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**SUPPORTING INFORMATION**

**Biological and Environmental Monitoring of Volatile Organic Compounds among Greater Boston Nail Technicians**

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|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **No.**  |  |  | **MDL†** | **Personal**  | **Area**  |
| **Analytes** | **Analyte** | **CAS#** |  **g/m3** | **%>MDL** | **%>MDL** |
| 1 | 1,1-Dichloroethylene | 75-35-4 | 0.15 | 0 | 0 |
| 2 | Acrylonitrile | 107-13-1 | 0.56 | 0 | 0 |
| 3 | Propanenitrile | 107-12-0 | 0.13 | 0 | 0 |
| 4 | trans-1,2-Dichloroethylene | 156-60-5 | 0.21 | 0 | 0 |
| 5 | 1,1-Dichloroethane | 75-34-3 | 0.22 | 0 | 0 |
| 6 | Propionitrile | 107-12-0 | 0.12 | 0 | 0 |
| 7 | Chloroprene | 126-99-8 | 0.31 | 0 | 0 |
| 8 | Methacrylonitrile | 126-98-7 | 0.60 | 0 | 0 |
| 9 | cis-1,2-Dichloroethylene | 156-59-2 | 0.18 | 0 | 0 |
| 10 | Ethyl Acetate | 141-78-6 | 0.28 | 100 | 100 |
| 11 | Methyl acrylate | 96-33-3 | 0.14 | 0 | 0 |
| 12 | Chloroform | 67-66-3 | 0.22 | 30 | 70 |
| 13 | Isobutanol | 78-83-1 | 2.25 | 0 | 0 |
| 14 | Tetrahydrofuran | 109-99-9 | 0.12 | 10 | 10 |
| 15 | 1,1,1-Trichloroethane | 71-55-6 | 0.26 | 0 | 0 |
| 16 | 1,2-Dichloroethane | 107-06-2 | 0.20 | 0 | 0 |
| 17 | 1,1-Dichloropropene | 563-58-6 | 0.20 | 20 | 10 |
| 18 | Benzene | 71-43-2 | 0.16 | 90 | 100 |
| 19 | Carbontetrachloride | 56-23-5 | 0.14 | 70 | 90 |
| 20 | 1,2-Dichloropropane | 78-87-5 | 0.32 | 0 | 0 |
| 21 | Trichloroethylene | 79-01-6 | 0.15 | 0 | 0 |
| 22 | Dibromomethane | 74-95-3 | 0.13 | 0 | 0 |
| 23 | Bromodichloromethane | 75-27-4 | 0.13 | 0 | 0 |
| 24 | 1,4-Dioxane | 123-91-1 | 0.23 | 40 | 50 |
| 25 | 2,5-Dimethylfuran | 625-86-5  | 0.33 | 0 | 0 |
| 26 | Methyl methacrylate | 80-62-6 | 0.37 | 80 | 60 |
| 27 | trans-1,3-Dichloropropene | 10061-02-6 | 0.23 | 0 | 0 |
| 28 | cis-1,3-Dichloropropene | 10061-01-5 | 0.18 | 0 | 0 |
| 29 | Toluene | 108-88-3 | 0.26 | 100 | 100 |
| 30 | 1,1,2-Trichloroethane | 79-00-5 | 0.18 | 0 | 0 |
| 31 | 1,3-Dichloropropane | 142-28-9 | 0.14 | 0 | 0 |
| 32 | Ethyl methacrylate | 97-63-2 | 0.28 | 70 | 70 |
| 33 | Dibromochloromethane | 124-48-1 | 0.09 | 0 | 0 |
| 34 | 1,2-Dibromoethane | 106-93-4 | 0.33 | 0 | 0 |
| 35 | Tetrachloroethylene | 127-18-4 | 0.10 | 20 | 70 |
| **†**MDL determined as described by Jia, C., Fu, X., 2017. Diffusive Uptake Rates of Volatile Organic Compounds on Standard ATD Tubes for Environmental and Workplace Applications. Environments 4, 87. |

