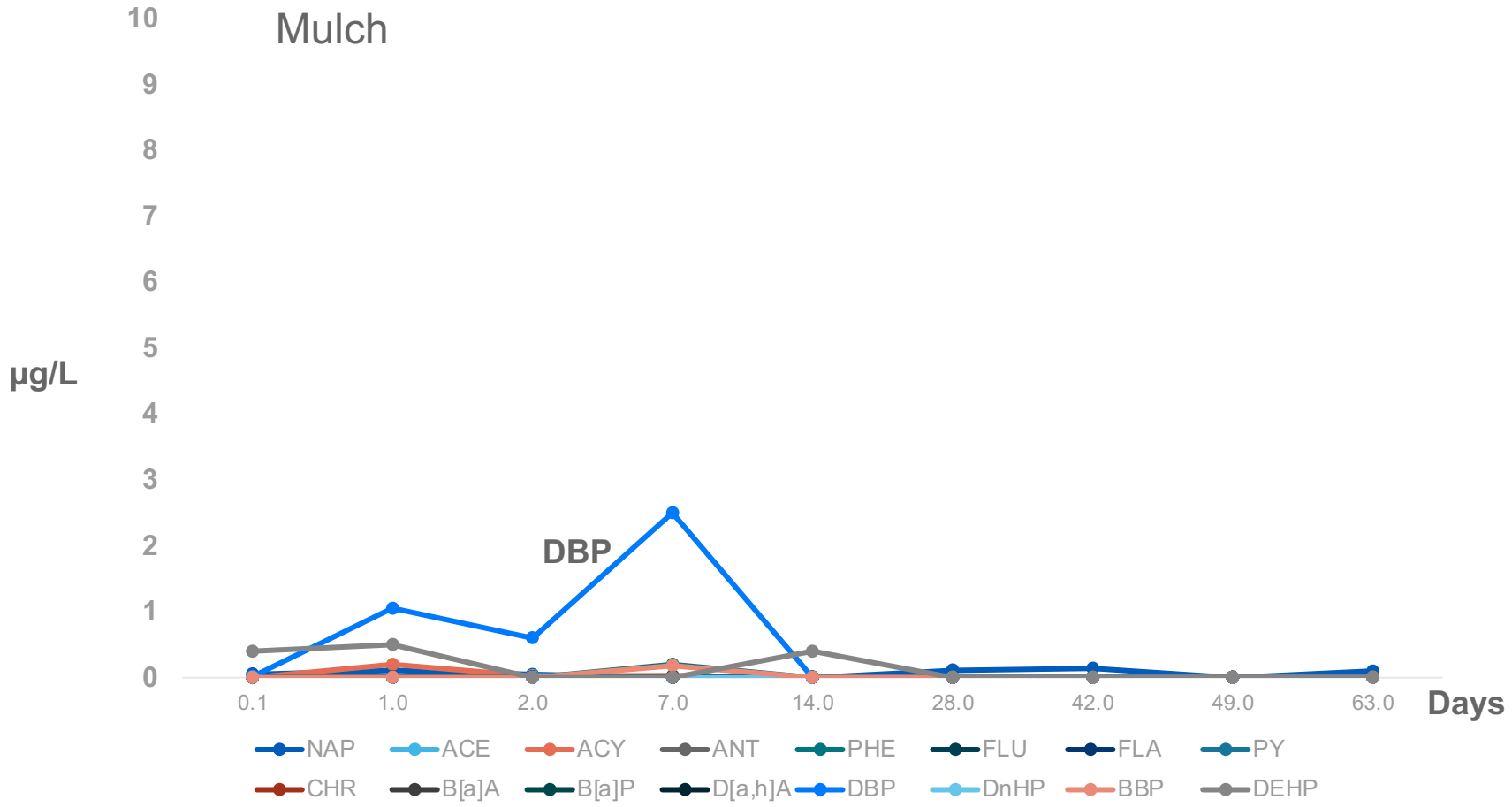
All Samples: Non-Detects or Below the Limit of Quantitation for:

