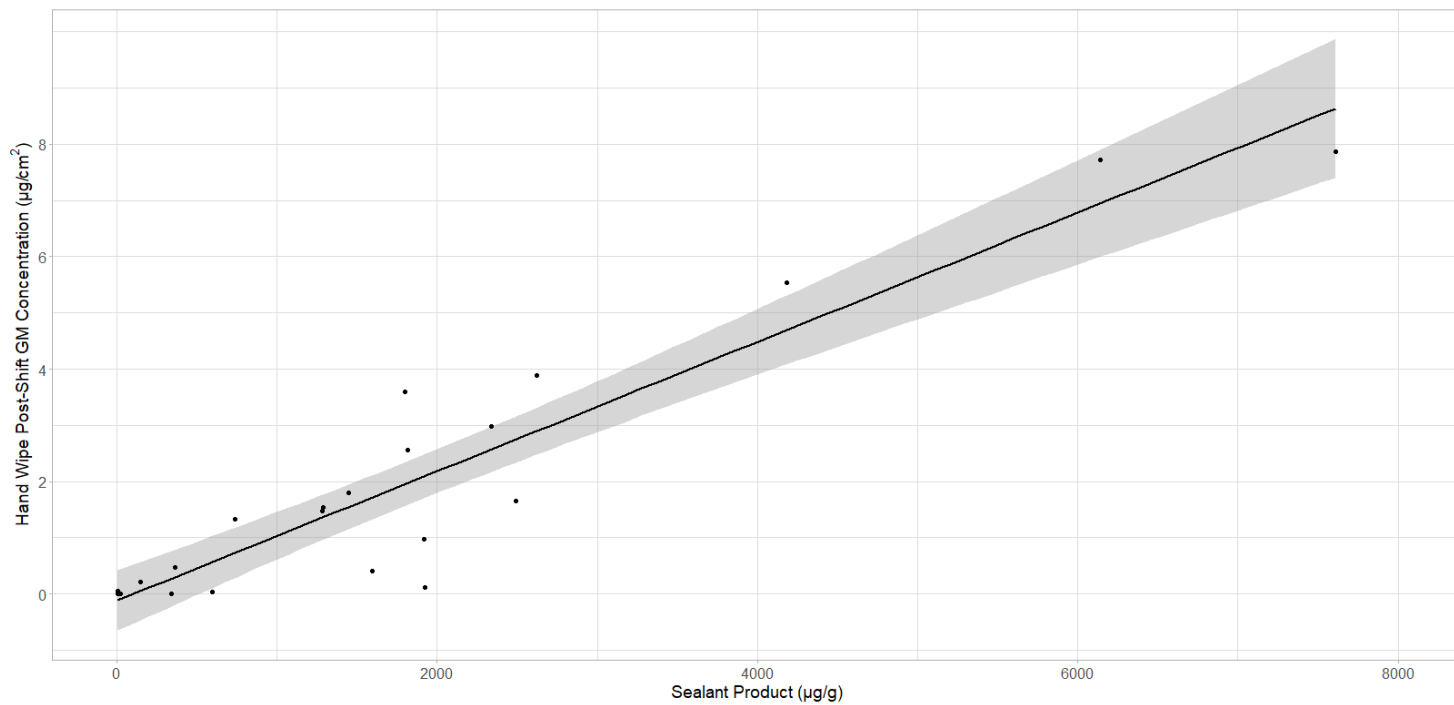


SUPPLEMENTAL FIGURE



Supplemental Figure S1. Fitted regression line of hand wipe post-shift ($\mu\text{g}/\text{cm}^2$) GM concentrations and assemblage of PAHs in products ($\mu\text{g}/\text{g}$). Estimated intercept and slope are -0.117 and 0.0012 , and corresponding p-value is less than 0.001 .

