

Characterizing the Contribution of Indoor Residential Phthalate and Phthalate Alternative Dust Concentrations to Internal Dose in the US General Population: An Updated Systematic Review and Meta-Analysis

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Table of Contents for Supplementary Information

| | |
|--|----|
| Table S1: List of ortho-phthalates and ortho-phthalate alternatives that are commonly detected (frequency ≥ 50) in the included studies..... | 4 |
| Table S2: List of <i>ortho</i> -phthalates and <i>ortho</i> -phthalate alternatives that are commonly detected (frequency < 50) in the included studies. | 5 |
| List of Abbreviations Used in Table S1 and S2 | 6 |
| Table S3. Systematic Review Search Strategy (for the updated review) | 6 |
| Table S4. References of Studies Excluded At Full Study Stage in Systematic Review:..... | 7 |
| Figure S1. Geographic Regions Represented by Studies Included in Meta-Analysis..... | 7 |
| Figure S2. Risk of bias ratings in exposure measurement, participant/house selection and analysis domains. Solid blue represents a rating of “good”, blue patch represents a rating of “adequate” while solid orange indicates a rating of “deficient” | 8 |
| Table S5. Sensitivity analysis exploring the influence of bias on the pooled median chemical concentrations..... | 8 |
| Table S6. Qualitative Summary of Extracted Data | 9 |
| Table S7. Quality assurance/ quality control measures | 13 |
| Table S8. Treatment of below-method of detection limit (MDL) values..... | 14 |
| Table S9. Measure of central tendency and measure of spread reported. | 15 |
| Table S10. Internal risk of bias assessment for studies included in meta-analysis. | 16 |
| Table S11: The weighted pooled median of <i>ortho</i> -phthalates and <i>ortho</i> -phthalate alternatives that were commonly detected (frequency ≥ 50) in at least two studies. | 19 |
| Figure S3. Weighted pooled median phthalate and phthalate alternative concentrations in the indoor residential environment across sub-populations in the United States. The number depicted to the right of each bar graph represents the number of datasets that contributed to the calculation of the pooled median concentrations while the numbers depicted in brackets represent the total number of dust samples included in all datasets in the analysis for each phthalate or phthalate alternative. | 20 |
| Figure S4. Proportion of intake for children (3 to <6 years old) across three exposure pathways: ingestion, air inhalation, and dermal from air. The proportional contribution of the exposure pathways to the aggregate intake rate was similar for the 50 th percentile for adults. On the x-axis, the abbreviation of each phthalate is in black while the abbreviation of each phthalate alternative is in blue. Within each grouping, the chemicals are arranged in order of increasing molecular mass | 21 |
| Equations used for modelling intake rate from dust | 22 |

| | |
|---|----|
| Table S12. Urine metabolites of detected phthalates and phthalate alternatives | 24 |
| Figure S5. Parent-metabolite mapping for phthalate and phthalate alternative metabolites of chemical substances identified in systematic review and measured in urine during the NHANES 2017-2018 cycle. Nodes that represent a parent chemical are displayed in dark blue and nodes that represent a metabolite measured in urine are displayed in teal. Metabolites not included in NHANES 2017-2018 year were not shown..... | 24 |
| Table S13. Excretion factors used to estimate daily intake from phthalate and phthalate alternative urinary metabolites | 25 |
| Table S14. Summary of data obtained from NHANES 2017-2018 Survey Year..... | 26 |
| Figure S6. Correlation plot between molecular weight of phthalates and phthalates alternatives and their relative contribution to internal phthalate dose in the US population..... | 27 |

Table S1: List of ortho-phthalates and ortho-phthalate alternatives that are commonly detected (frequency ≥ 50) in the included studies

| Short chain (C1 – C3 backbone) and branched <i>ortho</i> -phthalates | | | | | | |
|--|------------------------|--|--------------------------|-------------------|---------|-------------------|
| CASRN | Abbreviation | Substance name | Molecular Weight (g/mol) | Log Koa estimated | Log Kaw | Log Kow estimated |
| 131-11-3 | DMP | Dimethyl phthalate | 194.18 | 6.69 | -5.51 | 4.61 |
| 84-69-5 | DiBP | Diisobutyl phthalate | 278.35 | 8.41 | -5.91 | 4.46 |
| 84-66-2 | DEP | Diethyl phthalate | 222.24 | 7.02 | -6.40 | 2.65 |
| Medium chain (C4 – C8 backbone) linear and branched <i>ortho</i> -phthalates incl. aromatics and cyclics | | | | | | |
| CASRN | Abbreviation | Substance name | Molecular Weight (g/mol) | Log Koa estimated | Log Kaw | Log Kow estimated |
| 84-74-2 | DBP | Dibutyl phthalate | 278.35 | 8.63 | -5.91 | 4.61 |
| 85-68-7 | BBP | Benzyl butyl phthalate | 312.36 | 9.02 | -7.37 | 4.84 |
| 84-75-3 | DHP | Dihexyl phthalate | 334.45 | 9.80 | -5.42 | 6.57 |
| 117-81-7 | DEHP | Bis(2-ethylhexyl) phthalate | 390.56 | 12.56 | -4.93 | 8.39 |
| 117-84-0 | DnOP | Dioctyl phthalate | 390.56 | 12.08 | -4.93 | 8.54 |
| 28553-12-0 | DiNP | Diisononyl phthalate | 418.61 | 13.59 | -3.39 | 8.80 |
| 84-61-7 | DCP | Dicyclohexyl phthalate | 330.42 | 11.0 | -5.90 | 5.78 |
| Long chain (C9-C18 backbone) linear and branched <i>ortho</i> -phthalates | | | | | | |
| CASRN | Abbreviation | Substance name | Molecular Weight (g/mol) | Log Koa estimated | Log Kaw | Log Kow estimated |
| 84-76-4 | DNP | Dinonyl phthalate | 418.62 | 12.59 | -5.27 | 9.40 |
| 84-77-5 | DDP | Didecyl phthalate | 446.67 | 11.87 | -5.49 | 9.05 |
| <i>Ortho</i> -Phthalate alternatives which include terephthalates & trimellitates | | | | | | |
| CASRN | Abbreviation | Substance name | Molecular Weight (g/mol) | Log Koa estimated | Log Kaw | Log Kow estimated |
| 4654-26-6; 6422-86-2 | DOTP, DEHT or DEHTP | Dioctyl terephthalate or bis(2-ethylhexyl terephthalate) | 390.56 | 11.7 | -4.98 | 8.43 |
| 77-90-7 | ATBC | Acetyl tributyl citrate | 402.48 | 12.10 | -5.92 | 5.07 |
| 3319-31-1; 89-04-3 | TOTM | Trioctyl trimellitate | 546.79 | 16.24 | -4.96 | 11.7 |
| 103-23-1 | DEHA | Bis(2-ethylhexyl) adipate or di (2-ethylhexyl) adipate | 370.58 | 12.87 | -4.29 | 8.12 |
| 102-06-7 | - | 1,3-Diphenylguanidine | 211.27 | 8.33 | -6.81 | 2.70 |
| 88-19-7 | - | 2- Methylbenzenesulfonamid e or o-toluenesulfonamide | 171.21 | 6.75 | -6.06 | 0.84 |

| | | | | | | |
|----------|------|---|--------|------|-------|------|
| 141-04-8 | DIBA | Hexanedioic acid, bis(2-methylpropyl) ester or Diisobutyl adipate | 258.36 | 7.85 | -5.40 | 3.88 |
|----------|------|---|--------|------|-------|------|

