Estimating infants' and toddlers' inhalation exposure to fragrance ingredients in baby personal care products

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ABSTRACT

Fragrance ingredients are commonly added to many personal care products to provide a pleasant scent, including those intended for babies. While fragrance chemicals have a long history of safe use, at sufficiently high concentrations some may act as respiratory irritants or sensitizers. Little data have been reported on the inhalation exposures to fragrance compounds to infants and toddlers during bathing and lotion applications. This study demonstrates an *in vitro* method for measuring breathing zone air concentrations of fragrances from bath products and lotions. It employed simulated infant bathing and lotion application events and a robot to mimic a toddler's movement within a bathroom setting. The air concentrations in an infant's breathing zone were between <1 and $5 \mu\text{g}/\text{m}^3$ for each of seven common fragrance ingredients, while that in the breathing zone of toddlers in the bathroom was $\leq 1 \mu\text{g}/\text{m}^3$. The air concentrations from the bathing additive were linearly related to their Henry's law constants and from the lotion inversely related to their octanol-air coefficients. The proposed approach can help refine risk estimates from inhalation exposure to fragrances used in baby products and guide future risk assessments of new products' safety for their use in baby bath products.

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Introduction

The incorporation of fragrances is widespread not just in perfumes and cosmetics, but also in personal care products, household cleaners, and even retail stores to create an ambiance. The International Fragrance Association North America reported that the global market for fragrances and perfumes is currently \$12.5 billion and market researchers of Global Industry Analysts, Inc. indicate that this number is projected to exceed \$51 billion by 2022 [1,2]. Fragrances are added to baby products to provide a positive psychological impact and product identification. Many topical formulated baby products are intended for use during and after bathing, including shampoos, powders, body washes, and lotions. Exposure and risk models have begun to estimate aggregate exposure to components in personal care products, such as fragrances [3]. To determine exposure to fragrances, these models need data on their concentrations in the products, the amount emitted into the air and use patterns [4–8]. Furthermore, additional data are needed to accurately calculate inhalation exposure to volatile and semi-volatile fragrance chemicals from baby products.

While some concerns with inhalation exposures to fragrances exist, their exact health effects have not been definitely determined. It has been suggested

that collaborative efforts by industry, regulatory, scientific and medical communities would be the best approach to understand exposure and toxicological effects [9]. For example, in some individuals fragrances may elicit headaches, dizziness, shortness of breath, difficulty in concentrating, and exacerbation of allergies and asthma [10,11]. Studies of health effects of fragrances in toddlers are lacking. These studies are specifically needed since it is generally accepted that very young children and infants are often more sensitive to chemical irritation than adults due to their developing physiology [12]. In addition, infants and children have greater metabolic rates and activity levels leading to greater inhalation rates on a per-body-weight basis and higher inhalation exposure than for adults at the same air concentrations [13,14]. While guidance and safety assessment for fragrance inhalation exposure have been proposed, more exposure data are needed for infants and young children to better estimate their risk to fragrances in consumer products [15,16].

Several studies have simulated infant and children inhalation exposures to fragrance ingredients and other volatile organic compounds or calculated their emission rates from consumer products marketed for use on infants [11,17–21]. However, to our knowledge, no published studies have reported infants' and toddlers'

inhalation exposures to fragrance ingredients in topical personal care products, such as baby bath products and baby lotions, during and after bathing. Studying infants and toddlers can pose ethical issues and sampling challenges. Therefore, we conducted a series of controlled laboratory experiments to estimate infant and toddler inhalation exposure levels to fragrance during the use of baby bath additives and lotions. The toddler's movement and exposure measurements were simulated using a robotic surrogate, the Pre-toddler Inhalable Particulate Environmental Robotic (PIPER) sampler [22]. Generic baby bath and lotion products were formulated incorporating fragrance ingredients and base material typically present in fragranced baby products.