SUPPLEMENTAL TABLES

Supplemental Table S1. PAHs not currently classifiable or considered carcinogenic to humans quantified in air, hand wipe, and neck wipe samples. Abbreviations are shown in parentheses.

| Analyte | IARC Classification* | CAS Number | Molecular Weight (g/mole) |
|---------------------------------------|-------------------------|------------|------------------------------|
| PAH | | | |
| 1-methylnaphthalene (1MNAP) | NA | 90-12-0 | 142.2 |
| 2-methylnaphthalene (2MNAP) | NA | 91-57-6 | 142.2 |
| Acenaphthylene (ACY) | NA | 208-96-8 | 152.2 |
| Acenaphthene (ACE) | 3 | 83-32-9 | 154.2 |
| Anthracene (ANT) | 3 | 120-12-7 | 178.2 |
| Fluoranthene (FLA) | 3 | 206-44-0 | 202.3 |
| Benzo[<i>b</i>]fluoranthene (BbF) | 3 | 205-99-2 | 252.3 |
| Benzo[<i>g,h,i</i>]perylene (BghiP) | 3 | 191-24-2 | 288.4 |
| N-heterocyclic | | | |
| Isoquinoline (IQN) | NA | 119-65-3 | 129.2 |
| Acridine (ACR) | 3 | 494-38-2 | 179.2 |

* Group 3: Not classifiable as to its carcinogenicity in humans (IARC, 2012).

Supplemental Table S2. PBZ air ($\mu\text{g}/\text{m}^3$), hand wipe post-shift ($\mu\text{g}/\text{cm}^2$), and neck wipe post-shift ($\mu\text{g}/\text{sample}$) concentrations of PAHs for all companies. N of workers = 20 (exclude one female in company A).

| Analyte | PBZ Air Concentration (Number of Samples = 68) | | | | Hand Wipe Post-Shift Concentration (Number of Samples = 37) | | | | Neck Wipe Post-Shift Concentration (Number of Samples = 37) | | | |
|--------------|---|---------------------|-----------------|------------------|--|---------------------|-----------------|------------------|--|---------------------|-----------------|------------------|
| | K < LOD* (%) | Medain [†] | GM [†] | GSD [†] | K < LOD* (%) | Medain [†] | GM [†] | GSD [†] | K < LOD* (%) | Medain [†] | GM [†] | GSD [†] |
| IQN | 18 (26) | 0.30 | 0.11 | 13.53 | 32 (86) | 0.00 | 0.00 | 67.23 | 37 (100) | – | – | – |
| 1MNAP | 20 (29) | 6.63 | 6.99 | 2.32 | 22 (59) | 0.00 | 0.00 | 73.32 | 34 (92) | 0.00 | 0.00 | 172.0 |
| 2MNAP | 20 (29) | 13.59 | 13.29 | 2.23 | 10 (27) | 0.12 | 0.09 | 10.16 | 18 (49) | 0.96 | 0.06 | 43.44 |
| ACY | 41 (60) | 0.00 | 0.00 | 97.40 | 33 (89) | 0.00 | 0.00 | 110.2 | 36 (97) | 0.00 | 0.00 | 48.40 |
| ACE | 0 (0) | 11.83 | 11.96 | 2.54 | 2 (5) | 0.40 | 0.41 | 7.59 | 19 (51) | 0.00 | 0.05 | 52.28 |
| ANT | 0 (0) | 1.81 | 1.56 | 2.71 | 1 (3) | 1.59 | 1.60 | 7.62 | 17 (46) | 0.96 | 0.12 | 45.67 |
| ACR | 39 (57) | 0.00 | 0.00 | 101.0 | 2 (5) | 0.26 | 0.25 | 5.70 | 31 (84) | 0.00 | 0.00 | 105.9 |
| FLA | 0 (0) | 1.60 | 1.56 | 2.82 | 1 (3) | 8.50 | 7.31 | 10.47 | 5 (14) | 4.40 | 3.05 | 15.64 |
| BbF | 21 (31) | 0.16 | 0.06 | 15.59 | 1 (3) | 4.02 | 3.78 | 8.15 | 12 (33) | 2.20 | 0.79 | 32.61 |
| BghiP | 27 (40) | 0.09 | 0.01 | 29.33 | 1 (3) | 1.59 | 1.53 | 6.06 | 19 (51) | 0.00 | 0.08 | 53.53 |