Note: The values used for the following parameters: Log Koa estimated, Log Kaw, and Log Kow estimated were obtained from EPA Epi Suite as seen in Mitro et al and Schossler et al. In the absence of data from EPA Epi Suite as reported in these studies, values from EPA CompTox Dashboard were used where experimental averages (italicized) were prioritized over predicted averages.

Table S2: List of *ortho*-phthalates and *ortho*-phthalate alternatives that are commonly detected (frequency < 50) in the included studies.

| Medium chain (C4 – C8 backbone) linear and branched <i>ortho</i> -phthalates incl. aromatics and cyclics | | | | | | |
|--|--------------|---|--------------------------|-------------------|---------|-------------------|
| CASRN | Abbreviation | Substance name | Molecular Weight (g/mol) | Log Koa estimated | Log Kaw | Log Kow estimated |
| 131-18-0 | - | Dipentyl phthalate | 306.40 | 9.40 | -5.44 | 5.62 |
| 131-16-8 | - | Dipropyl phthalate | 250.29 | 7.38 | -5.34 | 3.72 |
| 3648-21-3 | DHpP | Diheptyl phthalate | 362.51 | 10.7 | -4.99 | 7.49 |
| Phthalate alternatives which include terephthalates & trimellitates | | | | | | |
| 120-55-8 | - | Diethylene glycol dibenzoate or Di-o-benzoyldiethylene glycol | 314.34 | 10.2 | -6.32 | 3.30 |

Note: The values used for the following parameters: Log Koa estimated, Log Kaw, and Log Kow estimated were obtained from EPA Epi Suite as seen in Mitro et al and Schossler et al. In the absence of data from EPA Epi Suite as reported in these studies, values from EPA CompTox Dashboard were used where experimental averages (italicized) were prioritized over predicted averages.

List of Abbreviations Used in Table S1 and S2

| <u>Abbreviation</u> | <u>Definition</u> |
|---------------------|--|
| CASRN | Chemical Abstracts Service Registry Number |
| K _{oa} | Octanol-Air Partitioning Coefficients |
| K _{aw} | Air-Water Distribution Ratio |
| K _{ow} | n-Octanol/Water Partition Coefficient |

Formula for calculating K_{aw}:

$$\frac{\text{Henry's Law constant}}{R * T}$$

where:

R = 0.080206 atm/mol-K

T = 298 K (normal room temperature)

Table S3. Systematic Review Search Strategy (for the updated review)

| Databases | Date of Search | Search strategy | Limits Placed on Search | Number of Records |
|----------------|----------------|---------------------------------------|---|-------------------|
| Web of Science | May 6, 2022 | phthalate* AND dust* AND human* | Date: Mar 1, 2015 - April 30, 2022 ; Language: English ; Countries/Regions: USA; Peer-Reviewed | 93 |
| PubMed | May 6, 2022 | phthalate* AND dust* | Date: Mar 1, 2015 - April 30, 2022 ; Species: Human ; Language: English; Peer-Reviewed | 132 |

Table S4. References of Studies Excluded At Full Study Stage in Systematic Review:

| Study | Reason for Exclusion |
|---|---|
| Sears et al. 2020. Lowering Urinary Phthalate Metabolite Concentrations among Children by Reducing Contaminated Dust in Housing Units: A Randomized Controlled Trial and Observational Study. | Did not include dataset |
| Rudel et al. 2001. Identification of Selected Hormonally Active Agents and Animal Mammary Carcinogens in Commercial and Residential Air and Dust Samples. | Did not include information on timeline of collection |

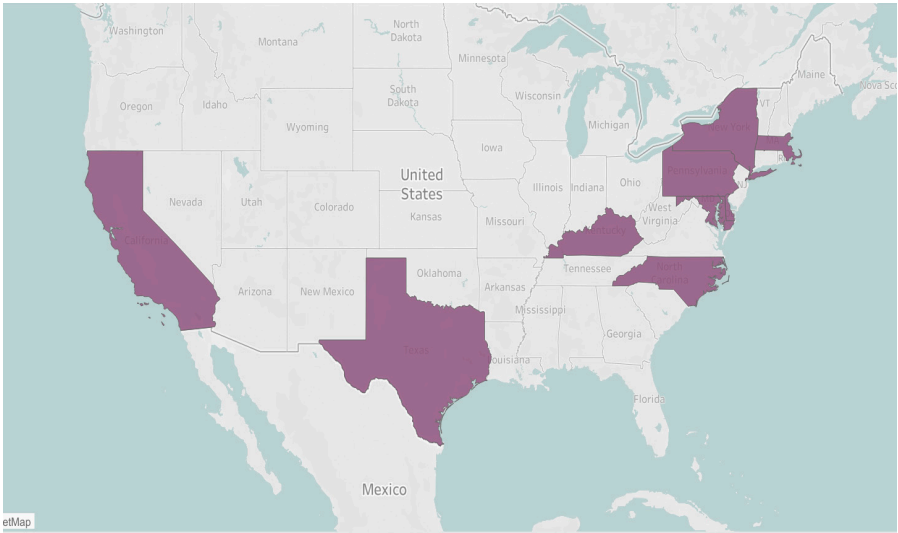


Figure S1. Geographic Regions Represented by Studies Included in Meta-Analysis.

