Supplementary Materials

Phthalates in children's intimate clothing: Occurrence, accumulation, source analysis, and partitioning

Zilong Yin, Lixin Wang*, Anqi Zhao, Gang Wang, Qunli Zhang

School of Environment and Energy Engineering, Beijing University of Civil Engineering and Architecture, Beijing, China

*Corresponding author: wanglixin@bucea.edu.cn

S1. Target PAEs and analytical standards

Mixing standards with 15 phthalates (Cat. No. M-8061-R1, AccuStandard, USA, 1000 μg/mL) were used to calibrate the samples. The components of mixing standards are shown in Table S1.

Table S1. Fifteen phthalates in mixing standards.

Components	CAS No.	MW
Dimethyl phthalate (DMP)	131-11-3	194.18
Diethyl phthalate (DEP)	84-66-2	222.24
Diisobutyl phthalate (DiBP)	84-69-5	278.34
Di-n-butyl phthalate (DnBP)	84-74-2	278.34
Di(2-methoxyethyl) phthalate (DMEP)	117-82-8	282.29
Di(2-ethoxyethyl) phthalate (DEEP)	605-54-9	310.34
Dipentyl phthalate (DPP)	131-18-0	306.4
Bis(4-methyl-2-pentyl) phthalate (BMPP)	146-50-9	334.45
Di-n-hexyl phthalate (DnHP)	84-75-3	334.46
Butyl benzyl phthalate (BBzP)	85-68-7	312.36
Di(2-n-butoxyethyl) phthalate (DBEP)	117-83-9	366.45
Dicyclohexyl phthalate (DCHP)	84-61-7	330.42
Di(2-ethylhexyl) phthalate (DEHP)	117-81-7	390.56
Di-n-octyl phthalate (DnOP)	117-84-0	390.56
Dinonyl phthalate (DNP)	84-76-4	418.61

S2. Questionnaire results and basis for clothing selection

The male-to-female ratio was approximately 1:1, and 88% of the children were between 6 and 14 years old. Regarding physical characteristics, more than three-quarters of the children were between 110 cm – 170 cm in height and weighed between 20 kg and 60 kg. Cotton was the predominant material in children's intimate apparel, while other fabrics such as polyester, linen, and blends were less common. The frequency of underwear changes varied seasonally: in spring and autumn, most children changed underwear every two to three days; in summer, over half changed daily, and a quarter changed every two to three days; in winter, the most common frequency was once every three to seven days. Detailed questionnaire results are provided in Table S2 and Table S3.

Table S2. Basic characteristics of participants and clothing material composition.

Items	Factors	Proportion
Gender	Male	51.90%
	Female	48.10%
Age (years)	3 – 5	12.00%
	6 – 14	88.00%
Height (cm)	<110	13.00%
	110 – 170	84.00%
	>170	3.00%
Weight (kg)	<20	9.00%
	20 – 60	82.00%
	>60	9.00%
Clothing material	cotton	70.50%
	non-cotton	29.50%

Table S3. Clothing replacement frequency by season.

Seasons	Clothing replacement frequency	Proportion
Spring and autumn	Once a day	16.90%
	Once every 1 to 3 days	58.20%
	Once every 3 to 7 days	24.60%
	Over 7 days at a time	0.30%
Summer	Once a day	66.70%
	Once every 1 to 3 days	25.00%
	Once every 3 to 7 days	8.00%
	Over 7 days at a time	0.30%
Winter	Once a day	9.40%
	Once every 1 to 3 days	43.00%
	Once every 3 to 7 days	47.00%
	Over 7 days at a time	1.60%

S3. Clothing pretreatment and residual PAE concentrations

Before use in the accumulation experiment, clothing items were pretreated to reduce

pre-existing background PAEs. Each clothing item was soaked in near-boiling water (~100 °C) for 30 min, and this washing procedure was repeated three times using fresh water each time. After washing, the clothing was dried at 25 °C and sealed in aluminum foil bags until use.

The residual fraction after pretreatment was estimated by comparing the average background concentrations of the corresponding clothing types before washing with the concentrations measured in the washed samples. The residual concentrations measured in the pretreated clothing were subtracted from the subsequent accumulation data. The residual concentrations of PAEs in washed clothing are listed in Table S4.

Table S4. Residual concentrations (ng/g) of PAEs in clothing after pretreatment.

Clothing	DMP	DiBP	DnBP	DEEP	DBEP	DEHP
Sock	86.6	nd	nd	33.0	nd	nd
T-shirt	nd	nd	nd	47.1	nd	nd
Shorts	72.9	26.5	nd	53.1	2.89×10^2	70.3
Long underwear top	85.5	41.5	12.2	65.5	4.85×10^2	1.53×10^2
Long underwear bottom	nd	nd	nd	68.3	1.71×10^2	nd

nd: not detected.

S4. Child dummy model and pre-experiment surface check

Three identical polypropylene child dummies were used in the accumulation experiment. Each dummy measured 130 cm in height, with a shoulder width of 30 cm, chest circumference of 52 cm, waist circumference of 47 cm, and hip circumference of 62 cm. These dimensions correspond to the average body size of Chinese children aged 7–10 years. The child dummy is shown in Fig. S1.

Fig. S1. Polypropylene child dummy used in the accumulation experiment.