* Non-detected values replaced using β -substitution (Ganser and Hewett, 2010). The PBZ air LOD for all analytes is $0.02 \mu\text{g}/\text{m}^3$. Exposure levels of PAHs were standardized by the surface area of both hands based on mean dermal exposure factor data (1070 cm^2 for males (EPA, 2011)). The hand wipe LODs are $0.0018 \mu\text{g}/\text{cm}^2$ for IQN and $0.0009 \mu\text{g}/\text{cm}^2$ for the other analytes when participants are males. The neck wipe LODs are $0.02 \mu\text{g}/\text{sample}$ for IQN and $0.01 \mu\text{g}/\text{sample}$ for the other analytes

[†] Reported medians, GMs, and GSDs for analytes with less than 50% detection rate may not be reliable.

Supplemental Table S3. PBZ air concentrations of PAHs ($\mu\text{g}/\text{m}^3$) by company and applicator status*.

| Analyte [†] | Company A (Number of Samples = 11) | | | | | | Company B (Number of Samples = 39) | | | | | | Company C (Number of Samples = 18) | | | | | |
|---------------------------|------------------------------------|-----------------|------------------|-------------------------------------|-----------------|------------------|------------------------------------|-----------------|------------------|--------------------------------------|-----------------|------------------|------------------------------------|-----------------|------------------|--------------------------------------|-----------------|------------------|
| | 1 Applicator With 4 Samples | | | 2 Non-Applicators With 7 Samples | | | 3 Applicators With 16 Samples | | | 5 Non-Applicators With 23 Samples | | | 2 Applicators With 4 Samples | | | 7 Non-Applicators With 14 Samples | | |
| | Median [†] | GM [†] | GSD [†] | Median [†] | GM [†] | GSD [†] | Median [†] | GM [†] | GSD [†] | Median [†] | GM [†] | GSD [†] | Median [†] | GM [†] | GSD [†] | Median [†] | GM [†] | GSD [†] |
| NAP ^Ω | 36.54 | 28.59 | 2.12 | 45.82 | 33.19 | 2.11 | 58.87 | 53.05 | 2.32 | 46.65 | 33.60 | 2.68 | 217.4 | 207.5 | 1.31 | 141.0 | 146.9 | 1.51 |
| QN ^Ω | 0.28 | 0.26 | 1.60 | 0.34 | 0.28 | 1.77 | 1.17 | 0.95 | 2.33 | 0.57 | 0.53 | 3.09 | 3.62 | 3.51 | 1.34 | 2.41 | 2.54 | 1.56 |
| FLU | 12.57 | 8.06 | 3.16 | 5.24 | 4.74 | 2.31 | 5.22 | 6.03 | 1.90 | 3.84 | 3.94 | 2.16 | 24.29 | 22.96 | 1.36 | 15.04 | 15.25 | 1.76 |
| CAR ^Ω | 1.62 | 0.86 | 4.13 | 0.11 | 0.18 | 6.04 | 0.42 | 0.33 | 2.18 | 0.18 | 0.15 | 3.87 | 1.24 | 0.90 | 2.63 | 0.50 | 0.54 | 1.98 |
| PHE | 26.22 | 16.38 | 3.42 | 7.99 | 8.02 | 2.40 | 10.15 | 9.70 | 1.91 | 5.20 | 6.16 | 2.06 | 32.29 | 28.29 | 1.80 | 16.41 | 17.28 | 1.87 |
| PYR | 3.50 | 1.75 | 4.76 | 0.16 | 0.42 | 4.45 | 1.17 | 1.00 | 2.31 | 0.61 | 0.66 | 2.40 | 4.16 | 2.70 | 3.12 | 1.36 | 1.58 | 2.02 |
| BaA ^Ω | 0.98 | 0.19 | 29.78 | 0.00 | 0.02 | 26.47 | 0.13 | 0.04 | 18.44 | 0.06 | 0.02 | 13.41 | 1.26 | 0.56 | 5.50 | 0.26 | 0.36 | 2.21 |
| CHR ^Ω | 0.89 | 0.20 | 22.10 | 0.00 | 0.02 | 19.40 | 0.18 | 0.09 | 11.56 | 0.11 | 0.04 | 10.62 | 1.43 | 0.62 | 5.45 | 0.29 | 0.42 | 2.24 |
| BaP [¥] | 0.92 | 0.18 | 30.29 | 0.00 | 0.02 | 27.01 | 0.13 | 0.04 | 18.23 | 0.08 | 0.02 | 13.81 | 1.05 | 0.40 | 6.50 | 0.21 | 0.28 | 2.32 |
| BkF ^Ω | 0.35 | 0.05 | 46.84 | 0.00 | 0.00 | 47.53 | 0.06 | 0.01 | 33.49 | 0.00 | 0.00 | 26.75 | 0.58 | 0.06 | 63.88 | 0.12 | 0.10 | 7.42 |
| IP ^Ω | 0.46 | 0.09 | 32.56 | 0.00 | 0.01 | 30.95 | 0.08 | 0.02 | 21.01 | 0.00 | 0.01 | 19.71 | 0.73 | 0.10 | 44.14 | 0.18 | 0.22 | 2.23 |
| DBahA ^B | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 98.70 | 0.00 | 0.00 | 11.7 | 0.14 | 0.00 | 60.55 | 0.00 | 0.00 | 26.07 |