Figure S2. Risk of bias ratings in exposure measurement, participant/house selection and analysis domains. Solid blue represents a rating of “good”, blue patch represents a rating of “adequate” while solid orange indicates a rating of “deficient”

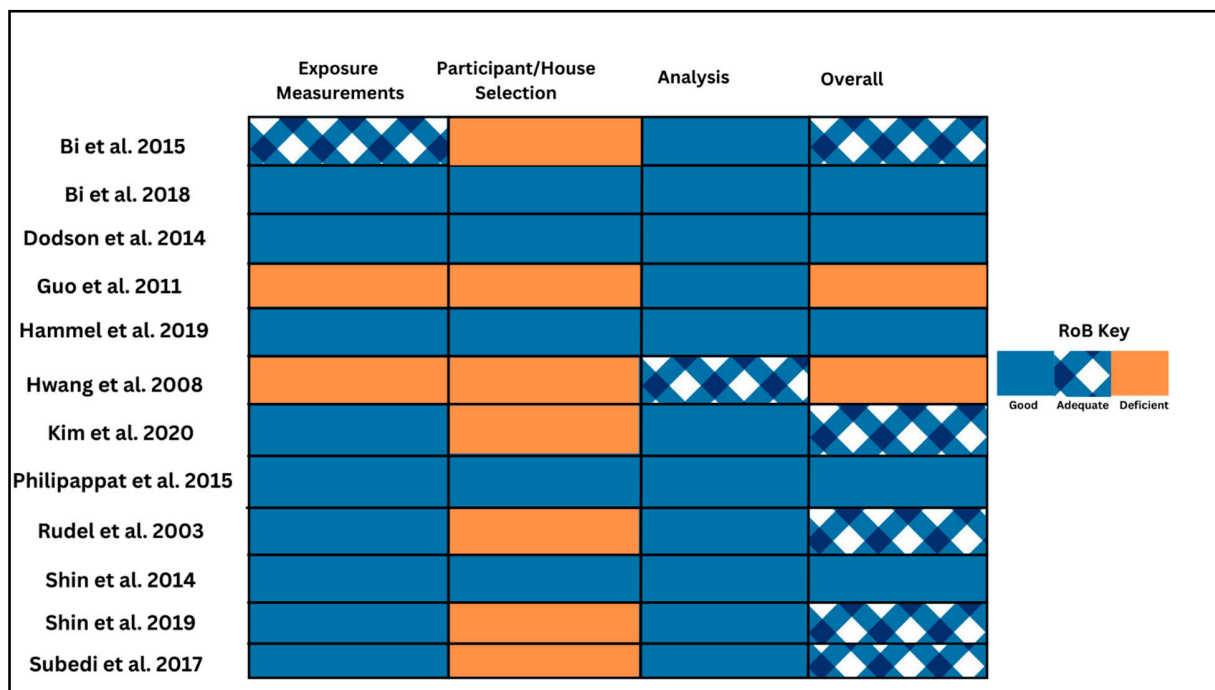


Table S5. Sensitivity analysis exploring the influence of bias on the pooled median chemical concentrations

| Phthalates* | Pooled Medians of All Studies (ug/g) | Pooled Medians of Low Bias Studies (ug/g) | Relative Percent Change (%) |
|-------------|--------------------------------------|---|-----------------------------|
| ATBC | 271.00 | 271.00 | 0.00 |
| BBP | 13.64 | 13.64 | 0.00 |
| DBP | 10.30 | 10.30 | 0.00 |
| DEHA | 5.97 | 5.97 | 0.00 |
| DEHP | 140.00 | 140.00 | 0.00 |
| DEHTP | 133.65 | 133.65 | 0.00 |
| DEP | 1.94 | 1.94 | 0.00 |
| DHP | 1.10 | 1.10 | 0.00 |
| DiBP | 4.37 | 4.37 | 0.00 |
| DiNP | 78.75 | 78.75 | 0.00 |
| DMP | 0.07 | 0.07 | 0.00 |
| DnOP | 1.60 | 7.34 | 358.75 |

Table S6. Qualitative Summary of Extracted Data

| Paper | Ortho-Phthalates & ortho-phthalate alternatives measured (frequency ≥50%) | Indoor Residential Environment | Study Length (Temporal Time Span) | Location of Study | Method | Sieve (µm) | Storage container | Storage temperature | Demographics Reported |
|---------------------------|---|--|--|---|-------------------|------------|---|---------------------|--|
| Bi et al. 2015 | DEHP, BBP, DBP, DiBP, DHP, DNP, DEP, DDP | Apartments (n=7), houses (n=10), student dormitories (n=5), house garage (n=3) | Mar 2013 | Dover, Delaware | Study used vacuum | 106 | Ethyl acetate rinsed glass jars with steel caps | -21°C | No (X) |
| Bi et al. 2018 | BBP, DEHP, DnOP | Settled dust in children's room including objects 30 cm above the floor. ----- The total no. of dust samples =54 | Jun 2014 – Sept 2014; Dec 2014 – Feb 2015 | Central Texas (a part of the Healthy Homes investigation (HUD: TXHHU0023-13) | Study used vacuum | | Cellulose thimbles in clean amber glass jars | -18°C | General description available |
| Dodson et al. 2014 | BBP, DEHP, DBP, DHP, DnOP, DEP, DiBP, DEHA | Main living areas including windowsills, ceiling fans, upholstery, furniture. ----- Dust samples =49; No repeat sampling | 2006 | Northern California – (Liberty and Atchison Village in Contra Costa County) in Richmond and Bolinas | Study used vacuum | 150 | Precleaned, certified glass jars with Teflon-lined lids | -4°C | Description of demographic composition |

| Paper | Ortho-Phthalates & ortho-phthalate alternatives measured | Indoor Residential Environment | Study Length (Temporal Time Span) | Location of Study | Method | Sieve (µm) | Storage container | Storage temperature | Demographics Reported |
|-----------------------|---|---|-----------------------------------|--|---------------------------------|------------|--|---------------------|--|
| Guo et al. 2011 | DMP, DEP, DiBP, DBP, DHP, BBP, DEHP, DnOP | Homes ----- Dust samples (n=33) | Dec 2007 – Jan 2008 | Albany, NY | Study used existing vacuum bags | 2000 | Clean aluminum foil | -4°C | No (X) |
| Hammel et al. 2019 | DEP, DiBP, DBP, DMP, BBP, DEHP, DiNP, DEHTP or DOTP, TOTM, DEHA | Main living area or play area for child. ----- Dust samples =188) | Sept 2014 – April 2016 | Durham, NC | Study used vacuum | 500 | Cellulose thimble wrapped in aluminum foil | -20°C | Yes (✓) |
| Hwang et al. 2008 | DEHP | Apartments ----- No of dust samples (n = 10) | Fall 2014 (months not specified) | Davis, California | Study used existing vacuum bags | 100 | Glass jars pre-cleaned hexane | -20°C | No (X) |
| Kim et al. 2020 | DEHP, BBP, DiBP, DBP, DnOP, DMP, DEHTP or DOTP, DEHA, ATBC | Main living area (except under furniture, between cushions and upholstered furniture) ----- Dust samples (n = 87) | Jul 2015 – May 2018 (22 months) | California ----- Northern California | Study used vacuum | 150 | Cellulose extraction thimble, wrapped in pre-cleaned aluminum foil | -20°C | Income of the underlying population was reported |
| Philippat et al. 2015 | DMP, DBP, DEP, BBP, DEHP | Main living area carpets and rugs ----- No. of dust samples = 145 | 2010 - 2011 | California (Community not specified) | Study used vacuum | 105 | Glass jars pre-cleaned hexane | -20°C | Yes (✓) |

