

Introduction

Phthalates are common plasticizers found in everyday items from single use plastics, PVC pipes, vinyl flooring, medical devices, toys, and electronics. Phthalates increase the plastics flexibility, durability, and temperature range (1). Since they are not chemically bound to polymers, they are therefore able to leach out. Over the years, more phthalates have been synthesized. From 2000 to 2010, global production increased from 3.5 to 6 million tons/yr (2). Phthalates have been found in the air, ocean, dust, wastewater, cosmetics, and food (3, 5-15). Exposure to phthalates is associated with allergies, asthma, rhinoconjunctivitis, reduced birth weight, and endocrine disruptions (3, 15, 16, 17, 18). Due to increasing awareness of the environmental and health impacts of phthalates within the last thirty years, regulations have been implemented across the globe for particular phthalates. In the US, for example, 8 phthalates are regulated. This has caused a shift to alternative phthalates in the global market (3). We developed a selective ion monitoring (SIM) gas chromatography mass spectrometry (GCMS) method on an Agilent 8890 5977B GCMS for quantitation of 27 phthalates and 3 alternative phthalates for passive samplers and biological matrices. See table 2 for full analyte list.

Method Validation and Optimization

- Oven profile
Started with oven profile from Takeuchi et al (2014) (Table 1)
Broad peaks for high molecular weight (MW) compounds
Series of oven profile experiments
Reduced hold on 3rd ramp to improve high MW compounds except ditridecyl phthalate
Fourth ramp was added to improve ditridecyl phthalate
5 minute post-run added to reduce silicone passive samplers matrix carry over
Final oven profile achieved Gaussian peak shape with a minimum of 15 scans across a peak for all compounds (Table 1 and Table 3)

Table 1. Initial versus final oven profile

Table with 2 columns: Initial Oven Profile and Final Oven Profile, detailing temperature and hold times.

Table 2. Full compound list with peak number, structure, physical and chemical properties, and limits of detection (LODs) and of quantitation (LOQs). Orange compounds are alternative plasticizers.

Table with columns: Peak #, Compounds, CAS, Structure, Mol Wt (g/mol), Log Ko, Log Kow, Henry's Law (ppb), LOD (ppb), LOQ (ppb). Lists 27 phthalates and 3 alternatives.

Table 3. Full GC/MS settings for method

Table with 2 columns: Description and Conditions, detailing instrument, column, temperature, inlet, scan mass range, and injection volume.

Calibration curve

- Multi level calibration curve
0.25 ng/μL to 101 ng/μL and 2 ng/μL to 25 ng/μL
Average r² of 0.995
30 compounds on a linear fit
5 compounds on a quadratic fit.

LODs and LOQs

- Ran 7 aliquots of the full curve the first day, 4 of those were run again on the following 2 days for n=15
Limits of detection (LODs) were calculated by multiplying the standard deviation by the one-sided student t value for the 99% confidence interval
Average LOD is 83 pg/μL
Minimum is 1.6 pg/μL
Maximum is 231 pg/μL
Limits of quantitation (LOQs) were calculated by multiplying the rounded LOD value by 5
Average LOQ is 535 pg/μL
Minimum is 250 pg/μL
Maximum is 1250 pg/μL
Average percent recoveries for the targets: 111%
LODs and LOQs values are shown in Table 1

Storage Stability

- To demonstrate storage stability, 3 aliquots of the same full curve mix were taken 4 times at 0, 12, 50, 133 days.
Percent recovery (Figure 2)
Average at 0 days: 84%
Average at 12 days: 87%
Average at 50 days: 94%
Average at 133 days: 86%
All compounds are stable for at least 133 days