* Non-detected values replaced using β -substitution (Ganser and Hewett, 2010). The LOD for all analytes is $0.02 \mu\text{g}/\text{m}^3$.

[†] Reported medians, GMs, and GSDs for analytes with less than 50% detection rate may not be reliable.

[¥] IARC Group 1: Carcinogenic to humans. ^B IARC Group 2A: Probably carcinogenic to humans. ^Ω IARC Group 2B: Possibly carcinogenic to humans.

Supplemental Table S4. Air concentrations of PAHs ($\mu\text{g}/\text{m}^3$) measured in area samples.

| All Companies (Number of Area Samples = 36) | | | | |
|--|------------------------|---------------|-----------------------|------------------------|
| Analyte | K < LOD* (%) | Median | GM[†] | GSD[†] |
| NAP ^Ω | 0 (0) | 6.48 | 6.50 | 5.88 |
| QN ^Ω | 13 (36) | 0.13 | 0.05 | 20.86 |
| FLU | 6 (17) | 1.44 | 0.85 | 9.82 |
| CAR ^Ω | 22 (61) | 0.00 | 0.00 | 77.09 |
| PHE | 1 (3) | 2.08 | 1.58 | 4.77 |
| PYR | 17 (47) | 0.10 | 0.01 | 32.77 |
| BaA ^Ω | 36 (100) | – | – | – |
| CHR ^Ω | 36 (100) | – | – | – |
| BaP [¥] | 35 (97) | 0.00 | 0.00 | 187.8 |
| BkF ^Ω | 36 (100) | – | – | – |
| IP ^Ω | 36 (100) | – | – | – |
| DBahA ^B | 36 (100) | – | – | – |

* Non-detected values replaced using β -substitution (Ganser and Hewett, 2010). The LOD for all analytes is $0.02 \mu\text{g}/\text{m}^3$.

[†] Reported medians, GMs, and GSDs for analytes with less than 50% detection rate may not be reliable.

[¥] IARC Group 1: Carcinogenic to humans.

^B IARC Group 2A: Probably carcinogenic to humans.

^Ω IARC Group 2B: Possibly carcinogenic to humans.

Supplemental Table S5. Unadjusted urinary biomarker pre-shift and post-shift concentration ($\mu\text{g/L}$), and difference of pre- and post-shift concentrations for all companies (Number of samples = 71; N of workers = 20).