Methods

The air concentrations of the fragrances in the breathing zones were determined by simulating a baby's bath and lotion application, in separate experiments, in a tiled bathroom at the Environmental and Occupational Health Science Institute (EOHSI) in Piscataway, New Jersey. The bathroom's dimensions were 2.5 m by 2.8 m by 2.4 m (length x width x height). Room temperature was maintained at 24°C using a portable oil-filled radiator. The room air exchange rate was eight changes per hour, a value consistent with bathrooms having exhaust fans [23]. Two different baby-bathing activities were simulated: 1) adding a generic liquid bath product directly to the

water; and 2) applying a generic baby lotion, which had a creamy consistency, on a surface that represented an infant's body. The baby products contained seven fragrance ingredients commonly used in topical products (isoamyl salicylate, amyl salicylate, benzyl acetate, dimethylheptenal, methyl benzoate, α -ionone, and β -ionone). The bath product contained 0.012% of each fragrant compound in a proprietary base. Structures and characteristics of the tested fragrance chemicals are presented in Table 1. Control samples were collected with just the base material applied to verify that the inert ingredients did not contribute any background interference. A commercially available portable plastic baby bathtub was used.

Simulation of bathing with baby bath product

The plastic tub was filled with 6 L of water at 37°C, the recommended temperature to bathe infants [24]. A 15 ml aliquot, a capful, of the bath product was added to the water in the infant tub per the suggested direction of this product type. This is also consistent with the average amount of baby bath additive used per application, 14.7 g, reported in the literature [25]. The added bath product was then mixed using a gloved hand for ~10 s to disperse it throughout the water. A bathing time of 5 min was used with an additional 5 min exposure in the room to represent the time to dry the baby. During the 5 min of bathing, the water was continually agitated using a

Table 1. Characteristics of target fragrance ingredients.

Compound	CAS No.	Molecular Structure	Description of Odor
Isoamyl salicylate	87-20-7		Floral and sweet, herbaceous and balsamic character with a greenish tone
Amyl salicylate	2050-08-0		Floral and sweet, herbaceous and balsamic character with a greenish tone
Benzyl acetate	140-11-4		Powerful but thin, sweet floral fresh, fruity odor of Jasmine
Dimethylheptenal	106-72-9		Powerful, green, melon, Cucumber
Methyl benzoate	93-58-3		Powerful floral
α -ionone	127-41-3		Floral, orris, violet, woody
β -ionone	79-77-6		Warm and woody character, scent of violets

magnetic stirring bar to simulate an infant's movement in the tub. The experiments were repeated with the tub placed on the floor (10 cm above the floor to accommodate the stirring motor) and the tub placed on a counter (80 cm above the floor). These provided an assessment of the effect of the height of the emission source on the target ingredients' air concentrations. Each experimental condition was run in triplicate.

Simulation of lotion application

To evaluate the air concentration of the fragrance ingredients when lotion is applied to an infant, a 15 cm by 10 cm piece of aluminum foil was placed on a glass bottle containing water at 37 °C. A surface area of 150 cm² is approximately one third of the surface area of an infant's entire body, estimated to be 0.45 m² [26]. Aluminum foil was chosen since it would not absorb nor react with the baby lotion applied, though it is recognized that fragrances might be absorbed into the skin. Thus, only the initial volatilization of the fragrant compounds during application was considered. The bottle was placed on a counter (80 cm above the floor) during the application. A total of 0.4 g of baby lotion, with or without the fragrance, was applied on the foil and gently rubbed to provide a thin layer of lotion, consistent with both the manufacturer's application instructions and the reported median amount of baby lotion used per application, 3.7 g, which is typically applied to the entire body of a 0–3 year old [27]. Three replicate tests were conducted. These study results represent a fragrance inhalation exposure without consideration of dermal absorption.

Sample collection

Air samples were collected using stainless steel traps filled with 0.2 g of the adsorbent Tenax® TA 60/80 mesh. The traps were connected to personal air sampling pumps (BGI Omni, BGI 400S or SKC AirCheck XR5000) with flow rates adjusted to between 0.1 and 0.5 L/min. The flow rates of the sampling pumps were verified before and after sample collection with a flow meter (Dry Cal DC-Lite). Air samples were collected for 5 min at a height of 7.6 cm (3 in) and at 30.5 cm (12 in) above the bath water, which represent the breathing zone heights of a lying and sitting infant receiving a bath, respectively. Additionally, 10 min mobile samples were collected with the PIPER sampler, which was programmed to move around the room mimicking a toddler's movement while a caregiver bathed a sibling, and at four stationary locations in the corners of the room (Figure 1). The mobile and stationary samples were collected at a height of 80 cm, the average breathing

Figure 1. Bathroom layout and sampling location.

zone height of a toddler. PIPER is a semi-autonomous platform that is designed to simulate the activity patterns of young children [22]. It is capable of carrying two sampling trains for the collection of air samples and to vary the height of the sample collection. PIPER's movements were controlled by its software program which was set to mimic a time-activity pattern of a 1-year old female, an age that a child might be kept in a bathroom while a sibling is bathed. Background air samples were collected at all locations prior to any simulation experiment.