| Paper | <i>Ortho</i> -Phthalates & <i>ortho</i> -phthalate alternatives measured | Indoor Residential Environment | Study Length (Temporal Time Span) | Location of Study | Method | Sieve (µm) | Storage container | Storage temperature | Demographics Reported |
|--|---|---|-----------------------------------|--|-------------------|------------|---|---------------------|---|
| Rudel et al. 2003 | DEP, DBP, BBP, DEHP | Most frequently used rooms including hallways, windowsills, fans, and furniture | Jun 1999 – Sept 2001 | Cape Cod, Mass | Study used vacuum | 150 | Certified glass jars with Teflon-lined lids | –4°C | No (X) |
| Shin et al. 2014 | DEHP, DiNP, BBP, DBP, DiBP, DEP | Main living room but no samples were collected from under furniture or between cushions. ----- (no. of dust samples = 30) | 2009 - 2010 | Northern California, SE Pennsylvania, NE Maryland (community location was not given) | Study used vacuum | 150 | Wrapped in pre-cleaned aluminum foil and placed in poly-propylene vials | –20°C | Yes (✓)* ----- Demographic information was provided for the larger survey pop. from which this data was drawn |
| Shin et al. 2019 (targeted & non-target analysis) | BBP, DEHP, DiBP, DBP, DEP, DMP, ATBC, DOTP, 1,3-diphenylguanidine toluene-2-sulfonamide | Main living room Dust samples (n= 38) | May 2015 – August 2016 | Sacramento and Fresno, CA | Study used vacuum | 106 | Polytetrafluoroethylene (PTFE) container | –20°C | No (X) |

| Paper | <i>Ortho</i> -Phthalates & <i>ortho</i> -phthalate alternatives measured | Indoor Residential Environment | Study Length (Temporal Time Span) | Location of Study | Method | Sieve (µm) | Storage container | Storage temperature | Demographics Reported |
|---|--|--|-----------------------------------|--|-------------------|------------|-------------------|---------------------|-----------------------|
| Subedi et al. 2017 | DMP,DEP,DiBP, DBP,BBP,DEHP, DnOP, DIBA or hexanedioic acid, DEHA, ATBC | Homes ----- (No. of dust samples = 11) | September 2016 – October 2016 | <ul style="list-style-type: none"> •El Cerrito, CA •San Diego, CA •Waco, TX •Murray, KY •Silver Spring, MD •Medway, MA | Study used vacuum | 1400 | Aluminum foil | -20°C | No (X) |
| *Phthalates noted are limited to the phthalates detected in the following indoor residential environments: apartment, house, house garage and student dormitory. No specific room where sampling was done was indicated in the paper. | | | | | | | | | |

Table S7. Quality assurance/ quality control measures

| Paper | Analysis | Reference Material | Internal Standard | Lab blank | Field blank | Additional Accuracy/Precision methods |
|-----------------------|--|--------------------|-------------------|-----------|-------------|--|
| Bi et al. 2015 | GC/MS equipped with AOC-i20 auto-sampler in SIM mode | | ✓ | ✓ | | Background was subtracted from all sample extracts, replicates (n=3) of samples |
| Bi et al. 2018 | GC – FID system | | ✓ | ✓ | ✓ | Matrix spiking, replicates |
| Dodson et al. 2014 | GC/MS in selective ion-monitoring (SIM) mode | | ✓ | ✓ | | Analyzed solvent blanks (n=3), matrix spikes (n=3) and surrogate recoveries used to characterize accuracy, compound recovery from matrix, and extraction efficiency. |
| Guo et al. 2011 | GS/MS in SIM mode | | ✓ | ✓ | | Matrix spikes, extraction efficiency tested by performing 4 th extractions |
| Hammel et al. 2019 | GC/MS in electron impact (EI) mode | ✓ | ✓ | ✓ | | Laboratory blanks (n=6), house dust standard reference material (n=5) |
| Hwang et al. 2008 | GC/MS in EI and SIM mode | ✓ | ✓ | ✓ | | Replicates |
| Kim et al. 2020 | GC/MS quadrupole time-of-flight (Q/TOF) in EI mode | ✓ | ✓ | | | Replicates |
| Philippat et al. 2015 | GS/MS with glass capillary | ✓ | ✓ | ✓ | | Matrix spiking, Replicates |
| Rudel et al. 2003 | GS/MS in SIM mode | | ✓ | ✓ | | Matrix spiking, replicates (n = 4) |
| Shin et al. 2014 | GC-EI/MS | | ✓ | ✓ | | Matrix spiking, replicates |
| Shin et al. 2019 | LC-QTOF/MS and GC-QTOF/MS | ✓ | ✓ | ✓ | | Replicates, calculation of absolute recovery |
| Subedi et al. 2017 | GC/MS in SIM mode | | ✓ | ✓ | | Matrix spiking and matrix spike duplicate analysis, replicates (n=3), blank correction |

Table S8. Treatment of below-method of detection limit (MDL) values

| Paper | Treatment of MDL values | | | | |
|-----------------------|--------------------------|-----------------|-------|--|--------------|
| | No values fell below MDL | MDL/ $\sqrt{2}$ | MDL/2 | Other treatment of MDL | Not reported |
| Bi et al. 2015 | | | | | ✓ |
| Bi et al. 2018 | | | ✓ | | |
| Dodson et al. 2014 | ✓ | | | | |
| Guo et al. 2011 | | | | 0 | |
| Hammel et al. 2019 | | | ✓ | | |
| Hwang et al. 2008 | ✓ | | | | |
| Kim et al. 2020 | | ✓ | | | |
| Philippat et al. 2015 | | ✓ | | | |
| Rudel et al. 2003 | | | | 0 | |
| Shin et al. 2014 | | ✓ | | | |
| Shin et al. 2019 | | | ✓ | | |
| Subedi et al. 2017 | | | | Determined to be minimum concentration of analytes | |

Table S9. Measure of central tendency and measure of spread reported.