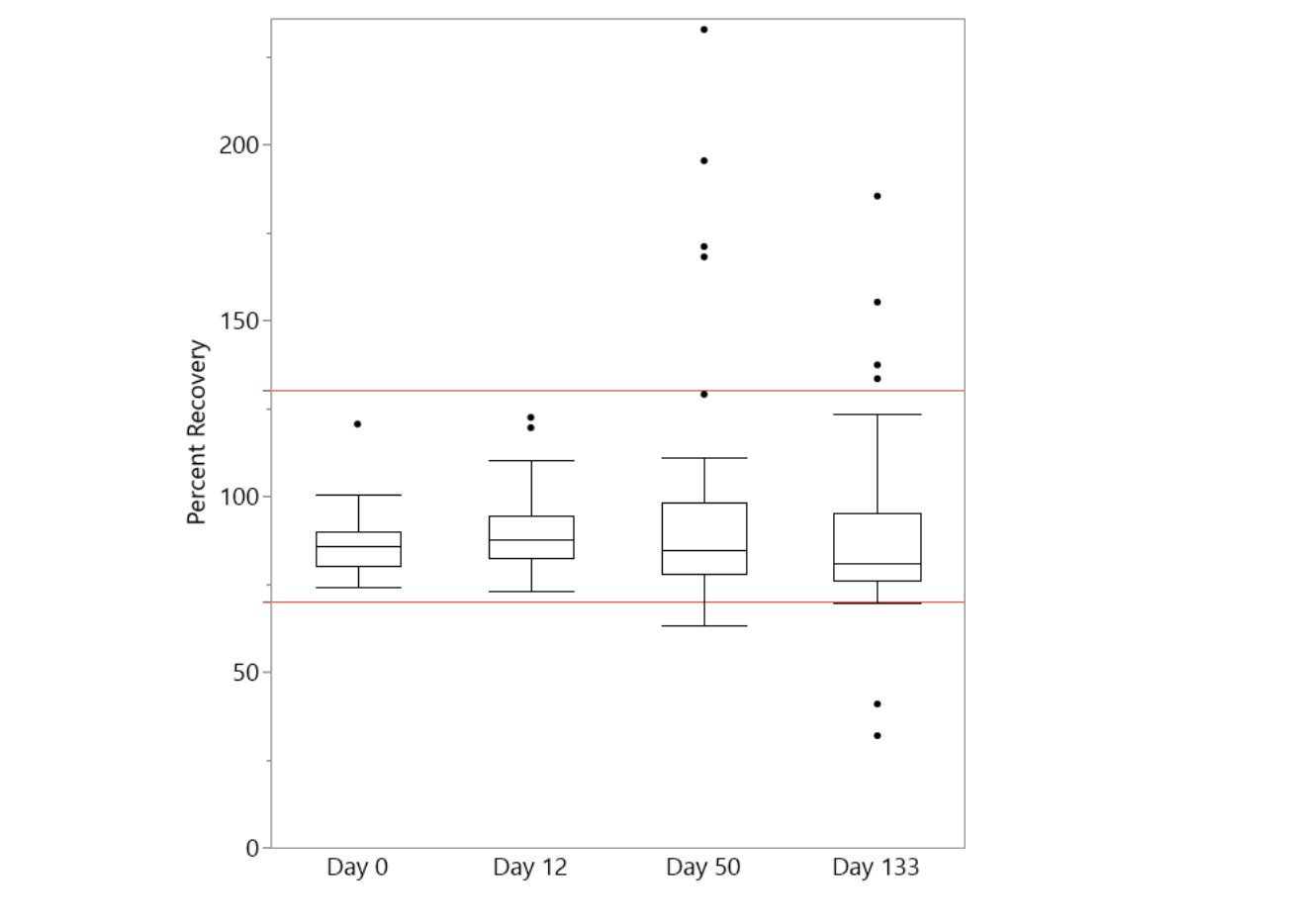


Figure 2. Storage stability. Red lines are at 70% and 130% FSES DQO's

Phthalates and Phthalate Alternatives Analysis Using Gas Chromatography Mass Spectrometry for Wristband and Environmental Passive Sampling Matrices