Table S1b. Analytes method detection limit (MDL) and percent of thermal desorption tube personal and area air samples above MDL (Part 2/2)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **No.**  |  |  | **MDL†** | **Personal**  | **Area**  |
| **Analytes** | **Analyte** | **CAS#** |  **g/m3** | **%>MDL** | **%>MDL** |
| 36 | Chlorobenzene | 108-90-7 | 0.11 | 10 | 30 |
| 37 | 1,1,1,2-Tetrachloroethane | 630-20-6 | 0.15 | 0 | 0 |
| 38 | Ethylbenzene | 100-41-4 | 0.16 | 80 | 100 |
| 39 | m,p-Xylene | 108-38-3/106-42-3 | 0.35 | 90 | 100 |
| 40 | Bromoform | 75-25-2 | 0.19 | 0 | 0 |
| 41 | Styrene | 100-42-5 | 0.17 | 50 | 90 |
| 42 | o-Xylene | 95-47-6 | 0.23 | 60 | 90 |
| 43 | cis-1,4-Dichloro-2-butene | 1476-11-5 | 0.20 | 0 | 0 |
| 44 | 1,1,2,2-Tetrachloroethane | 79-34-5 | 0.16 | 0 | 0 |
| 45 | 1,2,3-Trichloropropane | 96-18-4 | 0.20 | 0 | 0 |
| 46 | Isopropylbenzene | 98-82-8 | 0.19 | 0 | 0 |
| 47 | trans-1,4-Dichloro-2-butene | 110-57-6 | 0.23 | 0 | 0 |
| 48 | Bromobenzene | 108-86-1 | 0.25 | 0 | 0 |
| 49 | 2-Chlorotoluene | 95-49-8 | 0.26 | 0 | 0 |
| 50 | Propylbenzene | 103-65-1 | 0.26 | 0 | 0 |
| 51 | 3-Ethylpyridine | 536-78-7  | 0.21 | 0 | 0 |
| 52 | 4-Chlorotoluene | 106-43-4 | 0.19 | 0 | 0 |
| 53 | 1,3,5-Trimethylbenzene | 108-67-8 | 0.19 | 10 | 0 |
| 54 | Pentachloroethane | 76-01-7 | 0.21 | 0 | 0 |
| 55 | tert-Butylbenzene | 98-06-6 | 0.25 | 0 | 0 |
| 56 | 1,2,4-Trimethylbenzene | 95-63-6 | 0.31 | 22 | 60 |
| 57 | 1,3-Dichlorobenzene | 106-46-7 | 0.15 | 0 | 0 |
| 58 | sec-Butylbenzene | 135-98-8 | 0.18 | 0 | 0 |
| 59 | 1,4-Dichlorobenzene | 541-73-1 | 0.15 | 20 | 70 |
| 60 | p-Isopropyltoluene | 99-87-6 | 0.16 | 80 | 90 |
| 61 | d-Limonene | 5989-27-5 | 0.53 | 100 | 100 |
| 62 | 1,2-Dichlorobenzene | 95-50-1 | 0.13 | 0 | 0 |
| 63 | Butylbenzene | 104-51-8 | 0.16 | 0 | 0 |
| 64 | 1,2-Dibromo-3-chloropropane | 96-12-8 | 0.16 | 0 | 0 |
| 65 | Nitrobenzene | 98-95-3 | 0.42 | 0 | 0 |
| 66 | 1,2,4-Trichlorobenzene | 120-82-1 | 0.20 | 0 | 0 |
| 67 | Naphthalene | 91-20-3 | 0.35 | 20 | 70 |
| 68 | 1,2,3-Trichlorobenzene | 87-61-6 | 0.27 | 0 | 0 |
| 69 | Hexachlorobutadiene | 87-68-3 | 0.26 | 0 | 0 |
| 70 | Phenylcyclohexane | 827-52-1 | 0.27 | 0 | 0 |
| 71 | Nicotine | 54-11-5 | 9.88 | 0 | 0 |
| **†**MDL determined as described by Jia, C., Fu, X., 2017. Diffusive Uptake Rates of Volatile Organic Compounds on Standard ATD Tubes for Environmental and Workplace Applications. Environments 4, 87. |