Before the formal accumulation experiment, wipe tests were conducted on representative body regions of the dummy to confirm the absence of detectable PAEs on the surface. The tested regions included the forehead, arms, hands, torso, legs, and

feet. Sampling areas were defined using tape frames, with 25 cm² for the forehead, hands, and feet, 100 cm² for the torso, and 50 cm² for the arms and legs. Pre-cleaned gauze pads moistened with isopropanol were used for wiping. Each area was wiped four times, using a clean surface of the gauze for each pass[1]. No target PAEs were detected on the dummy surface.

After confirmation of a clean dummy surface, a 1:1 mixture of artificial sweat and artificial sebum (20 mL in total) was applied to simulate the characteristics of the human skin surface before dressing the dummy in clean clothing[2]. Artificial sweat (ISO 3160-2, BZ111) and artificial sebum (ASTM D4265, BZ116) were purchased from Biochemazone™ (Beijing Mokedong Biotechnology Co., Ltd., Beijing, China).

S5. Accumulation experiment setup and sample collection

Details of sample collection in the accumulation experiment are provided here. Clothing samples were collected from the arms, torso, legs, and feet of the dressed dummies. For each body section, two 2 cm × 2 cm fabric pieces were collected and combined as one sample.

Skin wipe samples were collected from the forehead, arms, hands, torso, legs, and feet using the wipe procedure described in Section S4. The long underwear tops and bottoms used in the experiment were made of 100% cotton, and the socks consisted of 75% cotton, 22% nylon, and 3% spandex. The placement environment of the child dummy models is shown in Fig. S2.

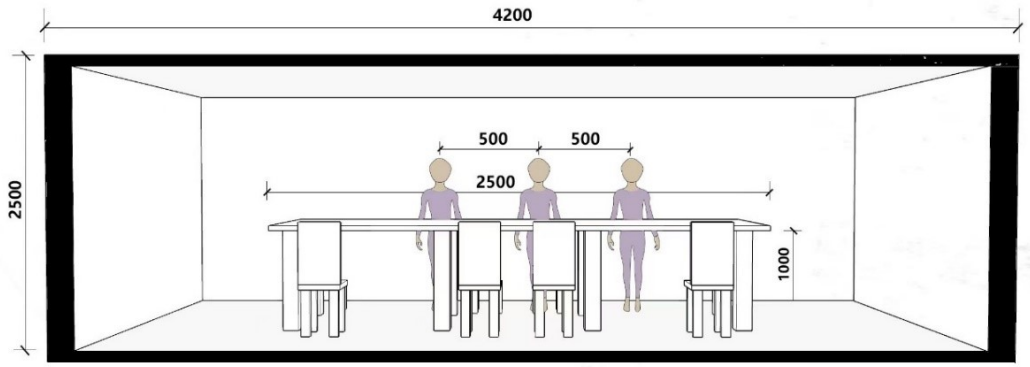

Fig. S2. Experimental room and placement of child dummy models.

S6. Indoor environment, air sampling, and source/surface sampling details

Additional details of the indoor environment and sampling procedures are provided here. The experiment was conducted in a recently renovated conference room measuring 8.5 m × 4.2 m × 2.5 m. The room contained office desks, leather chairs, PVC flooring, glass curtain walls, and wood composite panel walls finished with coating and emulsion paint, with adhesives used in the wall decoration materials.

Indoor airborne PAEs were sampled using an MH1200-F high-volume air sampler (Qingdao Minghua Electronic Instrument Co., Ltd., Guangzhou, China). Polyurethane foam (PUF; 90 mm diameter × 50 mm thickness) was used for gas-phase collection, and glass fiber filters (GFF; 80 mm effective diameter) were used for particle-phase collection (PM10). Air samples were collected for 24 h at a flow rate of 100 L/min. In total, three gas-phase samples and two particle-phase samples were obtained and stored at −20°C prior to analysis.

Representative indoor material samples were collected from synthetic leather, adhesive, wall coating, emulsion paint, and PVC flooring. Approximately 1 g of each material was collected and stored in brown wide-mouth bottles.

Surface wipe samples were collected from representative indoor surfaces, including glass, wood composite panel walls, desks, and flooring. For each sample, a predefined area of 20 cm × 20 cm was wiped using gauze moistened with isopropanol, and the gauze was stored in brown bottles at −20°C prior to analysis.

S7. Sample preparation, extraction, thawing validation, and instrumental analysis

S7.1. Cleaning and pretreatment of sampling materials

All glassware was washed with detergent and distilled water, sonicated twice in dichloromethane for 30 min each, baked at 300°C, sealed with aluminum foil, and stored in a desiccator until use. Gauze pads were ultrasonically cleaned twice in dichloromethane for 30 min each, dried in a desiccator for 24 h, and stored in amber wide-mouth bottles until use. Before air sampling, GFFs were baked at 300°C for 4 h, and PUF media were pre-cleaned by Soxhlet extraction with dichloromethane[3]. Samples were weighed to a precision of 0.1 mg using an analytical balance, where applicable, before and after sampling.

S7.2. Extraction of clothing samples

Clothing samples were cut into small pieces and accurately weighed. Each sample was transferred into a glass centrifuge tube, and 10 mL tetrahydrofuran (THF, chromatographic grade) was added. Samples were extracted in a constant-temperature ultrasonic water bath at 20°C for 30 min. This extraction was repeated three times, and the extracts were combined.