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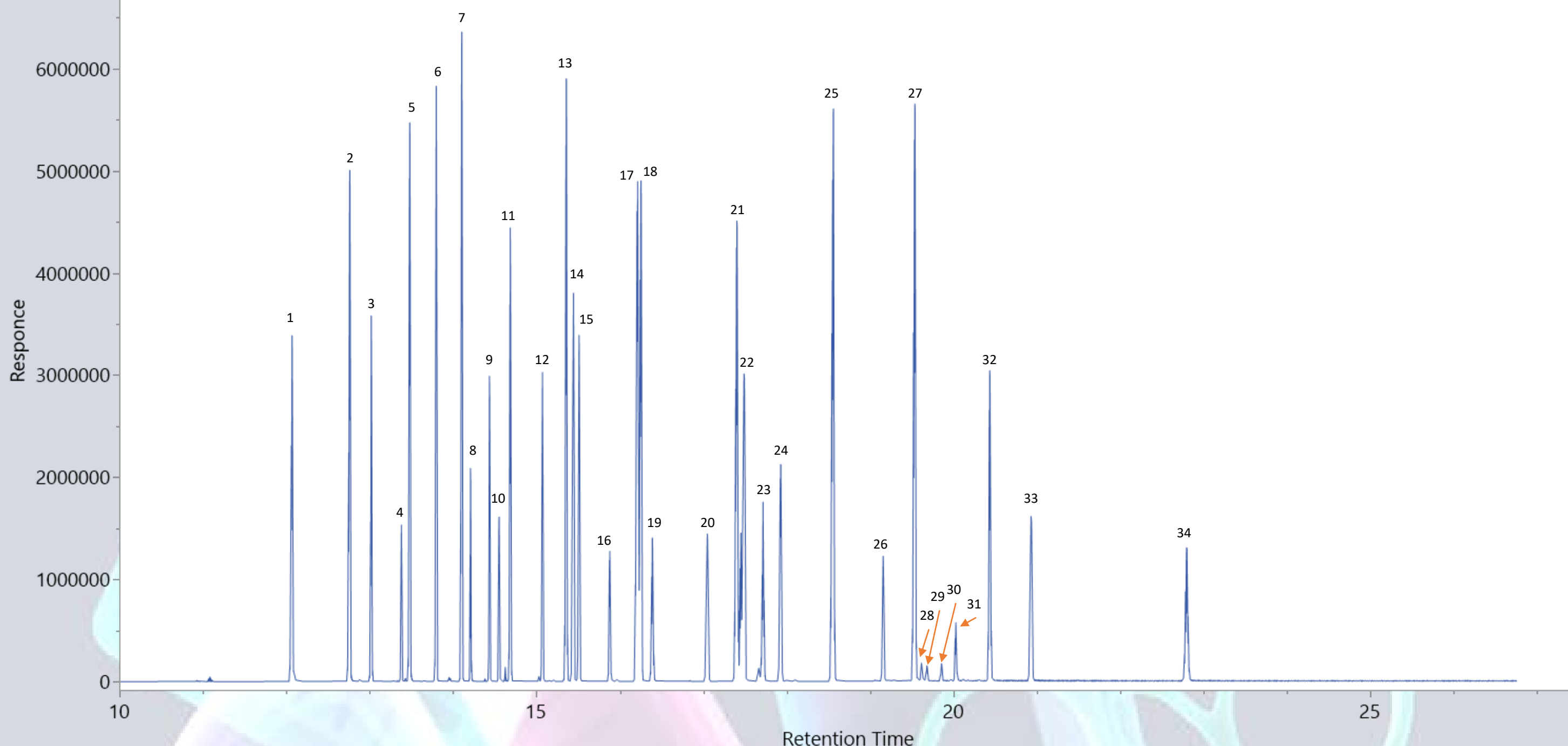
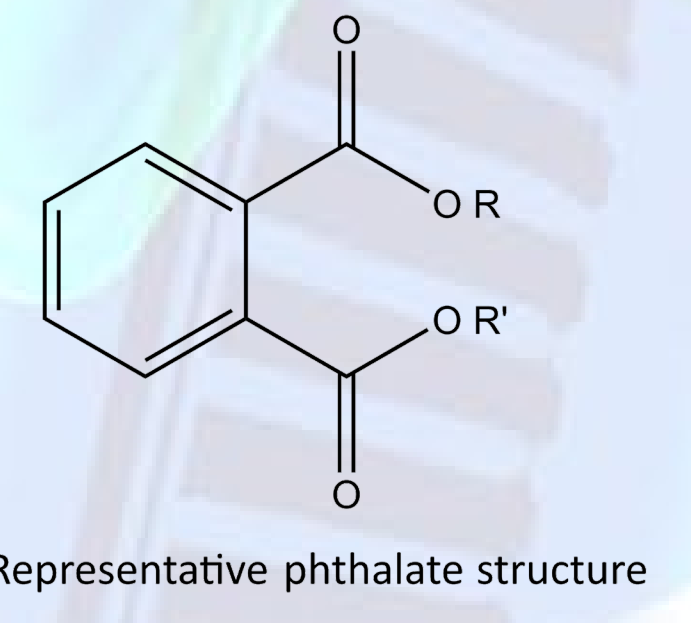


