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### Dermal uptake of benzophenone-3 from clothing

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#### 1 Introduction

Benzophenone-3 (aka BP-3, oxybenzone) is added to sunscreens, plastics and some coatings to filter UV radiation. A suspected endocrine disruptor, BP-3 has been widely detected and not only in summertime, where a more intended use of sunscreen might be expected in the urine of Danish children (Frederiksen et al., 2016; Krause et al, 2016) and other populations. BP-3 has been found in the air and settled dust of homes (Wan et al., 2015) and is expected to redistribute from its original sources to other indoor compartments, including clothing. As has been previously observed for phthalates (Morrison et al., 2016), we hypothesized that dermal uptake from clothing would occur and could contribute to the body burden of this compound.

#### 2 Materials/Methods

**Shirts.** New long-sleeve t-shirts, comprised of 100% cotton, were washed, dried and then exposed to airborne BP-3 in a dosing chamber for 32 days at 25°C. The airborne concentration of BP-3 at the end of the dosing period was 4.4 µg/m<sup>3</sup>.

**Participant exposure chamber.** The 55 m<sup>3</sup> exposure chamber was ventilated at an air change rate of 0.7/h and has been described in detail by Weschler et al (2015). Unlike previous dermal uptake experiments, the concentration of

the target analyte was not intentionally elevated in the chamber air.

**Participants.** Prior to the exposure, the 3 male participants (aged 27, 36 and 51), all with normal BMI (21.9-24.8 kg/m<sup>2</sup>) were asked not to apply any sunscreen or any other products that may contain UV filters. Participants collected a urine sample on the morning prior to exposure and also immediately prior to donning the shirt and entering the chamber. All urinations were collected during the first 24 hours from the beginning of the exposure. Spot samples were collected on the morning of the following 2 days. Blood samples were also collected prior to, during and after the exposure period, but results are not reported here.

**Participant exposure.** Participants donned the dosed t-shirts and spent a total of 3 hours in the exposure chamber. Participants did not wear breathing hoods (as was the case in Morrison et al., 2016). Breathing zone samples verified that air concentrations were below detection limits for BP-3.

**Analysis of urine.** Urine samples were analysed for BP-3 and other UV filters by on-line Turboflow-LC-MS/MS preceded by enzymatic deconjugation (Frederiksen et al., 2016). Excreted mass was calculated by multiplying the urination concentration by the urine volume. The rate of excretion (mass) for each interval was calculated by dividing the excreted mass for

each urination by the elapsed time since the previous urination.

**Analysis of air and clothing.** Air samples were collected on thermal desorption (TD) tubes containing Tenax-TA, analyzed by TD-GCMS. Samples from shirts were extracted in acetonitrile and analyzed by high-performance liquid chromatography (HPLC). Both methods were calibrated using analytical standards.

### 3 Results and Discussion

The urine of all participants exhibited elevated BP-3 after wearing the t-shirts exposed to BP-3. Benzophenone-1 (BP-1), a potential metabolite of BP-3, was also elevated and correlated with BP-3 in urine samples. Total excreted mass of BP-1 and BP-3 for participants 1, 2 and 3 were 33, 19 and 112  $\mu\text{g}$  respectively. The excretion rate (BP-1+BP-3) for each participant is shown in Figure 1.

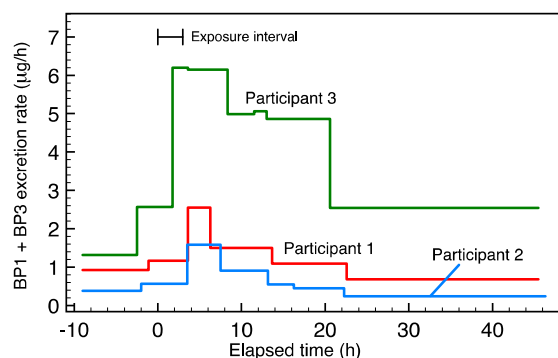


Figure 1: Excretion rate of the sum of BP-3 and BP-1 in urine.

Even with relatively high background urinary concentrations, wearing BP-3-dosed shirts clearly elevated excretion rates relative to pre-exposure (background) rates. For all subjects, excretion rates peaked within 4-8 hours after donning shirts. BP-3 continued to be excreted for at least 24 hours after exposure and perhaps longer (participant 3). Therefore, BP-3 that is sorbed by the skin continues to be released for an extended period after exposure. Note that the rise in excretion rate prior to the exposure interval is an artifact of reporting the average excretion rate between urinations.

Participant 3 absorbed substantially more BP-3 from the dosed shirt than participants 1 or 2. This effect is not due to differences in the composition of the shirts: the average concentration of BP-3 on the shirt worn by participant 3 was not larger than for participants

1 or 2. Dermal permeability varies among individuals and, for lipophilic compounds, may be higher for older individuals (Weschler et al., 2015). Participant 3 may also have had compromised barrier function due to dry skin. Therefore, the effect of clothing on dermal uptake can be highly dependent on individual differences in dermal permeability.

### 4 Conclusions

BP-3 that has sorbed from air to cotton shirts resulted in dermal uptake and urinary excretion in three male participants. Given that BP-3 has been observed in the air of residences (Wan et al., 2015), dermal uptake from air and clothing is likely to contribute to the overall body-burden of BP-3.

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