Several studies have shown endocrine-disrupting effects of parabens. Parabens are a group of antimicrobials used as preservatives in a wide variety of products, mainly in personal care products. However, little information is available regarding the occurrence of parabens in baby products. In this study, the concentrations of five commonly used parabens, methyl-, ethyl-, propyl-, butyl- and, benzyl-paraben in 50 Brazilian baby wet wipes were analyzed by liquid chromatography coupled to mass spectrometry. All samples contained parabens, and the total concentrations ranged from 16 to 332,470 ng g⁻¹ (geometric mean: 5344 ng g⁻¹). Methyl-paraben, ethyl-paraben, propyl-paraben, and butyl-paraben were found in >65% of the samples. 24 out of 50 samples exceed the permitted value of 0.4 % for methyl-paraben for their use in personal care products. Although, propyl-paraben and butyl-paraben are forbidden in cosmetic products designed for application on the nappy area of children under three years of age, the detection rate of them were 94 and 70 %, respectively. Based on the measured concentrations and use frequency of baby wipes the estimated daily intake of parabens was calculated. The median estimated daily intake values of total concentrations of parabens for babies of one year old was 391 ng kg⁻¹ bw day⁻¹. In conclusion, babies and children may be exposed to high levels of parabens through use of baby wipes. It is also worth to mention that two forbidden parabens were frequently detected.

Keywords: parabens; preservatives; endocrine-disrupting chemicals; baby wipes; estimated daily intake.

INTRODUCTION

Endocrine disruptors constitute a group of chemical compounds, of natural or synthetic origin, that have been gaining a great prominence in the areas of toxicology and environmental health, for which exposure may lead alterations in the normal functions of the endocrine system, causing possible adverse health effects.¹⁻³ Among them, we can cite the parabens, widely used preservative chemicals. Parabens are alkyl esters derived from p-hydroxybenzoic acid and their bio- and physico-chemical properties such as water solubility, stability and antimicrobial activity make them interesting additives in consumer products.¹⁻⁴⁻¹⁰ Over the recent years the concern over the human exposure to paraben-containing products has raised mainly due to their potential endocrine-disrupting effects on the hormonal system.¹¹⁻¹³ Dermal absorption is the main source of exposure to parabens and personal care products account for about 66% of this exposure.³,¹⁰⁻¹¹⁻¹⁷ After human exposure, the parabens penetrate the systemic circulation and are rapidly biotransformed in the liver. The rapid metabolism of parabens suggests that they are metabolized faster after the intake than by dermal absorption, thus explaining that topical use is the main source of exposure to parabens.¹⁸⁻²¹ Parabens are rapidly absorbed through the gastrointestinal tract or, more slowly, through the skin because the latter mechanism depends on the action of carboxylesterase enzymes and subcutaneous fat that affect the dermal absorption.²² After absorption or ingestion, metabolism and urinary excretion are influenced by the size of the paraben alkyl chain, giving them short half-lives in the human body, ranging from 22 minutes for methylparaben to 87 minutes for butylparaben.²³

Decrease in sperma production, complications in the couple’s fecundity, breast tumors and melanomas have been observed in the presence of parabens in biological models and epidemiologic studies.²⁴⁻²⁷ Hormones control the normal development of tissues from the fertilized sperm and egg to the fully developed of human. When a tissue is developing, it is more sensitive to the action of hormones and thus endocrine disruptors, such as, parabens. Moreover, children’s metabolic pathways are immature. This means that children’s ability to metabolize and excrete those compounds is lower than that of adults’, making them more vulnerable to these chemicals.²⁸ Therefore, regulatory agencies in several countries banned the use of some parabens in baby wipes²⁹ or reduced the maximum percentage allowed in cosmetic formulations, for example, as in the European Union a maximum concentration of 0.14% was established for the use of PrP and BuP when used alone or in mixtures with other esters.³⁰

Due to direct contact, some quick-clean personal hygiene products such as adult personal hygiene wet wipes and baby wipes become facilitators of human exposure to parabens,¹¹ triggering, even, other additional pathologies like allergic processes and anogenital dermatitis.³¹ So, the present study aimed to determine concentrations of five parabens (methylparaben and propylparaben, the most frequently used paraben compounds and, ethylparaben, butylparaben, and benzylparaben, important synthetic compounds in the paraben family) in 50 commercial baby personal hygiene wet wipes collected from Brazil and estimating the exposure doses via dermal contact.