Chemical analysis

The adsorbent traps were analyzed for the seven fragrance ingredients (isoamyl salicylate, amyl salicylate, benzyl acetate, dimethylheptenal, methyl benzoate, α -ionone, β -ionone) by thermal desorption (Perkin Elmer ATD 400) coupled with a gas chromatograph/mass spectrometer (Agilent GC 6980/MS 5973) equipped with a 30 m $\times$ 0.25 mm, Stabilwax®-DA column (Restek Corp.). The initial column temperature of 80 °C was raised to 180°C at a ramp rate of 6°C/min, held for 5 min and then raised to 230°C at a rate of 15°C/min, where it was held for 5 min.

Calibration curves were prepared by spiking traps with known quantities of each target ingredient. Both isoamyl salicylate and amyl salicylate were present in a single standard. Since the peak areas of the total ion chromatograph of the GC/MS trace of the two isomers were approximately equivalent ($\pm 10\%$), we assumed that their concentration ratio in the standard was 1:1. Standard checks of the instrument were performed daily. The method detection limit was determined using the U.S. Environmental Protection Agency Method Detection Limit (MDL) procedure [28]. The air concentration detection limit was calculated based on nominal sample volumes of 5 and 10 l of air ranged between 0.01 and 0.08 $\mu\text{g}/\text{m}^3$ for the seven target compounds (Table 2).

Table 2. Method Detection Limit (MDL) for each ingredient*.

Compound name	MDL ng/ trap	MDL assuming 1L air sampled $\mu\text{g}/\text{m}^3$	MDL assuming 5L air sampled $\mu\text{g}/\text{m}^3$	MDL assuming 10L air sampled $\mu\text{g}/\text{m}^3$
Isoamyl Salicylate	0.12	0.12	0.024	0.012
Amyl Salicylate	0.18	0.18	0.036	0.018
Benzyl Acetate	0.23	0.23	0.046	0.023
Dimethylheptenal	0.13	0.13	0.026	0.013
Methyl Benzoate	0.36	0.36	0.072	0.036
α -Ionone	0.39	0.39	0.078	0.039
β -Ionone	0.18	0.18	0.036	0.018

*MDL is analytical method detection limit as ng per trap analyzed. The three columns to the right are the MDL in air for the indicated volume of air sampled. Between 5 and 10 l were typically sampled.

Results

Air concentrations for the simulated baby bath product experiments

Air concentrations of the seven fragrances at each sampling location for the baby bath product simulation experiments are presented in Table 3. The samples collected at 7.6 cm (3 in) above the bathtub water when the tub was placed on a counter had the highest observed air concentrations, varying between 2 and 5 $\mu\text{g}/\text{m}^3$ across the different fragrance ingredients. The second highest air concentrations were between 1 and 4 $\mu\text{g}/\text{m}^3$ for samples collected 30.5 cm above the bathtub water when the tub was on the counter. Breathing zone air concentrations for a toddler, as measured on the samples collected by PIPER and at the four corners of the room, were $\leq 1 \mu\text{g}/\text{m}^3$ when the tub was on the counter and the floor. Air concentrations measured in the background air samples when no bath product was added to the water were either below or just at the detection limit.

Unpaired, two tailed t-tests were conducted to assess if the tub height affected air concentrations using a *p*-value at a significance level of 0.05. The air concentrations of all target ingredients at locations 7.6 cm and 30.5 cm above the water were statistically greater ($p < 0.05$) when the tub was on the counter compared to the floor (Table 3). This suggests that the bathtub placement can affect the dispersion rate just above the water. A possible explanation is that air movement and turbulence were different when the individual was standing while simulating a bath compared to sitting on the floor. This could have altered the mixing of air emissions and the resulting air concentrations. Although the air concentrations measured for the mobile (PIPER) samples and the four corner samples were higher when the bathtub was on the counter, the differences were not statistically significant ($p < 0.05$).