The combined extract was concentrated to approximately 3 mL using a rotary evaporator at 40°C under reduced pressure. Cleanup was carried out using a Florisil column preconditioned with 5 mL *n*-hexane. The sample container was rinsed twice with 2 mL *n*-hexane, and the rinsing solution was loaded onto the column. Elution was performed with 20 mL *n*-hexane/isopropanol (4:1, v/v). The eluate was concentrated to approximately 5 mL by rotary evaporation and then further reduced to 1 mL under a gentle nitrogen stream (2–4 L/min) using a Kuderna–Danish concentrator. The final extract was filtered through a 0.45 μm organic membrane and transferred to an autosampler vial[4].

S7.3. Extraction of wipe samples

Wipe samples were transferred into sample bottles, and 50 mL dichloromethane (DCM, chromatographic grade) was added to fully immerse the gauze. Samples were extracted by ultrasonic extraction in a water bath at 20°C for 30 min. The extracts were concentrated to approximately 5 mL using a rotary evaporator at 70°C and then reduced to 1 mL under a nitrogen stream. The final extracts were filtered through a 0.45 μm organic membrane and stored at 4°C prior to instrumental analysis[5].

S7.4. Extraction of air samples

GFF samples were placed in extraction vessels, and 10 mL dichloromethane was added. Samples were extracted by ultrasonic extraction for three cycles of 30 min each. The extracts were combined and concentrated following the same procedures described for wipe samples[3].

PUF samples were extracted by Soxhlet extraction using 300 mL dichloromethane at 70°C for 24 h. The resulting extracts were then concentrated, filtered, and reduced to 1 mL following the same procedures used for clothing samples[3].

S7.5. Thawing validation

Samples were processed with and without the 24 h thawing procedure (n = 3) to evaluate possible handling-related losses. As shown in Table S5, concentrations of the tested PAEs were consistently lower after thawing than without thawing, indicating that minor analyte losses may have occurred during this step, particularly for relatively volatile PAEs.

Table S5. Comparison of PAE concentrations (μg/mL) in samples processed with and without 24 h thawing.

Treatment	Mean ± standard deviation		
	DMP	DEP	DiBP
No thawing (n=3)	4.31±0.13	5.98±0.43	8.39±0.59
24 h thawing (n=3)	3.94±0.10	5.46±0.73	7.90±0.70

S7.6. GC–MS operating conditions and calibration

An Agilent 7820A-5977E system equipped with an HP-5MS capillary column was used. A 1 μL aliquot was injected in splitless mode at an inlet temperature of 280 °C. Helium was used as the carrier gas at a flow rate of 1 mL/min.

The oven temperature program was as follows: 60 °C for 1 min, ramped at 20 °C/min to 220°C and held for 1 min, then ramped at 5 °C/min to 300°C and held for 4 min. The ion source temperature was 250°C, the transfer line temperature was 280°C, and electron ionization was performed at 70 eV. Selected ion monitoring (SIM) mode was used for quantification.

A 1000 μg/mL mixed PAE standard solution in dichloromethane was serially diluted to 0.1, 0.4, 1, 2, 6, 8, 10, 50, and 100 μg/mL for calibration. All standard solutions were stored at 4°C. Calibration equations and coefficients of determination are listed in Table S6. Instrument detection limits ranged from 0.0006 to 0.036 μg/mL at a signal-to-noise ratio of 3. Method detection limits were calculated based on median instrument detection limits, garment mass (0.50 g), and median skin collection area (46 cm^2), resulting in ranges of 0.002–0.050 μg/g for clothing samples and 0.217–5.42 $μg/m^2$ for

skin wipe samples.

Table S6. Calibration equations and coefficients of determination for target PAEs.

Phthalates	Standard curves	R^2
DMP	y = 179872.685282 × x + 491.324433	0.997
DEP	y = 163026.056006 × x + 2593.663525	0.997
DiBP	y = 192511.670911 × x + 4464.943959	0.996
DnBP	y = 224930.943798 × x + 479237.219305	0.995
DMEP	y = 133413.864054 × x − 35332.161088	0.996
DEEP	y = 84638.551627 × x − 49237.027789	0.995
DPP	y = 280030.225479 × x + 543854.126221	0.992
BMPP	y = 110049.010888 × x − 7682.461260	0.999
DnHP	y = 367976.586390 × x − 643448.355671	0.996
BBzP	y = 162926.341685 × x − 110258.721359	0.996
DBEP	y = 78829.762780 × x − 64490.387678	0.993
DCHP	y = 252036.012988 × x − 15570.645986	0.998
DEHP	y = 227975.591279 × x + 30552.429262	0.998
DnOP	y = 326870.577099 × x + 19982.256289	0.999
DNP	y = 293439.865576 × x + 77998.846664	0.998

S8. Quality assurance and quality control procedures

Detailed blank levels, recovery ranges, and replicate precision are provided here to support the QA/QC summary in the main text. For each batch of 20 samples, a pure solvent blank was processed using the same pretreatment and analytical procedures. PAE concentrations in laboratory blanks ranged from 0.003 to 0.190 μg/mL. Ten solvent blanks prepared using chromatographic-grade solvent showed no detectable PAEs. Field blanks, including active air sampler blanks and wipe blanks, were also processed and analyzed under the same conditions; the measured concentrations of the 15 target PAEs ranged from 0.007 to 1.29 μg/mL. To further evaluate possible residual contamination from the analytical system, ten randomly selected samples, including clothing, wipe, air, and indoor material samples, were completely reprocessed and reanalyzed by GC–MS. No target PAEs were detected in the reprocessed samples.