EXPERIMENTAL

Chemicals and materials

Methyl-paraben (methyl 4-hydroxybenzoate; MeP), ethyl-paraben
A survey of parabens in commercial baby wipes from Brazil and estimation of daily exposure

Vol. 43, No. 4

Compound (internal standard) Precursor ion Product Ion CE Tube lens and retention times (tR) for parabens analysis

<table>
<thead>
<tr>
<th>Compound (internal standard)</th>
<th>Precursor ion</th>
<th>Product Ion</th>
<th>CE</th>
<th>Tube lens</th>
<th>tR (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MeP (13C6-MeP)</td>
<td>151 (157)</td>
<td>92 (98)</td>
<td>22 (24)</td>
<td>105 (40)</td>
<td>2.5 (2.5)</td>
</tr>
<tr>
<td>EtP (13C6-EtP)</td>
<td>165 (171)</td>
<td>92 (98)</td>
<td>23 (25)</td>
<td>117 (46)</td>
<td>3.3 (3.3)</td>
</tr>
<tr>
<td>PrP (13C6-PrP)</td>
<td>179 (185)</td>
<td>92 (98)</td>
<td>25 (36)</td>
<td>103 (50)</td>
<td>4.1 (4.1)</td>
</tr>
<tr>
<td>BuP (13C6-BuP)</td>
<td>193 (199)</td>
<td>92 (98)</td>
<td>27 (24)</td>
<td>85 (55)</td>
<td>4.8 (4.8)</td>
</tr>
<tr>
<td>BzP (13C6-BzP)</td>
<td>227 (199)</td>
<td>92 (98)</td>
<td>27 (24)</td>
<td>115 (55)</td>
<td>4.7 (4.8)</td>
</tr>
</tbody>
</table>
Data analysis was performed using SPSS software, Version 20, and Microsoft Excel 2013. Descriptive statistics were calculated on a wet weight (ng g⁻¹) basis. The concentrations are reported on a nanogram per gram (ng g⁻¹) and concentrations below the LOQ were assigned a value equal to the LOQ divided by the square root of 2. To examine the relationship among parabens, Spearman’s correlation was used. All statistical tests were considered significant if the p-value was < 0.05.

RESULTS AND DISCUSSION

The concentrations of each paraben and the total concentrations of parabens (sum of five detected parabens: ΣPBs) found in Brazilian baby wet wipes are summarized in Table 2 and Figure 1. The four parabens, namely, MeP, EtP, PrP, and BuP were detected together in at least 65% of the Brazilian baby wet wipes (BBWW). The rank order of detection rate for each selected paraben was: MeP (100%) > PrP (94%) > BuP (70%) > EtP (66%). Since the BzP was not found in any of the samples, it was excluded from statistical analysis. The highest geometric median concentrations were found for MeP (4914 ng g⁻¹), PrP (44.1 ng g⁻¹), EtP (16.9 ng g⁻¹), and BuP (2.5 ng g⁻¹). ΣPBs concentrations ranged from 16 to 332470 ng g⁻¹, and the geometric mean and median values were 5348 and 4645 ng g⁻¹, respectively.

![Figure 1. Concentrations of parabens (ng g⁻¹) in Brazilian baby wet wipes. The horizontal lines represent 10th, 50th and 90th percentiles and the boxes represent 25th and 75th percentiles.](image)

The concentrations of MeP, after logarithmic transformation, were significantly correlated with concentrations of EtP (r = 0.535, p < 0.001), and PrP (r = 0.671, p < 0.001). A correlation among MeP/EtP and MeP/PrP in BBWW samples suggested that these compounds are used in combination. No significant correlations were found among the concentrations of EtP, PrP and BuP. The size of the alkyl group of parabens influences the antimicrobial activity, the larger the chain, the greater the activity. Due to the fact of microbial replication occurs in aqueous medium, the use of parabens of higher carbon chain is uncommon in commercial products since an increase in carbon chains decreases its solubility in water. Thus, short chain parabens such as MeP, EtP and PrP or mixtures of these are the ones most commonly used in commercial products.

MeP is used either alone or with PrP, EtP and/or BuP because of a synergistic effect. Their presence in cosmetic products, especially long-term exposure on a daily basis, may induce adverse health effects. Brazilian and European Cosmetics Regulatory Agencies consider the use of parabens as preservatives and name them such as 4-hydroxybenzoic acid and its salts and esters. Since the maximum concentration limits for parabens can be found in the legislation with values of 0.4% when used as single ester and of 0.8% when used as mixtures of esters. According to European agency legislation, BuP and PrP can be used safely in cosmetic products provided that their concentrations do not exceed 0.14% and are prohibited in the use of cosmetic products for children less than 3 years of age. There are also parabens not allowed for use in cosmetic, such as isopropyl, isobutyl, phenyl, benzyl and pentyl parabens. In this study, MeP was found in all samples at very high concentration in many of them. The median concentration of MeP was higher than the maximum concentration permitted by the Brazilian and European regulation. It should be noted that 24 out of 50 samples exceed the permitted value of 0.4% for MeP for their use in cosmetics and personal care products. Moreover, the detection rate of PrP and BuP were 94 and 70 %, respectively. Our studies suggest that Brazilian babies may be exposed to parabens and its harmful effects through dermal absorption.