Air concentrations for the simulated baby lotion experiments

Results for the simulated baby lotion experiments are presented in Table 4. The highest air concentrations of the targeted fragrances were measured in samples

collected closest to the simulated infant's skin, at a distance of 7.6 cm, and ranged from 1 to 4 $\mu\text{g}/\text{m}^3$, similar to the air concentrations for the bath product experiment. Air concentrations at 30.5 cm were between 0.3 and 0.6 $\mu\text{g}/\text{m}^3$. The air concentrations were mostly $< 0.1 \mu\text{g}/\text{m}^3$, in samples collected by PIPER and the four corners of the room except for benzyl acetate which varied between 0.13 and 0.29 $\mu\text{g}/\text{m}^3$. The air concentrations measured when the non-fragranced baby lotion was applied were either below or just at the detection limit.

Discussion

Analysis of Henry's law constant vs. air concentration

Henry's law constant can be used to characterize the partitioning of a volatile compound between the gas phase and aqueous phase under equilibrium conditions for equivalent aqueous concentrations. Compounds with higher Henry's law constants have higher air concentrations. For the baby bath product experiments, the air concentrations measured for each fragrance compound are plotted against their Henry's law constants for the two sampling heights above the water's surface, corresponding to when the tub was on the counter (Figure 2) and on the floor (Figure 3). Each fragrance compound was present at the same concentration in the baby bath product. The Henry's law constants (25°C) and air concentrations are linearly correlated with R^2 values of ~ 0.8 , when the tub was on the counter, and ~ 0.6 , when it was on the floor, at both 7.6 cm and 30.5 cm above the tub. The lower R^2 values when the tub was on the floor could be explained by potentially greater air turbulence.

For the baby lotion experiments, the air concentration should be a function of the partitioning coefficient between the air and the lotion, since the lotion was directly applied on a simulated baby's skin. The log octanol-air partition coefficient ($\log K_{oa}$) for each compound was used as a surrogate for that partitioning coefficient. The measured air concentrations divided by the compounds' concentrations in the baby lotion were plotted against the $\log K_{oa}$'s at the two sampling heights (Figure 4).

Table 3. Air concentrations of target ingredients for representative baby bath product experiments "Mean $\pm$ standard deviation", unit: $\mu\text{g}/\text{m}^3$.

Sampling location	Tub height*	Isoamyl salicylate	p-value	Amyl Salicylate	p-value	Benzyl Acetate	p-value	Dimethyl heptenal	p-value	Methyl Benzoate	p-value	α -Ionone	p-value	β -Ionone	p-value
7.6cm	C	2.05 $\pm$ 0.86	0.03	2.05 $\pm$ 0.68	0.01	1.63 $\pm$ 0.28	<0.01	5.16 $\pm$ 1.73	0.03	2.75 $\pm$ 0.51	<0.01	3.29 $\pm$ 0.99	0.02	2.33 $\pm$ 0.72	0.02
	F	0.40 $\pm$ 0.16		0.39 $\pm$ 0.11		0.51 $\pm$ 0.14		1.58 $\pm$ 0.70		0.88 $\pm$ 0.24		0.94 $\pm$ 0.33		0.62 $\pm$ 0.27	
30.5cm	C	1.36 $\pm$ 0.64	0.07	1.41 $\pm$ 0.46	0.02	1.15 $\pm$ 0.14	0.02	3.50 $\pm$ 0.69	0.01	1.81 $\pm$ 0.22	<0.01	2.18 $\pm$ 0.63	0.02	1.52 $\pm$ 0.55	0.03
	F	0.44 $\pm$ 0.12		0.31 $\pm$ 0.16		0.44 $\pm$ 0.08		1.23 $\pm$ 0.40		0.78 $\pm$ 0.16		0.73 $\pm$ 0.15		0.48 $\pm$ 0.12	
PIPER	C	0.50 $\pm$ 0.66		0.51 $\pm$ 0.66		0.55 $\pm$ 0.69		1.12 $\pm$ 1.37		0.95 $\pm$ 1.20		0.87 $\pm$ 1.17		0.57 $\pm$ 0.74	
	F	0.12 $\pm$ 0.03		0.12 $\pm$ 0.02		0.16 $\pm$ 0.02		0.29 $\pm$ 0.06		0.27 $\pm$ 0.03		0.25 $\pm$ 0.05		0.16 $\pm$ 0.03	
Corner A	C	0.26 $\pm$ 0.33		0.30 $\pm$ 0.36		0.38 $\pm$ 0.42		0.78 $\pm$ 0.77		0.65 $\pm$ 0.71		0.54 $\pm$ 0.60		0.35 $\pm$ 0.40	
	F	0.12 $\pm$ 0.04		0.14 $\pm$ 0.03		0.21 $\pm$ 0.04		0.45 $\pm$ 0.19		0.35 $\pm$ 0.06		0.30 $\pm$ 0.07		0.18 $\pm$ 0.07	
Corner B	C	0.33 $\pm$ 0.44		0.38 $\pm$ 0.48		0.44 $\pm$ 0.53		0.65 $\pm$ 0.73		0.76 $\pm$ 0.96		0.67 $\pm$ 0.87		0.42 $\pm$ 0.56	
	F	0.16 $\pm$ 0.02		0.17 $\pm$ 0.04		0.19 $\pm$ 0.04		0.24 $\pm$ 0.08		0.32 $\pm$ 0.05		0.31 $\pm$ 0.04		0.20 $\pm$ 0.03	
Corner C	C	0.30 $\pm$ 0.19		0.36 $\pm$ 0.29		0.42 $\pm$ 0.33		0.84 $\pm$ 0.49		0.75 $\pm$ 0.61		0.66 $\pm$ 0.47		0.40 $\pm$ 0.24	
	F	0.21 $\pm$ 0.06		0.15 $\pm$ 0.04		0.19 $\pm$ 0.05		0.28 $\pm$ 0.14		0.33 $\pm$ 0.09		0.29 $\pm$ 0.09		0.18 $\pm$ 0.07	
Corner D	C	0.48 $\pm$ 0.48		0.48 $\pm$ 0.49		0.58 $\pm$ 0.55		1.02 $\pm$ 0.98		0.97 $\pm$ 1.01		0.85 $\pm$ 0.86		0.55 $\pm$ 0.53	
	F	0.13 $\pm$ 0.03		0.13 $\pm$ 0.03		0.18 $\pm$ 0.02		0.29 $\pm$ 0.09		0.29 $\pm$ 0.03		0.27 $\pm$ 0.02		0.18 $\pm$ 0.03	