Recovery tests were performed by spiking blank solutions with known concentrations of the mixed PAE standards and subjecting the samples to the same pretreatment procedure. Because cleanup involved a Florisil solid-phase extraction cartridge, recovery was evaluated both with and without the cleanup step. Recovery rates ranged from 70.8% to 119% without the Florisil cartridge and from 71.4% to 108% with the cartridge. Five replicate analyses of the 10 μg/mL mixed standard yielded relative standard deviations below 10%, indicating acceptable analytical precision.

S9. Parameters used for partition coefficient calculations

The mass, thickness, and volumetric density of the accumulated clothing samples used for partition coefficient calculations are listed in Table S7.

Table S7. Physical parameters of accumulation clothing samples.

Clothing No.	Mass, g	Thickness, mm	Volumetric density, g/cm^3
Sock 1	0.276	0.305	1.13
Sock 2	0.414	0.305	1.7
Sock 3	0.310	0.305	1.27
Sock 4	0.388	0.305	1.59
Sock 5	0.455	0.305	1.86
Sock 6	0.455	0.305	1.86
Sock 7	0.510	0.305	2.09
Sock 8	0.481	0.305	1.97
Sock 9	0.481	0.305	1.97
Long underwear top 1	0.344	0.293	1.47
Long underwear top 2	0.238	0.293	1.01
Long underwear top 3	0.229	0.293	0.98
Long underwear top 4	0.243	0.293	1.04
Long underwear top 5	0.257	0.293	1.09
Long underwear top 6	0.308	0.293	1.31
Long underwear top 7	0.230	0.293	0.98
Long underwear top 8	0.220	0.293	0.94
Long underwear top 9	0.217	0.293	0.93
Long underwear top 10	0.290	0.293	1.24
Long underwear top 11	0.281	0.293	1.20
Long underwear top 12	0.229	0.293	0.98
Long underwear top 13	0.248	0.293	1.06
Long underwear top 14	0.200	0.293	0.85
Long underwear top 15	0.287	0.293	1.22
Long underwear top 16	0.210	0.293	0.89
Long underwear top 17	0.275	0.293	1.17
Long underwear top18	0.270	0.293	1.15
Long underwear bottom 1	0.245	0.294	1.04
Long underwear bottom 2	0.227	0.294	0.96
Long underwear bottom 3	0.319	0.294	1.36
Long underwear bottom 4	0.243	0.294	1.03
Long underwear bottom 5	0.200	0.294	0.85
Long underwear bottom 6	0.183	0.294	0.78
Long underwear bottom 7	0.233	0.294	0.99
Long underwear bottom 8	0.246	0.294	1.04
Long underwear bottom 9	0.248	0.294	1.05

S10. Difference between phthalate background concentrations in children's clothing

Table S8. Mann-Whitney U test results (*p*-values) between phthalate background concentrations in children's clothing.

Phthalates	DMP	DEP	DiBP	DnBP	BMPP	DnHP	BBzP	DBEP	DEHP	DNP
DMP	1	0.387	**<0.001**	**<0.001**	0.82	0.715	**0.001**	**<0.001**	**<0.001**	0.128
DEP	-	1	**<0.001**	**<0.001**	0.377	0.563	0.278	**<0.001**	**<0.001**	0.085
DiBP	-	-	1	**<0.001**	**<0.001**	**<0.001**	**0.002**	**<0.001**	**<0.001**	**<0.001**
DnBP	-	-	-	1	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
BMPP	-	-	-	-	1	0.507	**0.028**	**<0.001**	**<0.001**	0.174
DnHP	-	-	-	-	-	1	**0.006**	**<0.001**	**<0.001**	0.07
BBzP	-	-	-	-	-	-	1	**<0.001**	**<0.001**	**0.006**
DBEP	-	-	-	-	-	-	-	1	0.051	**<0.001**
DEHP	-	-	-	-	-	-	-	-	1	**<0.001**
DNP	-	-	-	-	-	-	-	-	-	1

S11. Difference between different clothing types for phthalates

Table S9. Mann-Whitney U test results (*p*-values) between different clothing types for phthalates.

Clothing types	Sock	Vest	T-shirt	Shorts	Long underwear top	Long underwear bottom
DMP						
Sock	1	**<0.001**	1	**<0.001**	0.068	**<0.001**
Vest	-	1	**<0.001**	1	**0.025**	0.07
T-shirt	-	-	1	**<0.001**	0.068	**<0.001**
Shorts	-	-	-	1	**0.045**	**0.041**
Long underwear top	-	-	-	-	1	0.076
Long underwear bottom	-	-	-	-	-	1
DEP						
Sock	1	0.821	**0.039**	**0.023**	0.364	0.705
Vest	-	1	**0.037**	0.364	0.791	0.821
T-shirt	-	-	1	**0.004**	**0.025**	0.066
Shorts	-	-	-	1	0.29	0.082
Long underwear top	-	-	-	-	1	0.406
Long underwear bottom	-	-	-	-	-	1
DiBP						
Sock	1	**0.008**	**0.001**	0.496	0.65	0.29
Vest	-	1	0.364	0.45	0.15	**0.023**
T-shirt	-	-	1	0.705	0.449	0.082
Shorts	-	-	-	1	0.496	0.364
Long underwear top	-	-	-	-	1	0.762
Long underwear bottom	-	-	-	-	-	1

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Table S9. Mann-Whitney U test results (*p*-values) between different clothing types for phthalates, continued.