| Biomarker* | Pre-Shift | | | Post-Shift | | | Difference |
|------------------|-----------|-------|------|------------|-------|------|------------|
| | Median | GM | GSD | Median | GM | GSD | Median |
| 1-OHNAP | 14.20 | 15.03 | 2.89 | 45.70 | 43.26 | 2.58 | 26.80 |
| 2-OHNAP | 20.38 | 19.58 | 2.60 | 58.30 | 55.18 | 2.36 | 30.80 |
| Sum-OHNAP | 36.41 | 37.83 | 2.51 | 114.00 | 105.3 | 2.31 | 60.20 |
| 2-OHFLU | 22.87 | 21.96 | 3.01 | 83.40 | 74.33 | 2.82 | 43.74 |
| 3-OHFLU | 10.10 | 8.88 | 3.12 | 24.20 | 21.97 | 2.91 | 12.03 |
| Sum-OHFLU | 33.10 | 31.35 | 2.97 | 104.70 | 98.03 | 2.78 | 58.02 |
| 1-OHPHE | 11.35 | 9.39 | 2.88 | 33.30 | 26.26 | 3.10 | 15.70 |
| 2,3-OHPHE | 11.11 | 11.66 | 2.74 | 44.10 | 42.21 | 3.05 | 26.69 |
| Sum-OHPHE | 23.30 | 21.48 | 2.74 | 80.00 | 69.49 | 3.03 | 40.84 |
| 1-OHP | 24.10 | 18.82 | 4.05 | 52.10 | 39.47 | 4.45 | 18.24 |

* Abbreviations of biomarkers: 1-Hydroxynaphthalene (1-OHNAP), 2-Hydroxynaphthalene (2-OHNAP), 2-Hydroxyfluorene (2-OHFLU), 3-Hydroxyfluorene (3-OHFLU), 1-Hydroxyphenanthrene (1-OHPHE), 2,3-Hydroxyphenanthrene (2,3-OHPHE), 1-Hydroxypyrene (1-OHP).

Supplemental Table S6. PBZ air ($\mu\text{g}/\text{m}^3$), hand wipe post-shift ($\mu\text{g}/\text{cm}^2$), and neck wipe post-shift ($\mu\text{g}/\text{sample}$) concentrations of PAHs for all companies. N of workers = 21 (include one female in company A).

| Analyte | PBZ Air Concentration (Number of Samples = 72) | | | | Hand Wipe Post-Shift Concentration (Number of Samples = 38) | | | | Neck Wipe Post-Shift Concentration (Number of Samples = 38) | | | |
|---------------------------|---|---------------------|-----------------|------------------|--|---------------------|-----------------|------------------|--|---------------------|-----------------|------------------|
| | K < LOD* (%) | Median [†] | GM [†] | GSD [†] | K < LOD* (%) | Median [†] | GM [†] | GSD [†] | K < LOD* (%) | Median [†] | GM [†] | GSD [†] |
| NAP ^Ω | 0 (0) | 59.54 | 52.10 | 2.82 | 6 (16) | 0.28 | 0.15 | 8.64 | 10 (26) | 1.10 | 0.39 | 11.97 |
| QN ^Ω | 1 (1) | 0.92 | 0.78 | 3.21 | 9 (24) | 0.16 | 0.05 | 14.67 | 28 (74) | 0.00 | 0.00 | 109.5 |
| FLU | 0 (0) | 6.52 | 6.50 | 2.51 | 0 (0) | 0.73 | 0.97 | 3.82 | 17 (45) | 0.93 | 0.13 | 40.92 |
| CAR ^Ω | 5 (7) | 0.38 | 0.28 | 3.74 | 1 (3) | 1.36 | 1.44 | 6.45 | 24 (63) | 0.00 | 0.02 | 62.89 |
| PHE | 0 (0) | 10.42 | 9.76 | 2.37 | 0 (0) | 6.03 | 7.86 | 3.70 | 1 (3) | 5.50 | 6.08 | 5.94 |
| PYR | 0 (0) | 0.90 | 0.92 | 2.91 | 1 (3) | 5.70 | 5.23 | 9.15 | 12 (32) | 2.80 | 0.88 | 31.96 |
| BaA ^Ω | 22 (31) | 0.15 | 0.06 | 15.04 | 1 (3) | 2.94 | 2.86 | 7.50 | 14 (37) | 1.45 | 0.39 | 35.02 |
| CHR ^Ω | 18 (25) | 0.18 | 0.09 | 10.93 | 1 (3) | 3.46 | 3.44 | 7.66 | 14 (37) | 1.55 | 0.47 | 36.38 |
| BaP [¥] | 22 (31) | 0.15 | 0.05 | 14.66 | 1 (3) | 2.62 | 2.48 | 7.18 | 13 (34) | 1.80 | 0.46 | 31.41 |
| BkF ^Ω | 33 (46) | 0.06 | 0.01 | 36.66 | 1 (3) | 1.40 | 1.30 | 6.00 | 20 (53) | 0.00 | 0.07 | 53.71 |
| IP ^Ω | 27 (38) | 0.10 | 0.02 | 21.43 | 1 (3) | 1.87 | 1.76 | 6.28 | 15 (40) | 1.25 | 0.25 | 36.55 |
| DBahA ^B | 58 (81) | 0.00 | 0.00 | 465.9 | 1 (3) | 0.45 | 0.47 | 4.45 | 28 (74) | 0.00 | 0.00 | 79.21 |

