Environmental Pollution xxx (2014) 1–7

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Health impact of bioaccessible metal in lip cosmetics to female college students and career women, northeast of China

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ARTICLE INFO

Article history:
Received 28 August 2014
Received in revised form
31 October 2014
Accepted 8 November 2014
Available online xxx

Keywords:
Cosmetics
Ingestion
Bioaccessible metals
Human exposure
Health risk

ABSTRACT

Actual measure-based studies have estimated ingestion rate of moderate and high daily use to female college students and career women in northeast of China. Sequential extraction analyses showed that total bioaccessible metals concentration in lipstick ranged from 2.103 to 31.103 μg/g and in lip balm ranged from 0.100 to 3.716 μg/g. The relationship between total bioaccessible metal concentrations and the cost of lip cosmetics showed a negative correlation. Lead was detected in all 30 products (100%), with an average concentration of 0.346 for lip balm and 0.407 μg/g for lipstick. With the exception of chromium content in three lipsticks, the estimated exposure in female college students and career women to target metals via lipstick and lip balm ingestion (calculated for moderate and high use) were much lower than the acceptable reference limits. The findings strongly emphasize the need to focus on the health risk of lip balm.

1. Introduction

Back in ancient Egypt, Greece, and Roman Empire times, women had been applying some reddish mineral or plant pigment to their cheeks and lips for the purpose of beautification. Therefore, the history of lip cosmetics might have been over thousands of years (Brown, 2013). During the last few decades, cosmetics products have had a big boost (Al-Dayel et al., 2011). As a kind of personal cosmetics, Lip cosmetic products contain wax, oil, and coloring agents as three main ingredients and some side ingredients as antioxidants, preservatives, and perfumes (Schneider et al., 2005). Lip cosmetics include lip balm, lip stick, lip brilliant and lip gloss. The major functions of lip balm are to hydrate and nourish the lips and prevent dryness, lip stick to color the lips, which can stress or change the contours of them and lip brilliant to moisturize and add color and shine to the lips. As for the lip gloss, a jelly-like liquid, it is used to highlight the natural color of the lips. Apart from the demand of cosmetic products on markets, the toxic metals exposure attracts the attention of researchers to find their distribution and adverse effects (Liu et al., 2013; Gardner et al., 2013; Atz and Pozebon, 2009; Piccinini et al., 2013; Loretz et al., 2005). The sources, presence, toxic effects, and mobilization potential of various contaminants in cosmetics have previously been discussed (Lu et al., 2011; Johnson et al., 2013; Fiume et al., 2013; Becker et al., 2013). Exposure of women to organic and inorganic contaminants in cosmetics via ingestion and dermal absorption due to personal habits and characteristics of the living environment (for example humidity) may significantly add to carcinogenic and non-carcinogenic risks following daily dietary exposure (Liu et al., 2013). Metals can be released from lip cosmetics into gastric and intestinal fluids following ingestion. The widespread use of lip cosmetics in everyday life leads to their ubiquity in the non-dietary intake of metals (Loretz et al., 2005; Lu et al., 2011; Reiner and Kannan, 2006). However, information on the bioaccessibility of metals in lip cosmetics and the magnitude of exposure in China is limited.

Significant amounts of metals may become bioavailable and damage various organs when they reach the systemic circulation (Ruby et al., 1996). A bioaccessible concentration is the fraction of a

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http://dx.doi.org/10.1016/j.envpol.2014.11.006
0269-7491/

contaminant reaching the systemic circulation from the gastrointestinal tract after ingestion, and bioaccessibility is the fraction of the substance that becomes soluble in the gastrointestinal tract and is thus available for absorption (Ruby et al., 1996). Bioaccessibility can be used as an estimate of bioavailability, and when available, validation in bioaccessibility tests may be preferred over bioavailability tests due to their cost advantage and ethical considerations. The bioaccessibility of metals, as well as their mobility and related eco-toxicity, greatly depend on their existing fraction (i.e. water-soluble/exchangeable, reducible fraction, oxidizable fraction, organic-associated and residual fractions). Among these fractions, metal ions in water-soluble/exchangeable form are in a weak combination form and vulnerable to environmental changes and sensitive to changes in pH values. This type of metal ion can be directly used by organisms. The reducible fraction combines amorphous iron along with manganese oxides and hydrous oxides. Metals in reducible fraction are also vulnerable to pH values and oxidation-reduction conditions and can be indirectly used by organisms. In addition, metals in the reducible fraction have strong potential for transformation and transportation; while the organic-associated and residual fractions are mainly non-bioavailable. The BCR (European Community Bureau of Reference) three-step sequential extraction procedure is a commonly used method and has been widely applied to determine the phases or fractions of metals associated with environmental solids including soils, sediments and dust (Ruby et al., 1996; Yuan et al., 2011; Li et al., 2013; Feng et al., 2009; Bakircioglu et al., 2011).