Clothing types	Sock	Vest	T-shirt	Shorts	Long underwear top	Long underwear bottom
DnBP						
Sock	1	0.226	0.705	0.88	0.762	0.174
Vest	-	1	0.29	0.496	0.199	0.94
T-shirt	-	-	1	0.65	1	0.226
Shorts	-	-	-	1	0.705	0.45
Long underwear top	-	-	-	-	1	0.364
Long underwear bottom	-	-	-	-	-	1
BMPP						
Sock	1	0.07	**0.023**	**<0.001**	0.226	**0.018**
Vest	-	1	0.404	0.168	0.879	0.247
T-shirt	-	-	1	0.283	0.819	0.699
Shorts	-	-	-	1	0.122	0.526
Long underwear top	-	-	-	-	1	0.412
Long underwear bottom	-	-	-	-	-	1
DnHP						
Sock	1	**0.001**	**<0.001**	**<0.001**	**0.016**	**0.001**
Vest	-	1	0.106	0.938	0.17	0.939
T-shirt	-	-	1	**0.048**	**0.002**	**0.019**
Shorts	-	-	-	1	0.16	0.819
Long underwear top	-	-	-	-	1	0.173
Long underwear bottom	-	-	-	-	-	1
BBzP						

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Table S9. Mann-Whitney U test results (*p*-values) between different clothing types for phthalates, continued.

Clothing types	Sock	Vest	T-shirt	Shorts	Long underwear top	Long underwear bottom
Sock	1	**0.001**	**<0.001**	**0.001**	**0.016**	**0.001**
Vest	-	1	**0.045**	0.777	0.247	0.643
T-shirt	-	-	1	**0.036**	**0.002**	**0.001**
Shorts	-	-	-	1	0.105	0.315
Long underwear top	-	-	-	-	1	0.495
Long underwear bottom	-	-	-	-	-	1
DBEP						
Sock	1	0.364	0.29	0.762	0.65	0.257
Vest	-	1	0.545	0.94	0.406	0.821
T-shirt	-	-	1	0.406	0.226	0.705
Shorts	-	-	-	1	0.406	0.705
Long underwear top	-	-	-	-	1	0.571
Long underwear bottom	-	-	-	-	-	1
DEHP						
Sock	1	0.705	0.29	0.821	0.821	0.45
Vest	-	1	0.364	0.88	0.821	0.705
T-shirt	-	-	1	0.45	0.406	0.131
Shorts	-	-	-	1	0.65	0.545
Long underwear top	-	-	-	-	1	0.496
Long underwear bottom	-	-	-	-	-	1
DNP						
Sock	1	0.791	0.122	0.467	0.226	0.325
Vest	-	1	0.154	0.292	0.594	0.819

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Table S9. Mann-Whitney U test results (*p*-values) between different clothing types for phthalates, continued.

Clothing types	Sock	Vest	T-shirt	Shorts	Long underwear top	Long underwear bottom
T-shirt	-	-	1	0.456	**0.024**	**0.019**
Shorts	-	-	-	1	0.105	0.122
Long underwear top	-	-	-	-	1	0.94
Long underwear bottom	-	-	-	-	-	1