*: C—counter height; F—floor height

Table 4. Air concentrations of target ingredients for fragranced baby lotion simulation “Mean $\pm$ standard deviation”, unit: $\mu\text{g}/\text{m}^3$.

Sampling location	Isoamyl salicylate	Amyl Salicylate	Benzyl Acetate	Dimethyl heptenal	Methyl Benzoate	α -lonone	β -lonone
7.6cm	1.48 ± 0.31	1.40 ± 0.34	4.06 ± 2.18	1.30 ± 1.05	2.04 ± 1.30	1.65 ± 0.51	1.69 ± 0.70
30.5cm	0.63 ± 0.80	0.40 ± 0.44	0.59 ± 0.57	0.29 ± 0.28	0.31 ± 0.30	0.30 ± 0.26	0.34 ± 0.35
PIPER	<0.04	<0.06	<0.07	<0.05	<0.10	<0.11	0.06 ± 0.11
Corner A	0.03 ± 0.04	0.02 ± 0.03	0.14 ± 0.18	<0.03	0.11 ± 0.08	0.07 ± 0.08	0.07 ± 0.05
Corner B	0.04 ± 0.04	0.02 ± 0.02	0.13 ± 0.15	<0.02	0.05 ± 0.09	0.03 ± 0.05	0.03 ± 0.03
Corner C	<0.05	<0.08	0.20 ± 0.19	0.22 ± 0.38	<0.15	0.13 ± 0.11	0.06 ± 0.06
Corner D	0.01 ± 0.02	<0.03	0.29 ± 0.10	<0.02	0.11 ± 0.03	0.09 ± 0.08	0.05 ± 0.02

Figure 2. Henry's law constant vs. air concentration for 7.6 cm and 30.5 cm above the water when the tub was placed on the counter for baby bath additive experiments. The same concentration of each fragrance compound was added to the water. **Figure 3.** Henry's law constant vs. air concentration for 7.6 cm and 30.5 cm above the water when the tub was placed on the floor for baby bath additive experiments. The same concentration of each fragrance compound was added to the water.

The $\log K_{\text{Oa}}$ (25°C) was inversely related to the air concentration, consistent with compounds having higher $\log K_{\text{Oa}}$'s being more soluble in the organic base used for the lotion. The R^2 values were 0.68 and 0.47 for samples collected 7.6 cm and 30.5 cm above the counter. Based on the data provided, the air concentrations for other fragrance compounds with known Henry's law constants and $\log K_{\text{Oa}}$'s could be estimated for the experimental conditions used.