1. Table S2. Analyte MDL and percent of blood VOC pre- and post-shift levels above MDL

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  | **Pre-****shift**  | **Post-****shift**  |  |  |  |  |  |  | **Pre-shift**  | **Post-shift**  |
| **No.** **Analytes** | **Analyte** | **CAS #** | **MDL†** | **%>MDL** | **%>MDL** |  | **No.** **Analytes** | **Analyte** |  | **CAS #** | **MDL†** | **%>MDL** | **%>MDL** |
| 1 | 2,5 Dimethylfuran | 625-86-5 | 0.011 | 0 | 0 |  | 23 | 1,4 Dioxane |  | 123-91-1 | 0.5 | 0 | 0 |
| 2 | Hexane | 110-82-7 | 0.122 | 0 | 0 |  | 24 | Ethyl acetate |  | 141-78-6 | 0.158 | 20 | 90 |
| 3 | Heptane | 142-82-5 | 0.1 | 0 | 0 |  | 25 | Ethyl benzene |  | 100-41-4 | 0.024 | 0 | 0 |
| 4 | Octane | 111-65-9 | 0.1 | 0 | 0 |  | 26 | Furan |  | 110-00-9 | 0.025 | 0 | 0 |
| 5 | 1,2 Dichlorobenzene | 95-50-1 | 0.025 | 0 | 0 |  | 27 | Isobutyronitrile |  | 78-82-0 | 0.04 | 0 | 0 |
| 6 | 1,2 Dichloroethane | 107-06-2 | 0.01 | 10 | 20 |  | 28 | Isopropylbenzene |  | 98-82-8 | 0.04 | 0 | 0 |
| 7 | 1,3 Dichlorobenzene | 541-73-1 | 0.025 | 0 | 0 |  | 29 | Methylene chloride |  | 75-09-2 | 0.25 | 0 | 0 |
| 8 | Tetrachloroethylene | 127-18-4 | 0.048 | 10 | 0 |  | 30 | Methylcyclopentane |  | 96-37-7 | 0.02 | 0 | 0 |
| 9 | 1,1,1,2 Tetrachloroethane | 630-20-6 | 0.04 | 0 | 0 |  | 31 | T Butyl methyl ether |  | 1634-04-4 | 0.02 | 0 | 10 |
| 10 | Bromoform | 75-25-2 | 0.008 | 0 | 0 |  | 32 | Methyl isobutyl ketone |  | 108-10-1 | 0.10 | 0 | 0 |
| 11 | Bromodichloromethane | 75-27-4 | 0.006 | 0 | 0 |  | 33 | Nitrobenzene |  | 98-95-3 | 0.32 | 0 | 0 |
| 12 | Benzene | 71-43-2 | 0.024 | 0 | 0 |  | 34 | o-Xylene |  | 95-47-6 | 0.024 | 0 | 0 |
| 13 | Benzonitrile | 100-47-0 | 0.15 | 0 | 0 |  | 35 | Styrene |  | 100-42-5 | 0.03 | 10 | 20 |
| 14 | Cyclohexane | 110-82-7 | 0.02 | 0 | 0 |  | 36 | Trichloroethylene |  | 79-01-6 | 0.012 | 0 | 0 |
| 15 | Chlorobenzene | 108-90-7 | 0.011 | 0 | 0 |  | 37 | 1,1,1-Trichloroethane |  | 71-55-6 | 0.01 | 0 | 0 |
| 16 | Chloroethane | 75-00-3 | 0.045 | 0 | 0 |  | 38 | a,a,a Trifluorotoluene |  | 98-08-8 | 0.04 | 0 | 0 |
| 17 | Chloroform | 67-66-3 | 0.008 | 20 | 20 |  | 39 | Tetrahydrofuran |  | 109-99-9 | 0.125 | 0 | 0 |
| 18 | Dibromochloromethane | 124-48-1 | 0.005 | 0 | 0 |  | 40 | Toluene |  | 108-88-3 | 0.025 | 90 | 100 |
| 19 | Carbon tetrachloride | 56-23-5 | 0.005 | 0 | 0 |  | 41 | 1,2,3 Trichloropropane |  | 96-18-4 | 0.04 | 0 | 0 |
| 20 | 1,4 Dichlorobenzene | 106-46-7 | 0.04 | 10 | 10 |  | 42 | Vinyl bromide |  | 593-60-2 | 0.045 | 0 | 0 |
| 21 | 1,2 Dibromoethane | 106-93-4 | 0.015 | 0 | 0 |  | 43 | m,p-Xylene |  | 108-38-3/106-42-3 | 0.034 | 30 | 20 |
| 22 | Ethyl ether | 60-29-7 | 0.04 | 0 | 0 |   |   |   |  |   |   |   |   |
| **†**Method detection limit (MDL) was determined empirically by the CDC at the concentration where the false positive rate among blank-level samples and the false negative rate among detection-level samples are both less than or equal to five percent. Note that the probability limit of five percent is a historical, consensus quantity recognized across scientific fields, and was established without regard to empirical or optimality criteria. |