S12. Background concentrations of PAEs in unwashed children's clothing

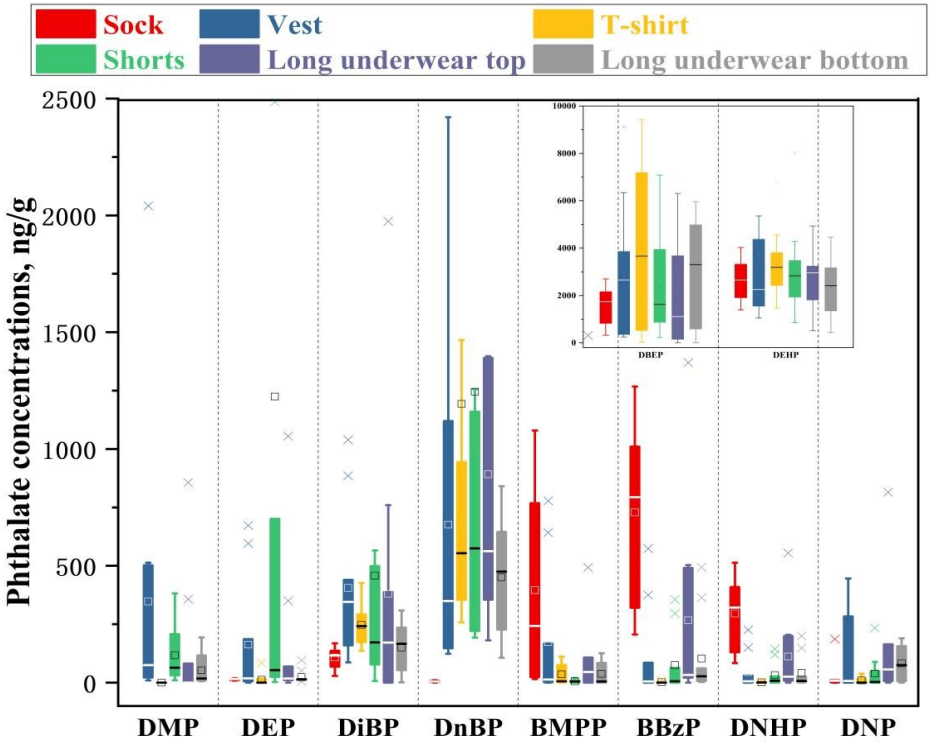

Fig. S3. Background concentrations of PAEs in different types of unwashed children's clothing.

S13. Difference between different accumulation durations for phthalates

Table S10. Mann-Whitney U test results between different accumulation durations (*p*-values) for phthalates.

Comparison of accumulation durations	DMEP	BMPP	DEEP	BBzP	DBEP	DEHP	DnOP	DNP
One day – three days	0.902	0.429	0.929	0.281	0.23	0.147	0.383	0.75
One day – seven days	0.902	0.518	0.859	0.352	0.626	0.773	0.054	0.26
Three days – seven days	0.902	0.836	0.929	**0.046**	0.23	0.295	0.144	0.311

S14. PAE concentrations on dummy skin

Table S11. Phthalate detection frequencies (DF) and concentrations (ng/m^2) on the dummy skin surface.

Accumulation durations	Values	DnBP	DMEP	BMPP	DEEP	BBzP	DBEP	DEHP	DnOP	DNP	∑PAEs
One day	DF	83%	78%	100%	100%	39%	94%	100%	94%	100%	100%
(n=18)	Mean	1.60×10^5	6.53×10^5	1.19×10^4	2.27×10^5	3.53×10^3	4.03×10^3	1.41×10^6	5.01×10^5	1.40×10^6	4.38×10^6
	Min	nd	nd	9.43×10^2	3.00×10^3	nd	nd	4.75×10^5	nd	1.92×10^4	5.93×10^5
	Median	1.26×10^5	1.15×10^5	4.39×10^3	7.95×10^4	nd	1.74×10^3	1.20×10^6	1.77×10^5	1.58×10^5	2.08×10^6
	Max	6.26×10^5	3.55×10^6	6.95×10^4	1.18×10^6	5.53×10^4	1.56×10^4	4.44×10^6	1.83×10^6	8.06×10^6	1.44×10^7
Three days	DF	94%	83%	89%	100%	50%	94%	100%	67%	100%	100%
(n=18)	Mean	2.03×10^5	8.96×10^5	3.11×10^4	2.58×10^5	1.99×10^3	5.29×10^3	8.39×10^5	1.05×10^6	1.33×10^6	4.61×10^6
	Min	nd	nd	nd	7.21×10^2	nd	nd	1.78×10^5	nd	8.46×10^3	2.39×10^5
	Median	1.18×10^5	2.02×10^5	6.20×10^3	1.31×10^5	1.14×10^2	1.06×10^3	5.25×10^5	3.38×10^4	6.36×10^4	1.39×10^6
	Max	7.67×10^5	4.07×10^6	2.50×10^5	1.13×10^6	1.77×10^4	5.87×10^4	2.19×10^6	9.54×10^6	7.88×10^6	1.98×10^7
Seven days	DF	83%	61%	100%	100%	56%	89%	100%	83%	100%	100%
(n=18)	Mean	1.25×10^5	4.32×10^5	1.99×10^4	2.09×10^5	1.14×10^3	2.00×10^3	8.62×10^5	4.37×10^5	6.10×10^5	2.70×10^6
	Min	nd	nd	9.37×10^2	7.76×10^2	nd	nd	1.74×10^5	nd	3.93×10^3	3.45×10^5
	Median	9.73×10^4	4.79×10^4	6.87×10^3	8.20×10^4	3.20×10^2	1.16×10^3	7.01×10^5	1.24×10^5	4.35×10^4	1.21×10^6
	Max	3.69×10^5	3.63×10^6	1.24×10^5	7.22×10^5	6.41×10^3	6.47×10^3	1.99×10^6	3.67×10^6	4.14×10^6	1.08×10^7
Accumulation durations	Values	DnBP	DMEP	BMPP	DEEP	BBzP	DBEP	DEHP	DnOP	DNP	∑PAEs
In total	DF	87%	74%	96%	100%	48%	93%	100%	81%	100%	100%
(n=54)	Mean	1.63×10^5	6.60×10^5	2.10×10^4	2.31×10^5	2.22×10^3	3.77×10^3	1.04×10^6	6.61×10^5	1.12×10^6	3.90×10^6
	Min	nd	nd	nd	7.21×10^2	nd	nd	1.74×10^5	nd	3.93×10^3	2.39×10^5
	Median	1.18×10^5	1.58×10^5	6.19×10^3	9.42×10^4	nd	1.32×10^3	7.40×10^5	1.05×10^5	7.88×10^4	1.78×10^6
	Max	7.67×10^5	4.07×10^6	2.50×10^5	1.18×10^6	5.53×10^4	5.87×10^4	4.44×10^6	9.54×10^6	8.06×10^6	1.98×10^7

nd: not detected.