| | Measure of central tendency reported | | | Measure of spread reported | | | | |
|-----------------------|--------------------------------------|----------------------------------|---------------|----------------------------|--------------------|--|------------------|--------------|
| Paper | Geometric Mean | Median | Unit reported | Variance | Standard Deviation | Range | IQR | Not reported |
| Bi et al. 2015 | ✓ | ✓ | mg/kg | | ✓ | ✓ | | |
| Bi et al. 2018 | ✓ | ✓ | µg/g | | ✓ | ✓ | | |
| Dodson et al. 2014 | | ✓ | µg/g | | | ✓ | | |
| Guo et al. 2011 | | ✓ | µg/g | | | | | |
| Hammel et al. 2019 | | ✓ | ng/g | | | | | |
| Hwang et al. 2008 | | To be calculated from raw values | µg/g | | | ✓ | | |
| Kim et al. 2020 | ✓ | ✓ | ng/g | | | ✓ | ✓ | |
| Philippat et al. 2015 | | ✓ | µg/g | | | | ✓ | |
| Rudel et al. 2003 | ✓ | ✓ | µg/g | | | ✓ | | |
| Shin et al. 2014 | ✓ | ✓ | µg/g | | ✓ | Max; not min but can be estimated from LOD | | |
| Shin et al. 2019 | | ✓ | ng/g | | | | ✓ | |
| Subedi et al. 2017 | | To be calculated from raw value | µg/g | | | To be calculated | To be calculated | |

Table S10. Internal risk of bias assessment for studies included in meta-analysis.

| Study Name | Risk of Bias Domain | Rating | Authors' Reasoning |
|--------------------|----------------------------|-----------|---|
| Bi et al. 2015 | Exposure Measurement | Adequate | Methodology described, quality assurance and validation described. Measured dust level in an untraditional indoor environment space, i.e., the garage, and did not say where in the house the samples were collected from, or the surfaces sampled. |
| | Participant/Home Selection | Deficient | Little (only when + where) or no information on recruitment process beyond, selection strategy, sampling framework, and/or participation was included. |
| | Analysis | Good | Quantitative results presented and distribution for dust data was discussed. |
| | Conflict of Interest | Good | No conflict of interest disclosed or identified. |
| Bi et al. 2018 | Exposure Measurement | Good | Methodology described in detailed, quality assurance and validation described. Minimal exposure media measurements were below the LOD. |
| | Participant/Home Selection | Good | Recruitment process was adequately described with minimal concern for selection bias based on description of recruitment process. |
| | Analysis | Good | Quantitative results were presented including details of how below-LOD measurements were treated. Distribution for dust data were discussed. |
| | Conflict of Interest | N/A | The presence or absence of conflict was not mentioned. |
| Dodson et al. 2014 | Exposure Measurement | Good | Valid exposure measurement method. Very detailed and validated QA/QC were discussed. |
| | Participant/Home Selection | Good | Recruitment process was adequately described with minimal concern for selection bias based on description of recruitment process. |
| | Analysis | Good | Quantitative results were presented including details of how below-LOD measurements were treated. Distribution for dust data were discussed. |
| | Conflict of Interest | Good | No conflict of interest disclosed or identified. |
| Study Name | Risk of Bias Domain | Rating | Reasoning |
| Guo et al. 2011 | Exposure Measurement | Deficient | Used an existing vacuum bag. Detailed and validated QA/QC were discussed. |
| | Participant/Home Selection | Deficient | Little or no information on recruitment process, selection strategy, sampling framework, and/or participation was included. |
| | Analysis | Good | Quantitative results were presented including details of how below-LOD measurements were treated. Distribution for dust data were discussed. |
| | Conflict of Interest | N/A | The presence or absence of conflict was not mentioned. |

| | | | |
|------------------------------|----------------------------|---------------|---|
| Hammel et al. 2019 | Exposure Measurement | Good | Valid exposure measurement method. Detailed and validated QA/QC were discussed. |
| | Participant/Home Selection | Good | Recruitment process was adequately described with minimal concern for selection bias based on description of recruitment process. |
| | Analysis | Good | Quantitative results were presented including details of how below-LOD measurements were treated. Distribution for dust data were discussed. |
| | Conflict of Interest | Good | No conflict of interest disclosed or identified. |
| Hwang et al. 2008 | Exposure Measurement | Deficient | Use of existing vacuum bag; make and model of vacuum cleaners/bags not identified. Validated analytical procedures. |
| | Participant/Home Selection | Deficient | Little or no information on recruitment process, selection strategy, sampling framework, and/or participation was included. |
| | Analysis | Adequate | Descriptive information provided but analysis of data was not robust. |
| | Conflict of Interest | N/A | The presence or absence of conflict was not mentioned. |
| Kim et al. 2020 | Exposure Measurement | Good | See Shin 2019. Methodology described in detailed, quality assurance and validation described. Minimal exposure media measurements were below the LOD. |
| | Participant/Home Selection | Deficient | Little or no information on recruitment process, selection strategy, sampling framework, and/or participation was included. |
| | Analysis | Good | Quantitative results presented including details of how below-LOD measurements were treated. MDLs high but detection of chemicals were well above the MDLs. |
| | Conflict of Interest | Good | No conflict of interest disclosed or identified. |
| Study Name | Risk of Bias Domain | Rating | Reasoning |
| Philippat et al. 2015 | Exposure Measurement | Good | Valid exposure measurement method. Detailed and validated QA/QC were discussed. |
| | Participant/Home Selection | Good | Recruitment process was adequately described with minimal concern for selection bias based on description of recruitment process. |
| | Analysis | Good | Quantitative results were presented but distribution for dust data were discussed briefly and showed table of variation. |
| | Conflict of Interest | Good | No conflict of interest disclosed or identified. |
| Rudel et al. 2003 | Exposure Measurement | Good | Methodology described in detailed, quality assurance and validation described. Minimal exposure media measurements were below the LOD. |
| | Participant/Home Selection | Deficient | Little or no information on recruitment process, selection strategy, sampling framework, and/or participation was included. |

| | | | |
|--------------------|----------------------------|---------------|--|
| | Analysis | Good | Methodology described in detailed, quality assurance and validation described. Minimal exposure media measurements were below the LOD. |
| | Conflict of Interest | N/A | The presence or absence of conflict was not mentioned. |
| Shin et al. 2014 | Exposure Measurement | Good | Methodology described in detailed, quality assurance and validation described. Minimal exposure media measurements were below the LOD. |
| | Participant/Home Selection | Good | Recruitment process was adequately described with minimal concern for selection bias based on description of recruitment process but lacked response rate. |
| | Analysis | Good | Quantitative results presented including details of how below-LOD measurements were treated. |
| | Conflict of Interest | N/A | The presence or absence of conflict was not mentioned. |
| Study Name | Risk of Bias Domain | Rating | Reasoning |
| Shin et al. 2019 | Exposure Measurement | Good | Methodology described in detailed, quality assurance and validation described. Minimal exposure media measurements were below the LOD. |
| | Participant/Home Selection | Deficient | Little or no information on recruitment process, selection strategy, sampling framework, and/or participation was included. |
| | Analysis | Good | Quantitative results presented including details of how below-LOD measurements were treated; missing data addressed. |
| | Conflict of Interest | Good | No conflict of interest disclosed or identified. |
| Subedi et al. 2017 | Exposure Measurement | Good | Methodology described in detailed, quality assurance and validation described. Minimal exposure media measurements were below the LOD. |
| | Participant/Home Selection | Deficient | Little or no information on recruitment process, selection strategy, sampling framework, and/or participation was included. |
| | Analysis | Good | Quantitative results presented including details of how below-LOD measurements were treated. |
| | Conflict of Interest | N/A | The presence or absence of conflict was not mentioned. |