Figure 4. $\log K_{\text{Oa}}$ vs. air concentration for 7.6 cm and 30.5 cm above the simulated infant's body for the baby lotion experiments. The air concentrations were normalized for the amount of each fragrance compound present in the lotion.

Potential human exposure

Potential exposure routes for the evaluated fragrance ingredients are inadvertent ingestion, dermal contact, and inhalation [9]. The current study provides a new approach to estimate infants' and toddlers' fragrance inhalation exposure from personal care products, such as baby bath additives and baby lotions during and after bathing. The air concentrations of fragrance ingredients measured during the use of baby bath products and baby lotions in this study were one to two orders of magnitude lower than the highest air concentrations measured due to emissions of fragrance compounds from a variety of other consumer products. While, only a few of the individual fragrance compounds reported among all studies were the same, the compounds in our study and the literature have similar ranges of Henry's law constants, volatility and $\log K_{\text{Oa}}$ (see Supplementary Information). Rogers et al. [11] measured post application exposure levels of fragrance compounds in a surrogate air freshener formulation and reported maximum concentrations for nine compounds ranging from 108 to 347 $\mu\text{g}/\text{m}^3$ and 125 to 362 $\mu\text{g}/\text{m}^3$ in the adult breathing zone and child breathing zone, respectively. Petry et al. [20] reported a range of $<0.1 \mu\text{g}/\text{m}^3$ to 137 $\mu\text{g}/\text{m}^3$ for eight different fragrance compounds along with other volatile and semi-volatile organic compounds emitted from scented candles. Masuck et al. [18] measured the air concentrations of 24 fragrances emitted from four

scented toys and reported their concentrations varied between 1.10 and 107 $\mu\text{g}/\text{m}^3$. One possible explanation for the higher air concentrations for the fragrances in these studies compared to the levels we measured is the longer emission time associated with the activities performed compared to the 5 min bath or lotion application we conducted.

The exposure methodological approach developed here can be used to estimate air concentrations for new compounds being incorporated in baby personal care products that infants and children could be exposed to, augmenting previous studies' approaches to evaluate the young children's exposures. Lamas et al. [29] developed a solid-phase microextraction (SPME) method to measure the fragrance concentrations in baby bathwater and found fragrance compounds were present in water used to bathe babies indicating potential dermal, inhalation and ingestion exposures. Moon et al. [19] evaluated baby and adult inhalation exposures to baby powder by applying the baby powder to a baby doll and collecting the airborne baby powder near the breathing zones of the doll and the applicator. They found average air concentrations of 22.1 $\mu\text{g}/\text{m}^3$ and 5.3 $\mu\text{g}/\text{m}^3$ near the simulated baby and the applicator, respectively. Young children's exposures to fragrance compounds in personal care products have also been estimated using exposure models. These models incorporate air concentrations associated with emissions from personal care and cosmetic products, and the rate and frequency that fragrance containing baby products are used [5–7,16,27,30].

To our knowledge, the data generated from our studies are the first reported estimates of inhalation exposure of fragrances contained in baby bath additives and baby lotions.

These exposure data, when combined with inhalation toxicities of fragrance compounds along with the exposure duration, can be used to screen for potential health hazards from fragrances added into consumer baby products and in developing risk assessments. The exposures associated with these uses should be considered in the estimate of aggregate and cumulative infant and toddler exposures from the variety of products that contain fragrance compounds. As with any personal care product, a complete exposure and risk assessment should be done to evaluate the overall safety of new ingredients added to personal care products, especially with regard to infants, toddlers and children.

Conclusions

A simulated approach was developed to assess the air concentrations in infants' and toddlers' breathing zones for fragrances added to baby bath additives and baby lotions. An infant's breathing zone air concentrations associated with the use of a baby bath

product or baby skin lotion were between <1 and 5 $\mu\text{g}/\text{m}^3$ for each of the seven common fragrance ingredients analyzed, while for toddlers present in the bathroom during these activities the air concentrations were $\leq 1 \mu\text{g}/\text{m}^3$. However, the widespread use of fragrances in consumer products can result in multiple exposures to infants and toddlers throughout the day. As with any personal care product, a complete exposure and risk assessment should be done to evaluate its overall safety in common uses. The method developed can provide guidance for: 1) refining infant's and toddler's inhalation exposure estimates used in risk estimates of baby product components and 2) future safety assessments of new products designed for use on infants and toddlers.

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