S15. Gas-phase and particle-phase PAE concentrations

Table S12. Gas-phase and particle-phase phthalate concentrations indoors (ng/m^3).

No.	DMP	DiBP	DnBP	DMEP	BMPP	DEEP	BBzP	DBEP	DEHP	DnOP	DNP
1 [a]	40.1	1.23×10^{2}	1.56×10^{2}	nd	1.54	12.6	3.12×10^{-1}	15.8	16.9	1.28	9.69
2 [a]	26.2	98.2	1.05×10^{2}	nd	1.48	13.1	1.93×10^{-1}	33.4	37.5	2.24	9.89
3 [a]	27.8	87.8	89.7	nd	1.32	12.6	5.93×10^{-1}	17.8	34.3	1.81	4.33
1 [b]	nd	7.54	9.52	11.3	nd	8.29×10^{-1}	nd	1.28×10^{2}	41.9	9.34×10^{-1}	23.5
2 [b]	nd	8.16	58.3	11.2	nd	8.53×10^{-1}	nd	94.9	26.7	4.12×10^{-1}	19.1

nd: not detected.
[a] Gas-phase.
[b] Particle-phase.

S16. Concentrations in indoor objects and surfaces

Table S13. Phthalate concentrations in indoor articles (μg/g) and on surfaces (μg/m^2).

Articles and surfaces	DiBP	DnBP	DMEP	DEEP	BBzP	DBEP	DEHP	DnOP	DNP	∑PAEs
Synthetic leather (n=1) [a]	nd	28.5	nd	7.30×10^{-1}	nd	17.1	3.45	2.29	nd	52.1
Adhesive (n=1) [a]	15.2	14.9	nd	25.3	23.8	99.2	5.55×10^{3}	3.84	10.9	5.74×10^{3}
Wall skin coating (n=3) [a]	4.89	23.4	nd	nd	nd	11.2	6.96	nd	nd	42.7
Emulsion paint (n=1) [a]	nd	nd	2.91×10^{-1}	nd	nd	2.81	1.72	nd	nd	4.81
PVC floor (n=4) [a]	nd	nd	nd	nd	nd	3.75×10^{-1}	nd	2.91×10^{4}	2.29	2.91×10^{4}
Wood composite panel wall (n=1) [b]	nd	nd	1.30	8.01	nd	nd	86.9	3.53	nd	99.7
Office desk (n=1) [b]	nd	nd	3.33	4.37	nd	2.44×10^{-1}	1.87×10^{2}	5.00	nd	2.00×10^{2}
Floor (n=1) [b]	nd	35.8	nd	3.86	nd	3.02×10^{-1}	5.56×10^{2}	2.50×10^{2}	3.11×10^{-1}	8.46×10^{2}
Interior glass (n=1) [b]	nd	1.42	nd	9.73×10^{-1}	2.74×10^{-1}	1.30	1.32×10^{2}	7.84	3.56×10^{-1}	1.45×10^{2}

nd: not detected.

[a] Indoor article.

[b] Indoor surface.

S17. Mean contributions under different accumulation durations

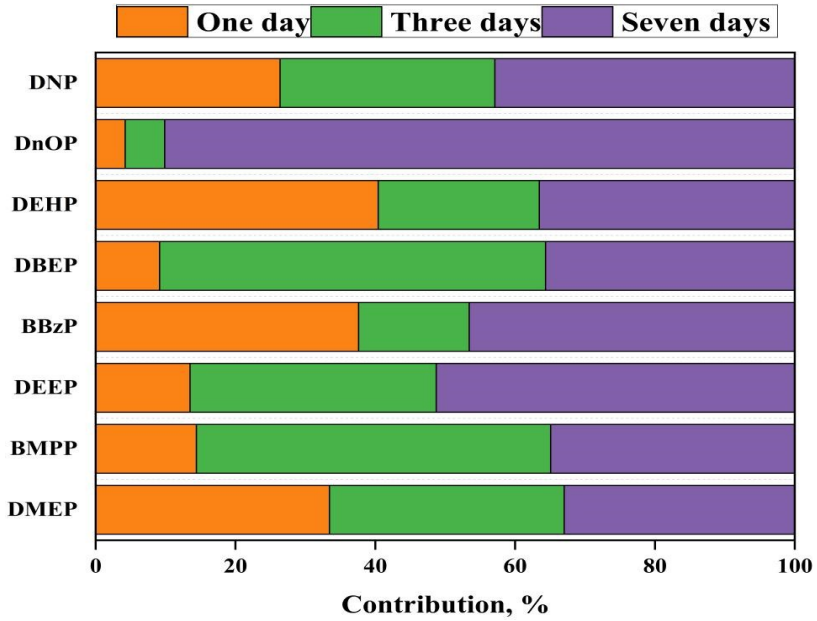

Fig. S4. Mean contributions of PAEs under different accumulation durations.