Table S11: The weighted pooled median of *ortho*-phthalates and *ortho*-phthalate alternatives that were commonly detected (frequency ≥ 50) in at least two studies.

| Abbreviation | Classification | Pooled Estimate Weighted Median (ug/g) | Pooled Median Lower Bound of 95% Confidence Interval (ug/g) | Pooled Medians Upper Bound of 95% Confidence Interval (ug/g) |
|--------------|--|--|--|---|
| ATBC | <i>Ortho</i> -phthalate alternative | 271.00 | 7.97 | 7900.00 |
| BBP | <i>Ortho</i> -phthalate | 13.64 | 13.4 | 29.00 |
| DBP | <i>Ortho</i> -phthalate | 10.30 | 9.63 | 13.10 |
| DEHA | <i>Ortho</i> -phthalate alternative | 5.97 | 5.10 | 144.50 |
| DEHP | <i>Ortho</i> -phthalate | 140.00 | 118.57 | 242.00 |
| DEHTP | <i>Ortho</i> -phthalate alternative | 133.65 | 35.68 | 133.65 |
| DEP | <i>Ortho</i> -phthalate | 1.94 | 1.01 | 2.10 |
| DHP | <i>Ortho</i> -phthalate | 1.10 | 0.60 | 1.10 |
| DiBP | <i>Ortho</i> -phthalate | 4.37 | 1.91 | 4.40 |
| DiNP | <i>Ortho</i> -phthalate | 78.75 | 78.75 | 110.00 |
| DMP | <i>Ortho</i> -phthalate | 0.07 | 0.07 | 0.11 |
| DnOP | <i>Ortho</i> -phthalate | 1.60 | 0.28 | 27.10 |

Figure S3. Weighted pooled median phthalate and phthalate alternative concentrations in the indoor residential environment across sub-populations in the United States. The number depicted to the right of each bar graph represents the number of datasets that contributed to the calculation of the pooled median concentrations while the numbers depicted in brackets represent the total number of dust samples included in all datasets in the analysis for each phthalate or phthalate alternative.

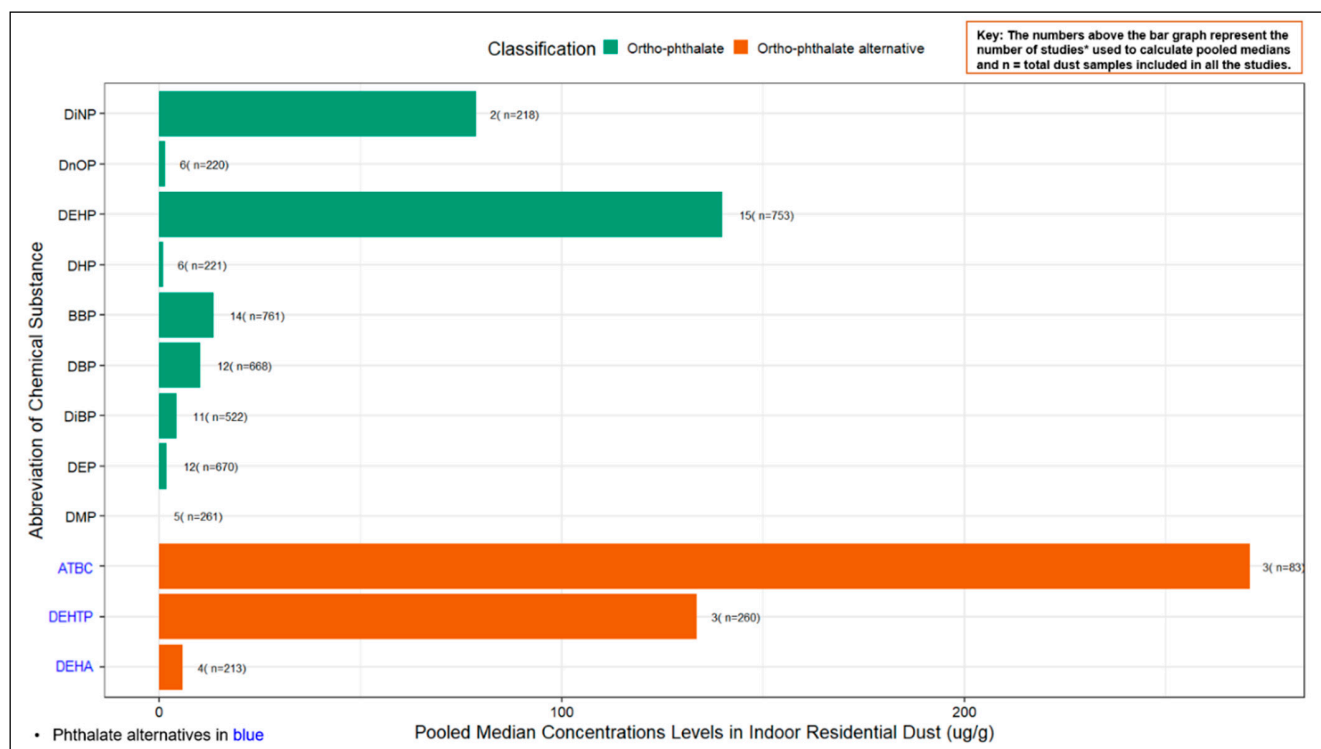
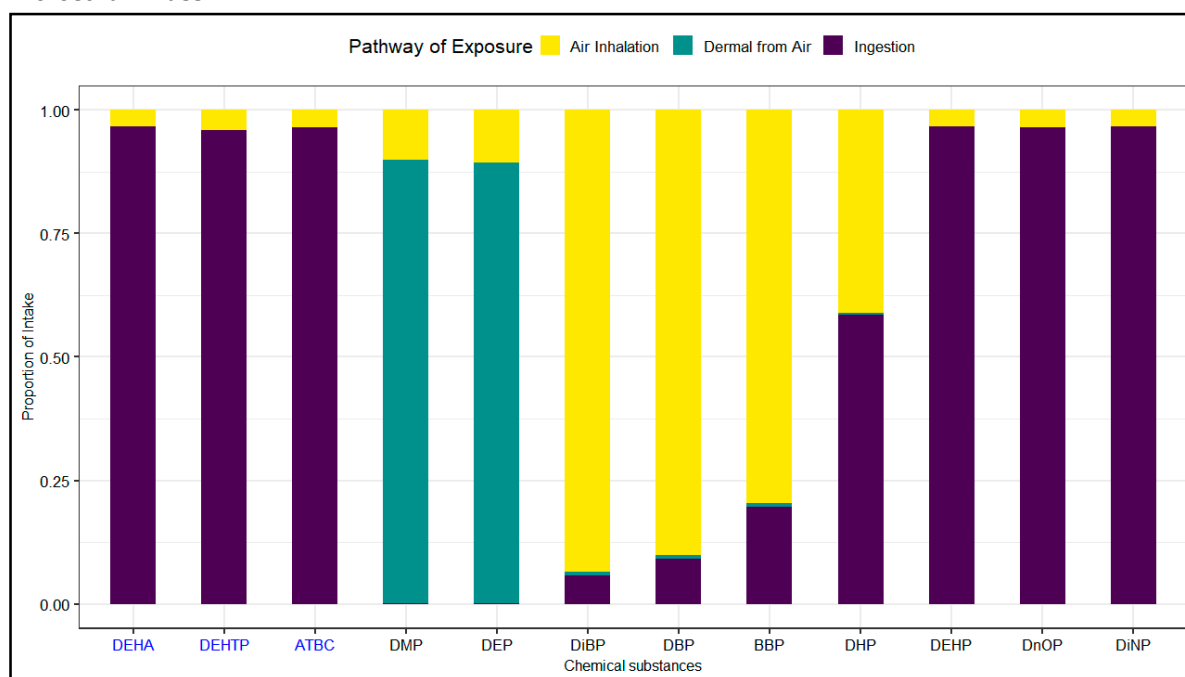