1. Table S3. Personal characteristics of the nail technicians

|  |  |
| --- | --- |
| **Personal behaviors** | **No. of nail technician responses** |
| **Washing hands** |  |
| *At work* | ***10*** |
| < 5 times/day | 1 |
| 5+ times/day  | 9 |
| *Before eating at work* | ***10*** |
| Always | 8 |
| Sometimes | 2 |
| *Before leaving work* | ***10*** |
| Always | 7 |
| Sometimes | 3 |
| **Paints own nails** | ***7*** |
| All/Most of the time | 2 |
| Sometimes | 5 |
| **If drank alcohol last night** |  |
|  Yes | 1 |
|  No/No response | 9 |

1. Table S4. Nail technicians use of personal protective equipment

|  |  |
| --- | --- |
|  **Self-reported personal protective equipment (PPE)** | **No. of nail technician responses** |
| **Glove use** |  |
| *At work* |  |
| Always | 4 |
| Most of time | 2 |
| Sometimes | 3 |
| Never | 1 |
| *While removing nail polish* |  |
| Always | 5 |
| Most of time | 2 |
| Sometimes | 2 |
| Never | 1 |
| *While painting nails* |  |
| Always | 3 |
| Most of time | 0 |
| Sometimes | 2 |
| Never | 4 |
| *Types of gloves reported* |  |
| Nitrile | 1 |
| Latex | 4 |
| Don't use gloves | 1 |
| *Had re-used gloves* | *2* |
| **Coat/coverall** |  |
|  Yes | 6 |
|  No | 3 |
| **Respirator** |  |
|  Yes | 3 |
|  No | 7 |
| **PPE Observations during our visit** |   |
| **Respirator use†** |  |
| Disposable N95 with charcoal cartridges | 2 |
| **Glove use** |  |
| Yes |  |
| Latex for pedicure | 9 |
| Nitrile for manicure | 3 |
| No | 1 |
| **Other PPE** |  |
| Safety glasses | 1 |

†Most salons used surgical masks that were mistakenly identified as respirators

1. **Estimated VOC emissions to outdoor air**

We estimated annual emissions to the outdoor air (without filtration) using a one-compartment box model.77 Assuming steady state conditions, the emission of an individual VOC per salon was calculated as the product of its average indoor concentration, the air exchange rate, and the volume of the salon.