Figure 1. Full chromatogram. Target peaks are numbered. See Table 2 for targets names and structures

- Phthalates are in PVC, personal care products, medical devices, vinyl flooring, perfumes, sanitary pads, diapers, insect repellent, plastic cling film, etc.
Out of the 7766 wristbands analyzed by FSES, 5751 hits for phthalates.
Exposure associated with asthma, allergies, and endocrine disruptions.
This method is a targeted analysis for over 30 phthalates and phthalate alternatives to be used with passive sampler technology as well as with biological matrices.



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Method Validation and Optimization (Continued)

- SPE
This method was built for analysis of passive samplers, some of which can be deployed on humans. Removal of fatty acids and other interferences was explored using solid phase extraction (SPE)
C18, florisil, and primary secondary amine (PSA) columns were tested with a 15 pg/μL matrix spike. (Figure 3)
C18 was effective for smaller MW, however the higher MW compounds percent recovery was 0%.
Florisil had average percent recovery of 90% and PSA had 96%
PSA had the highest number of compounds within FSES detection quantitation objectives (DQO's) (91%) compared to florisil (77%) and C18 (68%)
PSA was selected for SPE

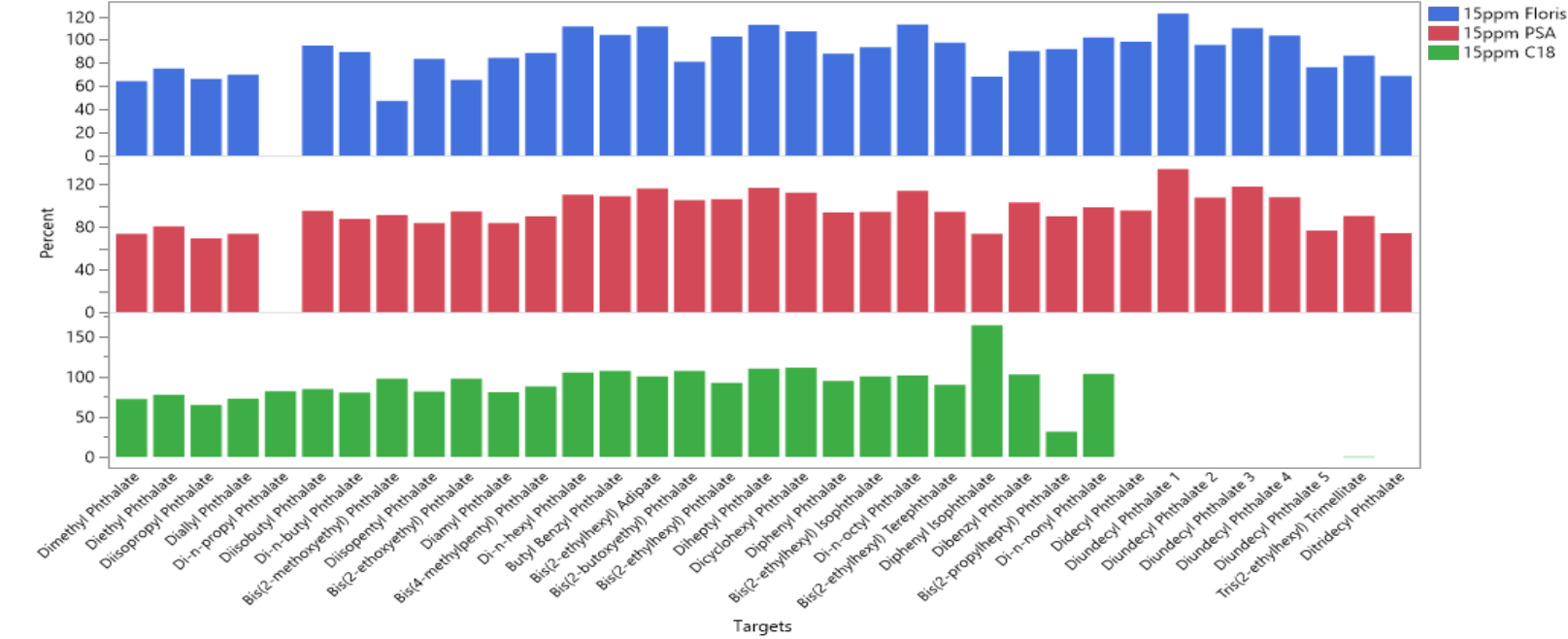


Figure 3: Comparison of the percent recoveries of C18, Florisil, and PSA SPE cartridges. Di-n-propyl phthalate was detected for both Florisil and PSA but 15 ng/μL is over its calibration range of 0.25 ng/μL -10 ng/μL. It is a quadratic fit, and the ratio of compound to ISTD was 5.3 which is over the vertex of 4.55 and therefore no concentration was given by MassHunter software.

Table 4. Method comparison table comparing this method with 11 other phthalate method papers

Table with columns: Method Paper, This Method, EPA Method 8061A, Guo et al, 2010, Gimeno et al, 2012, Feng et al, 2013, Raveane et al, 2013, Gimeno et al, 2014, Ye et al, 2014, Orecchio et al, 2015, Dong et al, 2020, Kartalovic et al, 2021, Sambolino et al, 2022. Rows include Number of compounds, Alternatives, Unique compounds, Matrices, Run time, Percent Recovery, LOD (μg/ml), and LOD Calculation method.