Figure S4. Proportion of intake for children (3 to <6 years old) across three exposure pathways: ingestion, air inhalation, and dermal from air. The proportional contribution of the exposure pathways to the aggregate intake rate was similar for the 50th percentile for adults. On the x-axis, the abbreviation of each phthalate is in black while the abbreviation of each phthalate alternative is in blue. Within each grouping, the chemicals are arranged in order of increasing molecular mass



Equations used for modelling intake rate from dust

Assumed parameters are based on values seen in Mitro et al., Bekö et al., and Weschler et al.:

For DMP and DEP (ug/m³):

$$\text{Concentration in gaseous phase} = \left(\frac{\text{Conc. in dust} + 0.2381}{0.0092} \right) \div 1000$$

For all phthalates except DMP and DEP:

Equation 1

$$\text{Dust to gaseous air concentration (ng/m}^3\text{): } \frac{\text{Dust concentration } (\frac{\text{ug}}{\text{g}}) * \rho_{\text{dust}}}{fom_{\text{dust}} * (10^{\log Koa})}$$

where: Volume fraction of organic matter associated with settled dust (fom_{dust}) = 0.2

Density of dust (ρ_{dust}) = 2×10^6 g/m³

- To convert to ug/m³, the output was divided by 1000 to use in dermal from air intake formula.

Equation 2

Gaseous air concentration to total air concentration (ug/m³):

$$\text{Gaseous air concentration } (\frac{\text{ng}}{\text{g}}) * \left(1 + \frac{\text{TSP}}{1 * 10^6} * \frac{fom_{\text{part}} * 10^{\log Koa}}{\rho_{\text{part}}} \right)$$

where: Total suspended particles (TSP)/ug/m³ = 20

Volume fraction of organic matter associated with airborne particles (fom_{part}) = 0.4

Density of airborne particles (ρ_{part})/g/m³ = 1×10^6

Equation 3

Indoor air transdermal permeability: $\frac{1}{\frac{1}{vd} + \frac{1}{kp_b}}$

where: Mass-transfer coefficient between bulk air and skin surface (vd)/cm/hr = 600

kp_b is a permeability coefficient that describes the transport of a gas-phase SVOC from the boundary layer at the skin surface (b) through the stratum corneum/viable epidermis composite to dermal capillaries (m/h) = $kp_w * 10^{\text{abs}(\log Kaw)}$

and

kp_w is a permeability coefficient through the stratum corneum/viable epidermis composite of SVOC when the species concentration is measured in water in contact with skin (m/h) = $\frac{kp_{cw}}{1+B}$

and

kp_{cw} is a permeability coefficient through stratum corneum (c) of an SVOC when the species concentration is measured in water (w) in contact with skin (m/h) =

$$\left(10^{0.7 \cdot \log Kow - 0.0722 \cdot \text{molecular weight}^{\frac{2}{3}} - 5.252}\right) * 3600$$

and

Ratio of stratum corneum permeability to viable epidermis permeability (**B**) =

$$kp_{cw} * \frac{\text{molecular weight}^{0.5}}{2.6}$$

References:

1. Bekö, G. et al. Children's Phthalate Intakes and Resultant Cumulative Exposures Estimated from Urine Compared with Estimates from Dust Ingestion, Inhalation and Dermal Absorption in Their Homes and Daycare Centers. PLOS ONE 8, e62442 (2013).
2. Mitro, S. D. et al. Consumer Product Chemicals in Indoor Dust: A Quantitative Meta-analysis of U.S. Studies. *Environ Sci Technol* **50**, 10661–10672 (2016).
3. Weschler, C. J. & Nazaroff, W. W. SVOC exposure indoors: fresh look at dermal pathways. *Indoor Air* 22, 356–377 (2012).

Table S12. Urine metabolites of detected phthalates and phthalate alternatives

| Parent Compound | Metabolite(s) |
|---|---|
| Diethyl phthalate (DEP) | Mono-ethyl phthalate (MEP) |
| Diisobutyl phthalate (DiBP) | Mono-isobutyl phthalate (MiBP) Mono-2-methyl-2-hydroxypropyl phthalate (MHiBP) |
| Dibutyl phthalate (DBP) | Mono (3-carboxylpropyl) phthalate (MCP) Mono-n-butyl phthalate (MBP) Mono-3-hydroxybutyl phthalate (MHBP) |
| Dioctyl phthalate (DnOP) | Mono (3-carboxylpropyl) phthalate (MCP) |
| Benzylbutyl phthalate (BBP) | Mono-benzyl phthalate (MBP) |
| Bis (2-ethylhexyl) phthalate (DEHP) | Mono(2-ethylhexyl) phthalate (MEHP) Mono(2-ethyl-5-carboxypentyl) phthalate (MECP) Mono(2-ethyl-5-hydroxyhexyl) phthalate (MEHHP) Mono(2-ethyl-5-oxohexyl) phthalate (MEOHP) |
| Parent Compound | Metabolite(s) |
| Bis (2-ethylhexyl) terephthalate (DEHTP/DOTP) | Mono(2-ethyl-5-hydroxyhexyl) terephthalate (MEHHTP) Mono(2-ethyl-5-carboxypentyl) terephthalate (MECPTP) |