Emission per salon (g/hr) = (Cin-Cout) \* Flow

                 = (Cin-Cout) \* ACH \* Volume (of salon)

 = Cin \* ACH \* Vol. (assuming If Cout << Cin)

Cin was the salon area concentration

The total emission in the city of Boston was estimated by assuming salons were open every day of the year and by multiplying the average emission of the sampled salons by 200, the number of the nail salons in the city.1 Our estimated annual VOC emissions to the outdoor air from nail salons in the City of Boston were compared with total on-site VOC emissions in the City of Boston and Suffolk County (where the City of Boston resides as the largest city) in 2016 reported by the Toxics Release Inventory (TRI) system of the U.S. (EPA).2

The estimated annual emissions to the outdoor air for the measured VOCs in the nail salons are listed in Table S5. The same comparison was not possible for other VOCs likely emitted from the nail salons, as they were not regulated.

1. Table S5. Annual estimates of outdoor emissions of VOCs in nail salons

|  |  |  |
| --- | --- | --- |
| **Analyte†** | **Nail salons emission****in the** **City of Boston****2016-17‡** | **U.S. EPA** **emission** **Suffolk County****2016§** |
| **Metric tons/year** | **Metric tons/year** |
| Benzene | 0.37 | 0.58 |
| Ethyl acetate | 182 | NR |
| Ethyl benzene | 0.06 | 0.42 |
| Ethyl methacrylate | 39.0 | NR |
| Carbon tetrachloride | 0.12 | NR |
| p-Isopropyl toluene | 0.20 | NR |
| d-Limonene | 7.23 | NR |
| Methyl methacrylate | 104 | NR |
| Styrene | 0.05 | NR |
| Toluene | 2.97 | 1.2 |
| o-Xylene | 0.06 | NR |
| m,p-Xylene | 0.16 |  NR  |
| The Xylenes (combined) | 0.22 | 1.8 |
| **†**VOCs >50% limit of detection |
| ‡Assuming 200 nail salons in the City of Boston§Total on-site disposal or other releases from the Toxic Release Inventory. Data obtained from: United States Environmental Protection Agency. (2019). TRI Explorer (2017 Dataset (released October 2018)) [Internet database]. Retrieved from https://www.epa.gov/triexplorer, (January 24, 2019).NR = none reported |

1. Ventilation rate calculation

To estimate ventilation rates we used the constant concentration method by ASHRAE4. This method requires the measurements to be collected in room air that has equilibrated and reached a steady state concentration. If CO2 levels are relatively stable the assumption is valid. The method also requires a value for the CO2 generation rate per person.

Ventilation rate (L/s) =                   G(CO2)(L/hr)

                                              (Ci- C0) x 3600 (s/hr)

where:

           G(CO2)= resting rate of production of CO2 by an average person (13.2 L/hr)5 times the number of occupants;

            Ci = concentration of CO2 measured at steady state; not in ppm so 1000 ppm is 0.001

            C0 = concentration of CO2 in the outside air; not in ppm so 400  ppm is 0.0004

**References**

1. Seller S. Personal communication with Ms. Stephanie Seller, Boston Public Health Commission. In:2017.
2. USEPA. Toxics Release Inventory (TRI) Program. <https://www.epa.gov/toxics-release-inventory-tri-program>. Accessed October 24, 2018, 2018.
3. Lee and Siconolfi (1994) measured G(CO2) on 23 astronauts in a seated position and obtained a value of 13.2 L/hr +/- 1.2 L/hr. People in a seated position have an M value of 1 (Persily 1997). Apart from the difference in M value, the measured G(CO2 ) value (13.2 L/hr) is comparable to the ASHRAE G(CO2) assuming 1 M (15 L/hr).
4. ASHRAE. 2001. ANSI/ASHRAE Stanndard 62-2001, Ventilation for Acceptable Indoor Air Quality Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineerings, Inc., Appendix C and Figure C-2.
5. Lee SM, Siconolfi SF. 1994. Carbon Dioxide and Water Vapor Production at Rest and During Exercise: A Report on Data Collection for the Crew and Thermal Systems Division, NASA Technical Paper no 3500.