Method Comparison

- Of the 11 phthalate method papers identified, the number of phthalates in the method ranged from 6 to 21 with run times of 16 minutes to 40 minutes. (Table 4)
This method has at least 10 more compounds and kept the total run time comparable with most other published phthalate methods.
Our method is one of 3 methods which incorporates alternatives plasticizers.
This method had 9 unique compounds: diamyl phthalate, bis (4-methylpentyl) phthalate, diheptyl phthalate, diphenyl isophthalate, dibenzyl phthalate, bis (2-propylheptyl) phthalate, didecyl phthalate, diundecyl phthalate, ditridecyl phthalate.
The only other method to incorporate unique phthalates was Gimeno et al (2014): DINCH and acetyl tributyl citrate.

Real World Samples

Table 5. Data for environmental samples to evaluate the method. Table is separated out by sample type and further delineated by sample or matrix spike.

Table with columns: Sample Matrix, Sample n, and various compound concentrations in ppm. Rows include Urban Children's Wristband, Urban Children's Wristband MS, 48 hour Adult SI Wristband, 48 hour Adult SI Wristband MS, Rural Children's Wristband, Rural Children's Wristband MS, Silicone Breast Explants, Silicone Breast Explant MS, Packaged Smoked Salmon, Packaged Smoked Salmon MS, Fresh Smoked Salmon, Fresh Trout, Roofers, Roofers MS, Fire Test Chamber (SI) Phthalates, Fire Test Chamber (SI) Wristband MS.

- To evaluate the method, we analyzed breast explants, smoked salmon stored in plastic from 6 stores, and silicone wristbands from urban and rural children, pregnant people, and roofers.
Roofers – hits for high MW compounds seen in building material.
Wristbands worn for 48 hours by pregnant people had high hits for phthalates associated with personal care products.
As high as 177 ng/μL.
Rural farm children showed hits of 1000 – 30000 ng/μL.

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Link to the FSES website