* Non-detected values replaced using β -substitution (Ganser and Hewett, 2010). The PBZ air LOD for all analytes is $0.02 \mu\text{g}/\text{m}^3$. Exposure levels of PAHs were standardized by the surface area of both hands based on mean dermal exposure factor data (1070 cm^2 for males and 890 cm^2 for females (EPA, 2011)). The hand wipe LODs are $0.0009 \mu\text{g}/\text{cm}^2$ when participants are males and are $0.0011 \mu\text{g}/\text{cm}^2$ when participants are females. The neck wipe LODs are $0.01 \mu\text{g}/\text{sample}$.

[†] Reported medians, GMs, and GSDs for analytes with less than 50% detection rate may not be reliable.

[¥] IARC Group 1: Carcinogenic to humans. ^B IARC Group 2A: Probably carcinogenic to humans. ^Ω IARC Group 2B: Possibly carcinogenic to humans.

Supplemental Table S7. Urinary biomarker pre-shift and post-shift concentration ($\mu\text{g/g}$ creatinine), and difference of pre- and post-shift concentrations by company. N of workers = 21 (include one female in company A).

| | Pre-Shift | | | Post-Shift | | | Difference |
|---|-----------|-------|------|------------|-------|------|------------|
| | Median | GM | GSD | Median | GM | GSD | Median |
| All Companies (Number of Samples = 75) | | | | | | | |
| 1-OHNAP | 8.49 | 8.26 | 2.35 | 14.75 | 15.99 | 2.15 | 6.26 |
| 2-OHNAP | 10.67 | 10.81 | 2.29 | 20.74 | 21.70 | 2.09 | 8.60 |
| Sum-OHNAP | 20.87 | 20.79 | 2.13 | 35.85 | 40.50 | 1.94 | 13.48 |
| 2-OHFLU | 12.29 | 11.65 | 2.51 | 31.42 | 27.47 | 2.28 | 14.06 |
| 3-OHFLU | 4.67 | 4.70 | 2.60 | 8.30 | 8.05 | 2.34 | 2.51 |
| Sum-OHFLU | 16.44 | 16.60 | 2.47 | 37.84 | 36.13 | 2.24 | 15.99 |
| 1-OHPHE | 6.09 | 4.93 | 2.66 | 10.33 | 9.68 | 2.49 | 3.83 |
| 2,3-OHPHE | 6.73 | 5.90 | 2.53 | 17.04 | 15.22 | 2.48 | 9.71 |
| Sum-OHPHE | 12.77 | 11.08 | 2.52 | 26.92 | 25.28 | 2.44 | 13.11 |
| 1-OHP | 14.59 | 9.59 | 3.86 | 18.28 | 14.20 | 3.63 | 2.41 |
| Company A* (Number of Samples = 15) | | | | | | | |
| 1-OHNAP | 8.20 | 8.19 | 1.79 | 12.00 | 11.91 | 1.49 | 3.56 |
| 2-OHNAP | 7.51 | 9.81 | 2.08 | 18.22 | 20.00 | 2.25 | 7.13 |
| 2-OHFLU | 8.83 | 9.37 | 2.12 | 30.29 | 23.75 | 2.15 | 14.37 |
| 3-OHFLU | 3.59 | 3.53 | 2.31 | 5.98 | 5.85 | 2.21 | 2.04 |
| 1-OHPHE | 3.43 | 3.52 | 2.59 | 8.76 | 6.75 | 2.59 | 3.40 |
| 2,3-OHPHE | 2.19 | 3.58 | 2.64 | 15.57 | 10.29 | 2.68 | 7.33 |
| 1-OHP | 4.75 | 4.24 | 5.24 | 9.45 | 5.80 | 5.16 | 2.21 |