Figure S5. Parent-metabolite mapping for phthalate and phthalate alternative metabolites of chemical substances identified in systematic review and measured in urine during the NHANES 2017-2018 cycle. Nodes that represent a parent chemical are displayed in dark blue and nodes that represent a metabolite measured in urine are displayed in teal. Metabolites not included in NHANES 2017-2018 year were not shown

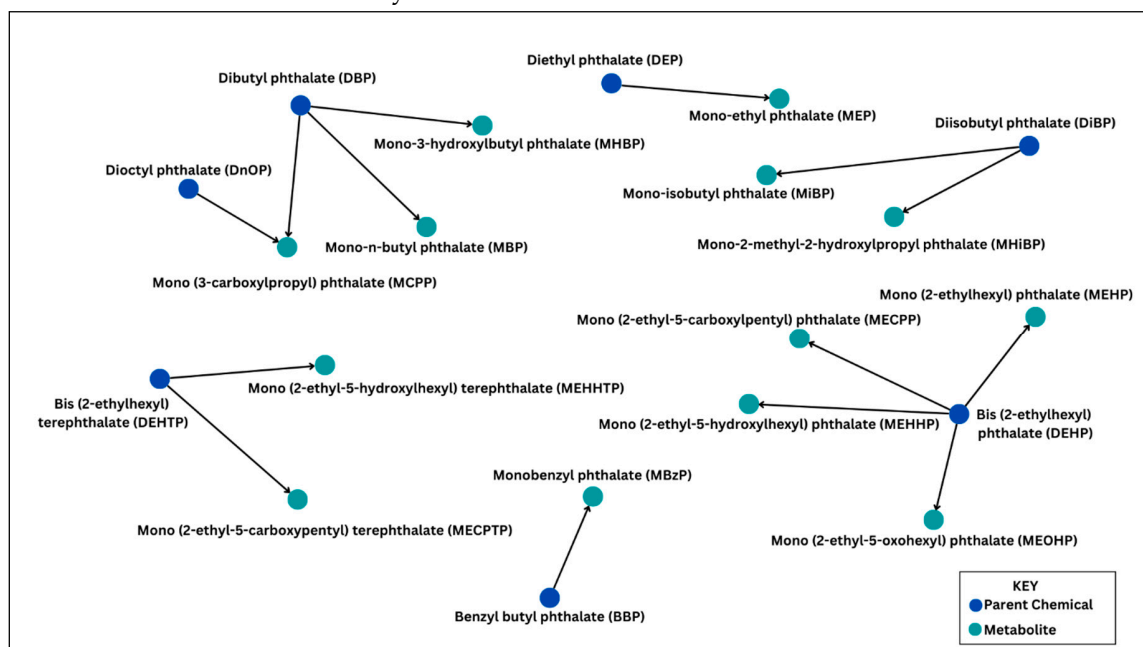


Table S13. Excretion factors used to estimate daily intake from phthalate and phthalate alternative urinary metabolites

| Phthalate/Phthalate Metabolite | Molecular Weights | Excretion factor (Fue) | References |
|--------------------------------|-------------------|------------------------|--|
| MBP | 222 | 0.690 | Anderson et al. (2001) |
| MHBP | 238 | 0.069 | Lee et al. (2021); Koch et al. (2011) |
| MiBP | 222 | 0.703 | Koch et al. (2011); Anderson et al. (2001) |
| MHiBP | 238 | 0.195 | Lee et al. (2021); Koch et al. (2011) |
| MEP | 194 | 0.69 | Wang et al. (2014) |
| MBzP | 256 | 0.73 | Anderson et al. (2001) |
| MEHP | 278 | 0.062 | Anderson et al. (2001) |
| MEOHP | 292 | 0.109 | Anderson et al. (2001) |
| MECPP | 308 | 0.132 | Anderson et al. (2001) |
| MEHHP | 294 | 0.149 | Anderson et al. (2001) |
| MEHHTP | 294 | 0.018 | Lessmann et al. (2016) |
| MECPTP | 308 | 0.13 | Lessman et al. (2016) |
| MCCP | 308 | 0.139 | Lee et al. (2021); Anderson et al. (2011) |

Table S14. Summary of data obtained from NHANES 2017-2018 Survey Year

| Metabolite Abbreviation | Age category | Median Creatinine adjusted phthalate concentration (ug/g) | Creatinine excretion rate (g/day) | Median Urinary excretion rate (ug-kg-day) | Median Weight (kg) |
|-------------------------|--------------|---|-----------------------------------|---|--------------------|
| MBP | Adult | 7.552 | 1.535 | 0.144 | 80.6 |
| | Child | 19.492 | 0.284 | 0.315 | 17.6 |
| MCP | Adult | 0.878 | 1.535 | | 80.6 |
| | Child | 2.658 | 0.284 | | 17.6 |
| MHBP | Adult | 0.6155 | 1.535 | 0.012 | 80.6 |
| | Child | 2.304 | 0.284 | 0.037 | 17.6 |
| MEP | Adult | 22.744 | 1.535 | 0.433 | 80.6 |
| | Child | 26.757 | 0.284 | 0.432 | 17.6 |
| MiBP | Adult | 5.884 | 1.535 | 0.112 | 80.6 |
| | Child | 16.479 | 0.284 | 0.266 | 17.6 |
| MHBP | Adult | 1.844 | 1.535 | 0.035 | 80.6 |
| | Child | 6.556 | 0.284 | 0.106 | 17.6 |
| MEHP | Adult | 0.501 | 1.535 | 0.010 | 80.6 |
| | Child | 1.595 | 0.284 | 0.026 | 17.6 |
| MECP | Adult | 5.971 | 1.535 | 0.114 | 80.6 |
| | Child | 22.858 | 0.284 | 0.369 | 17.6 |
| MEHHP | Adult | 3.776 | 0.072 | 0.100 | 80.6 |
| | Child | 12.227 | 0.197 | 0.203 | 17.6 |
| MEOHP | Adult | 2.371 | 1.535 | 0.045 | 80.6 |
| | Child | 8.683 | 0.284 | 0.140 | 17.6 |
| MBzP | Adult | 2.459 | 1.535 | 0.047 | 80.6 |
| | Child | 8.860 | 0.284 | 0.143 | 17.6 |
| MEHHTP | Adult | 5.269 | 1.535 | 0.100 | 80.6 |
| | Child | 12.581 | 0.284 | 0.203 | 17.6 |
| MECPTP | Adult | 17.212 | 1.535 | 0.328 | 80.6 |
| | Child | 80.270 | 0.284 | 1.296 | 17.6 |

Figure S6. Correlation plot between molecular weight of phthalates and phthalates alternatives and their relative contribution to internal phthalate dose in the US population