S18. PMF results

To improve the accuracy of the source apportionment, the classification of species into "strong," "weak," or "bad" categories was fine-tuned based on the signal-to-noise ratio of the data. The lowest Q (robust) value is typically employed as the key indicator for determining the optimal number of factors. The optimal solution was determined through a thorough residual analysis. This step was crucial in ensuring the robustness and reliability of the PMF model output, thereby providing clear and actionable insights into the sources of PAEs in indoor environments.

PMF analysis revealed that the observed rise in PAE concentrations was attributable to emissions from four distinct sources (Table S14). Bootstrapping (BS) and displacement (DISP) analyses were employed to evaluate the model's uncertainty. The decrease in Q value during displacement analysis (% dQ) was below 1% in all cases. Additionally, the swap counts are recorded as zero, and the BS mapping percentages range from 97% to 100%. These metrics collectively suggest that the PMF solution is stable.

Table S14. Factor contributions (%).

Phthalates	DF1	DF2	DF3	DF4
DMEP	5.5	3.5	**91.0**	0
BMPP	0.1	1.7	4	**94.2**
DEEP	49.7	23.7	26.6	0
BBzP	0	**89.2**	9.6	1.2
DBEP	47.5	41.4	8.5	2.6
DEHP	**89.0**	7.6	3.4	0
DnOP	42.9	15.9	0	41.2
DNP	**69.9**	12.6	4.2	13.3
DISP (% dQ)		<0.1		
DISP, swaps		0		
BS Mapping (%)	100	100	97	100

S19. Summary of the Log K_{oa} and Log (C_{clo}/C_g) parameters

Table S15. Log K_{oa} and Log (C_{clo}/C_g) parameters for all-cotton clothing.

Phthalates	Log K_{oa}	Log (C_{clo}/C_g)		
		One day	Three days	Seven days
BBzP	9.02	8.67	7.65	8.26
BMPP	10.24	8.51	9.15	9.04
DEEP	10.51	6.12	/	7.99
DBEP	11.98	6.28	/	6.10
DnOP	12.08	8.32	8.26	9.38
DEHP	12.56	8.26	7.59	7.90
DNP	12.59	6.61	6.57	6.90

/: PAE concentration not detected.

Table S16. Log K_{oa} and Log (C_{clo}/C_g) parameters for non-all-cotton clothing.

Phthalates	Log K_{oa}	Log (C_{clo}/C_g)		
		One day	Three days	Seven days
BBzP	9.02	8.30	8.94	9.22
BMPP	10.24	8.82	9.03	9.26
DEEP	10.51	8.25	8.71	8.49
DBEP	11.98	/	7.60	7.39
DnOP	12.08	7.90	8.22	9.67
DEHP	12.56	8.58	8.49	8.58
DNP	12.59	6.66	6.95	7.12

/: PAE concentration not detected.

S20. Difference between different dressing ways

Table S17. Mann–Whitney U test results (p-values) comparing clothing-covered and bare dummy skin.

Accumulation durations	DnBP	BMPP	DEEP	BBzP	DBEP	DEHP	DnOP	DNP
One day	**<0.001**	**0.026**	**0.026**	0.224	0.529	**0.002**	**0.005**	**0.003**
Three days	0.113	**0.018**	**0.002**	**0.005**	**0.003**	0.066	0.066	**0.008**
Seven days	0.864	**0.002**	0.088	**0.036**	0.108	**0.045**	**0.005**	**0.010**

S21. Summary of Log K_{oa} and Log K_{lg} parameters

Table S18. Log K_{oa} and Log K_{lg} under the condition of being covered by all-cotton clothing.

Phthalates	Log K_{oa}	Log K_{lg1}		
		One day	Three days	Seven days
DnBP	8.63	7.76	8.10	8.36
BBzP	9.02	8.44	8.11	7.99
BMPP	10.24	9.41	9.43	8.69
DEEP	10.51	9.21	8.95	9.11
DBEP	11.98	7.19	6.78	7.37
DnOP	12.08	10.3	10.1	10.2
DEHP	12.56	9.81	9.48	9.83
DNP	12.59	8.93	9.21	9.51

Table S19. Log K_{oa} and Log K_{lg} on the dummy surface of being covered by non-all-cotton clothing.

Phthalates	Log K_{oa}	Log K_{lg2}		
		One day	Three days	Seven days
DnBP	8.63	8.23	8.67	8.70
BBzP	9.02	9.05	8.27	/
BMPP	10.24	9.12	9.24	8.70
DEEP	10.51	9.37	9.69	9.22
DBEP	11.98	7.57	7.41	7.72
DnOP	12.08	9.70	9.72	10.46
DEHP	12.56	10.15	9.98	10.08
DNP	12.59	8.86	9.08	9.68

/: PAE concentration not detected.

Table S20. Log K_{oa} and Log K_{lg} on the bare surface of dummy.

Phthalates	Log K_{oa}	Log K_{lg3}		
		One day	Three days	Seven days
DnBP	8.63	8.52	8.74	8.43
BBzP	9.02	9.12	9.67	9.77
BMPP	10.24	9.56	9.91	9.62
DEEP	10.51	9.84	9.95	9.93
DBEP	11.98	7.58	8.06	7.72
DnOP	12.08	11.26	11.55	11.14
DEHP	12.56	10.19	10.00	10.15
DNP	12.59	10.58	10.92	11.02

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