* 1 and 3 workers had 3 and 4 samples, respectively, in company A.

Abbreviations of biomarkers: 1-Hydroxynaphthalene (1-OHNAP), 2-Hydroxynaphthalene (2-OHNAP), 2-Hydroxyfluorene (2-OHFLU), 3-Hydroxyfluorene (3-OHFLU), 1-Hydroxyphenanthrene (1-OHPHE), 2,3-Hydroxyphenanthrene (2,3-OHPHE), 1-Hydroxypyrene (1-OHP).

Supplemental Table S8. Results of unadjusted urinary 1-OHP last day post-shift concentration ($\mu\text{g/L}$) and corresponding ratios of pyrene (PYR) to benzo[*a*]pyrene (BaP) (adjusted BEI) for 26 PBZ air, hand wipe post-shift, and neck wipe post-shift samples.

| Sample | Company (Site) | Air BEI | Hand Wipe BEI | Neck Wipe BEI | Urinary 1-OHP ($\mu\text{g/L}$) [‡] |
|--------|----------------|---------|---------------|---------------|--|
| 1 | A | 3.43 | 2.45 | 1.55 | 52.17 |
| 2 | A | 4.21 | 2.38 | 2.63 | 145.2 |
| 3 | A | * | * # | * # | 0.53 |
| 4 | B (1) | 4.57 | 2.40 | * # | 11.49 |
| 5 | B (1) | 4.40 | 2.32 | 1.47 | 25.48 |
| 6 | B (1) | 2.43 | 2.60 | 1.60 | 32.10 |
| 7 | B (2) | * | 1.84 | 1.94 | 58.90 |
| 8 | B (2) | 5.36 | 2.22 | 2.35 | 114.0 |
| 9 | B (2) | * | 2.13 | 6.20 | 142.0 |
| 10 | B (2) | 14.00 | 2.00 | 1.90 | 273.0 |
| 11 | B (2) | * | 1.93 | 2.66 | 52.10 |
| 12 | B (2) | * | 2.40 | 1.79 | 78.70 |
| 13 | B (3) | * | 1.96 | * | 139.0 |
| 14 | B (3) | * | 2.79 | * # | 377.0 |
| 15 | B (3) | * | 2.55 | 2.31 | 229.0 |
| 16 | B (4) | 3.32 | 2.50 | 2.29 | 203.0 |
| 17 | B (4) | 3.88 | 1.64 | * | 5.13 |
| 18 | C | 3.50 | 2.39 | 2.33 | 90.00 |
| 19 | C | 17.62 | 2.44 | 2.18 | 24.70 |
| 20 | C | 7.11 | 1.82 | 0.88 | 44.30 |
| 21 | C | 6.00 | 1.97 | 1.57 | 25.10 |
| 22 | C | 16.82 | 2.17 | 2.16 | 109.0 |
| 23 | C | 5.38 | 2.00 | 2.13 | 145.0 |
| 24 | C | 5.27 | 2.20 | 0.68 | 14.50 |
| 25 | C | 5.53 | 1.91 | 1.38 | 5.20 |
| 26 | C | 8.80 | 1.76 | 0.81 | 14.00 |

* BaP was not detected for eight air samples, one hand wipe sample, and four neck wipe samples.

PYR was not detected for one hand wipe sample and three neck wipe samples.

‡ Concentrations of urinary 1-OHP exceeding the adjusted BEI for air, hand, or neck wipe indicates chronic occupational exposure and risk of genotoxicity.