**Estimation of daily intake (EDI)**

In addition to other sources, absorption of parabens via skin from the uses of wipes seems to be a relevant route of exposure. Considering the high concentrations of parabens found in BBWW and dermal absorption coefficient of parabens, the use of these wipes may constitute an important source of exposure to babies. The evaluation of the quantity and frequency of use of wipes over a day is still scarce. However, the frequency of use can be estimated by a specialist considering that a wiping with moist wipes is performed with each diaper change, which results in an average of five times of use per day. Moist wipes for commercial babies weigh approximately 5 g per wipe. During the hygiene of the baby, contact with the dermis is not permanent and not all the surface of the wipe is used, therefore, a retention factor should be applied. According to de van Engelen, each time a baby wipe is used, there is a dermal contact of 0.5 mL of liquid with the skin. If 5 g of wipes are used five times a day and considering the retention factor 0.1, the final value on the skin will be 2.5 g/day. Thus, dermal intakes of parabens could be calculated on the basis of equation:

\[
EDI = C \times A \times F \times RF \times \frac{DA}{W^2}
\]

Table 2. Concentrations of parabens (ng g⁻¹) in baby wet wipes from Brazil

<table>
<thead>
<tr>
<th>Baby wipes (n = 50)</th>
<th>MeP</th>
<th>EtP</th>
<th>PrP</th>
<th>BuP</th>
<th>BzP</th>
<th>ΣPBs</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM</td>
<td>4914</td>
<td>16.9</td>
<td>44.1</td>
<td>2.5</td>
<td>nd</td>
<td>5348</td>
</tr>
<tr>
<td>Median</td>
<td>3709</td>
<td>16.0</td>
<td>37.7</td>
<td>1.5</td>
<td>nd</td>
<td>4645</td>
</tr>
<tr>
<td>Minimum</td>
<td>7.6</td>
<td>2.1</td>
<td>0.7</td>
<td>0.3</td>
<td>nd</td>
<td>16</td>
</tr>
<tr>
<td>Maximum</td>
<td>332237</td>
<td>1251</td>
<td>2175</td>
<td>238</td>
<td>nd</td>
<td>332470</td>
</tr>
<tr>
<td>Frequency (%)</td>
<td>100</td>
<td>66</td>
<td>94</td>
<td>70</td>
<td>nd</td>
<td>100</td>
</tr>
</tbody>
</table>

Nd: not detected.
A survey of parabens in commercial baby wipes from Brazil and estimation of daily exposure

Estimated daily intake adjusted for body weight of parabens and sum of them are shown in Table 3. The highest EDI values were found for MeP, followed by PrP, EtP, and BuP. The median EDIs of MeP, PrP, EtP, and BuP were 385, 3.5, 2.0, and 0.23 ng kg\(^{-1}\) bw day\(^{-1}\), respectively. The EDI values found for parabens from baby wipes were below the acceptable daily intake (ADI) of 0-10 mg kg\(^{-1}\) bw day\(^{-1}\) for MeP, EtP and their sodium salts, according to the European Food Safety Authority’s recommendations. 41

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### Table 3. Estimated daily intake adjusted for body weight (ng kg\(^{-1}\) bw day\(^{-1}\)) of each and total parabens via uses of baby wet wipes by the babies of 1 year old (11.5 kg)

<table>
<thead>
<tr>
<th>Parabens</th>
<th>Median</th>
<th>95th Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>MeP</td>
<td>385</td>
<td>24,876</td>
</tr>
<tr>
<td>EtP</td>
<td>2.0</td>
<td>144</td>
</tr>
<tr>
<td>PrP</td>
<td>3.5</td>
<td>168</td>
</tr>
<tr>
<td>BuP</td>
<td>0.23</td>
<td>21</td>
</tr>
<tr>
<td>(\Sigma)parabens</td>
<td>391</td>
<td>25,209</td>
</tr>
</tbody>
</table>

However, the EDI values found for PrP in the current study opposed the recommendation of European Food Safety Authority (EFSA). EFSA’s panel evaluated the parabens’ toxicity and the safety of their usage in foods and established an ADI of 0-10 mg kg\(^{-1}\) bw for MeP and EtP and their sodium salts. However, the panel was unable to recommend an ADI for PrP because this specific paraben had endocrine disrupts effect at a low dose in male rats and also the lack of a clear No Observed Adverse Effect Level (NOAEL) for this effect. 42

### CONCLUSIONS

Indeed, its clearly the negligence regarding the human exposure to parabens through commercial baby wipes in comparison with the other sources such as food, cosmetics, and pharmaceuticals. Although low concentrations were measured in some parabens categories (MeP and EtP), we were able to identify concentrations of parabens’ classes which are prohibited in cosmetics designed for application on the nappy area of children below three years, PrP and BuP have shown a detection rate of 94 and 70%, respectively. The outcomes hereby bright the literature gap regarding the parabens exposure in commercial baby wipes including two parabens which are prohibited in cosmetic products for children under three years of age (PrP and BuP) and these milestones will serve as a base for future studies on commercial cosmetic products designed for application on children and babies.

### ACKNOWLEDGMENTS

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