B[b]F
B[k]F
B[ghi]P
I[123-cd]P
DiNP
DiDP

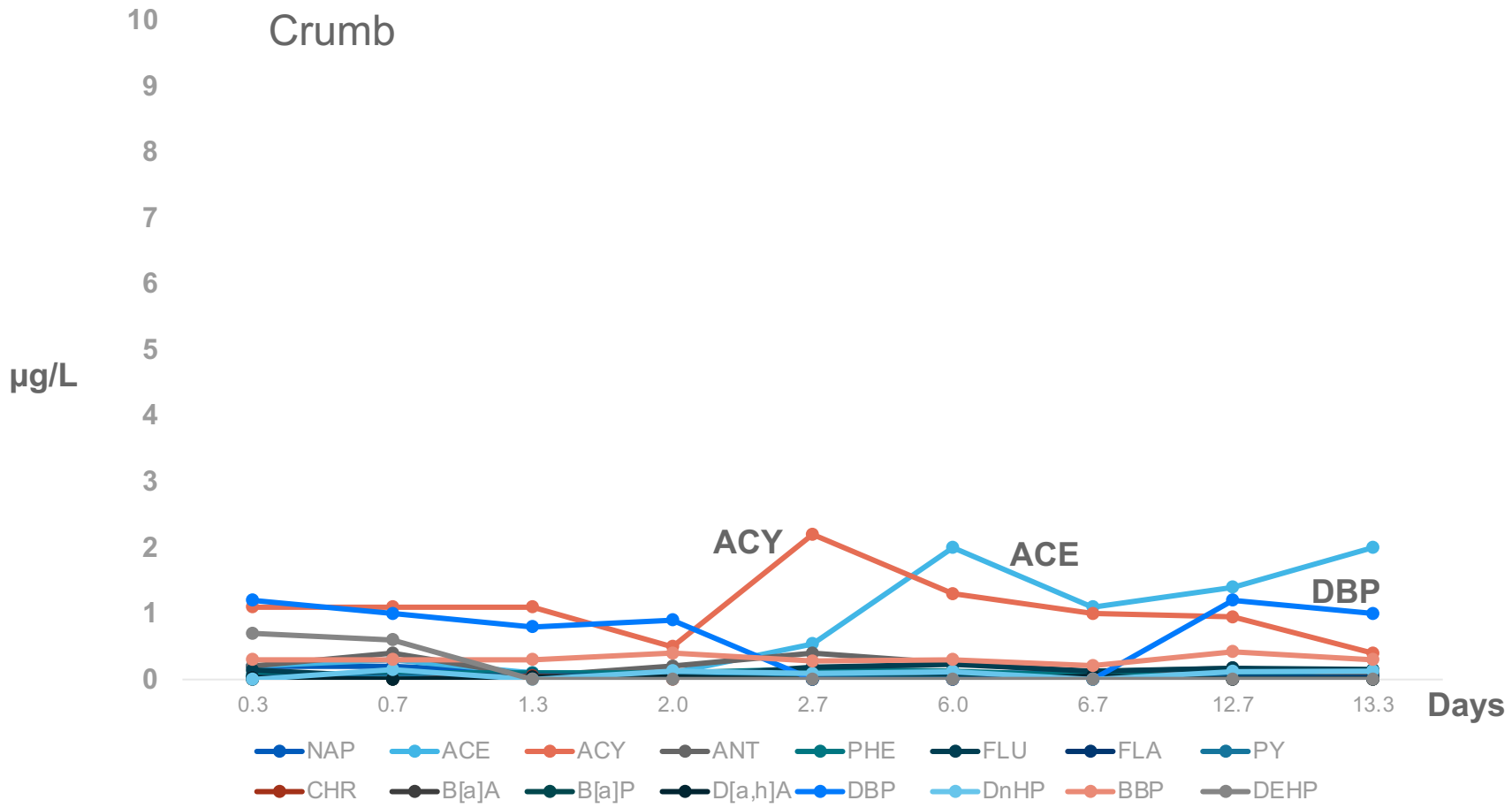
PAHs & Phthalate Esters – Aggregate



PAHs & Phthalate Esters – Mulch



PAHs & Phthalate Esters – Crumb



Short/Medium Chain Paraffins

No paraffins detected in any of the samples!

Metals

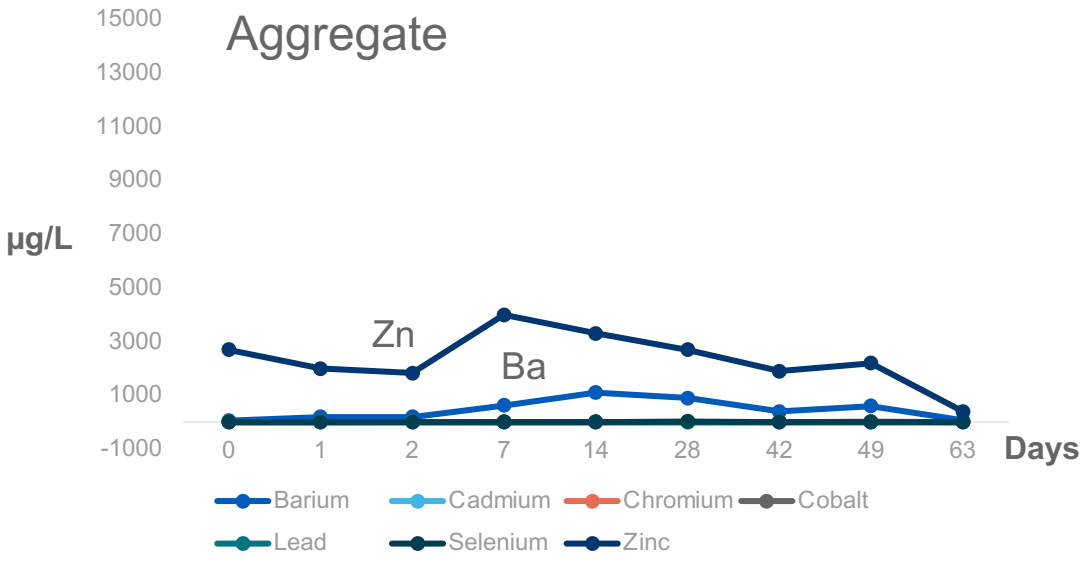
All Samples: Non-Detects or Below the Limit of Quantitation for:

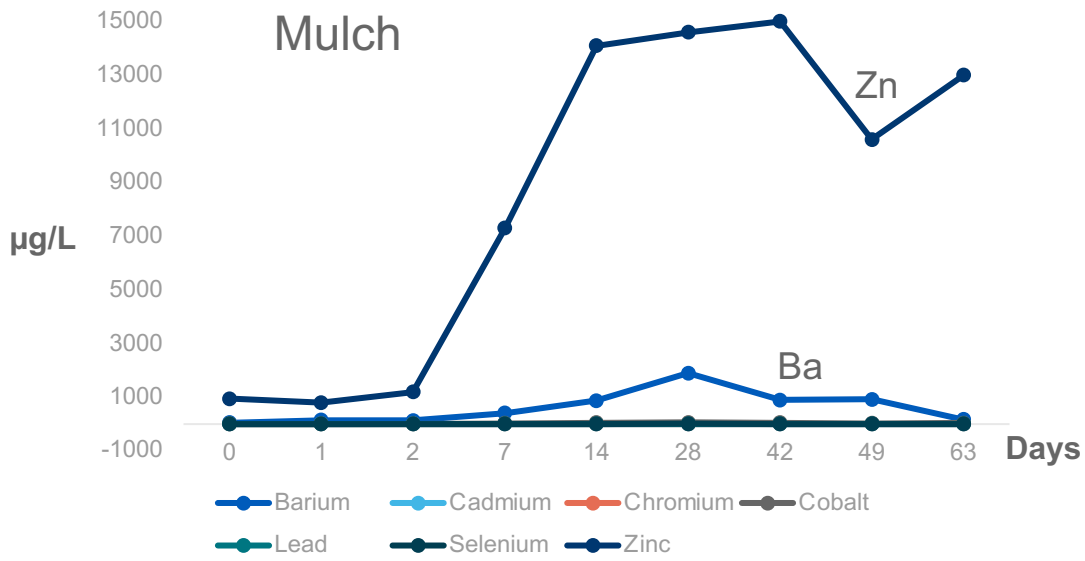
Arsenic

Silver

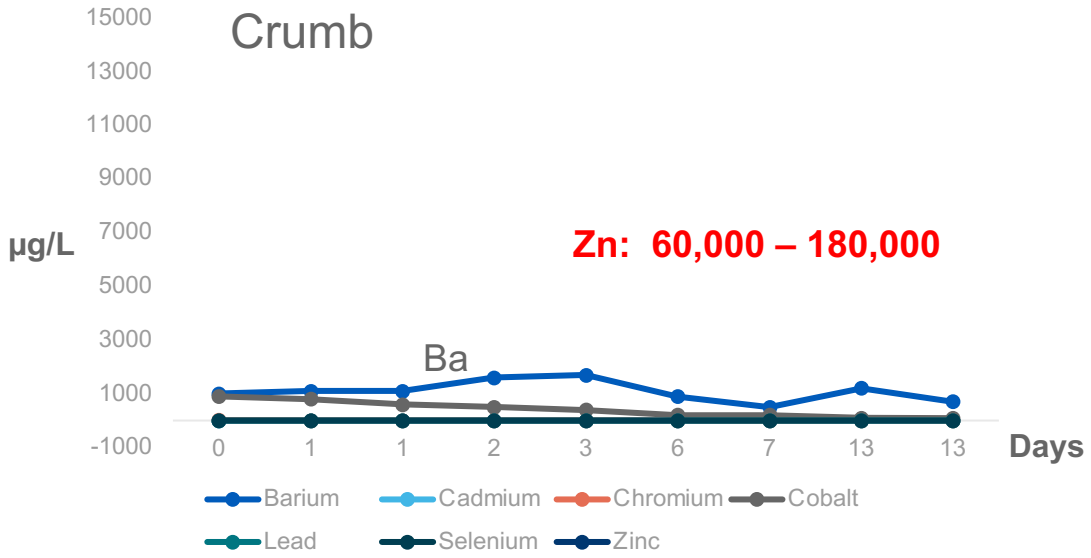
Mercury

Metals





Note:
Crumb tested
with different method



Zn: 60,000 – 180,000

Conclusions

- 6PPD and 6PPDQ consistently below limit of quantitation for crumb rubber
- Tire derived aggregate shows most leaching of tire-linked chemicals

- Crumb rubber leachate consistently contained the most PAHs and PEs
- With exception of limited benzon[a]pyrene and dibenz[a,h]anthracene detection in crumb rubber, higher molecular weight PAHs not detected

- Chlorinated paraffins not detected and not considered a priority chemical of concern

- Barium and Zinc were substantial in all leachate from all materials

Thank You!

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