Despite researches on metal concentrations and analyses regarding human ingestion of lip cosmetics both in the United States and in other countries (Liu et al., 2013; Gardner et al., 2013; Brandao et al., 2012; Al-Saleh et al., 2009; Al-Saleh and Al-Enazi, 2011; Gunduz and Akman, 2013; Gondal et al., 2010; Hepp et al., 2009), all of these studies mainly focused on the metal concentrations in lip cosmetics products, but none addressed the bioaccessible concentration and using habits by different social roles. The accurate assessment of metal concentrations subject to effective bioaccessibility in lip cosmetics is still challenging and may be associated with potential health risks. The objectives of this study are (1) to estimate bioaccessible cobalt (Co), chromium (Cr), cadmium (Cd), copper (Cu), nickel (Ni), lead (Pb) and manganese (Mn) in selected lipsticks and lip balm using the BCR three-step sequential extraction procedure; and (2) to characterize the risks of these metals via lip balm and lipstick ingestion in female college students and career women.

2. Materials and methods

2.1. Sampling and preparation

Prior to the initiation of this research, we randomly selected female college students ($n = 203$) and career women ($n = 57$) in Harbin. A questionnaire was designed to obtain information for lip cosmetics using from volunteers. This questionnaire contained general questions regarding daily frequency, type and brand of lip cosmetics product and user occupations. An experimental study was performed and the mean amounts used were calculated by weighing before and after application of the lip cosmetics product in our laboratory. After the information was analyzed, a total of 30 lip cosmetics were selected and purchased from retail stores in Harbin, northeast China in 2013. The lip cosmetics were grouped into two categories: lip balm (LB, $n = 14$) and lipstick (LS, $n = 16$).

2.2. Determination of total metal concentrations

Analysis of LB and LS followed the National Institute for Occupational Safety and Health (NIOSH) standard method for metals, with slight modifications (NIOSH, 2003). Approximately 0.5 g of each sample was transferred into a clean, 100 mL Teflon digestion tube and digested with 2.0 mL concentrated nitric acid (HNO_3) in a block digester at 130 °C for 15 h. The tubes were covered with glass funnels to allow nitric acid reflux during digestion. Samples were diluted to 12.5 mL with distilled, deionized water and then centrifuged to remove material that did not completely dissolve. Solutions were analyzed by inductively coupled plasma mass spectrometry (ICP-MS). The metals examined included Co, Cd, Cr, Cu, Pb, Mn and Ni.

2.3. Determination of the bioaccessible concentration

The BCR three-step sequential extraction procedure was designed to separate metals into four operationally defined fractions: water-soluble/exchangeable, reducible, oxidizable and residual fractions (Quevauviller et al., 1997; Niazi et al., 2011; Li et al., 2010; Jamali et al., 2009; Chou et al., 2009; Arain et al., 2008). A summary of this method is as follows: 0.5 g of lip cosmetic was placed in a 100 mL Teflon digestion tube and subjected to the following extraction regimen: water-soluble/exchangeable fraction (F1)-extract lipstick cosmetic with 40 mL of 0.11 mol/L CH_3COOH, and shake for 16 h at 20 ± 2 °C; reducible fraction (F2)-extract residues from step 1 with 40 mL of 0.1 mol/L $NH_2OH.HCl$ (adjusted to pH 2 with HNO_3), and shake for 16 h at 20 ± 2 °C; oxidizable fraction (F3)-digest residues from step 2 with 10 mL H_2O_2 (30%) at room temperature for 1 h with occasional manual shaking. Heat the mixture at 85 °C for 1 h or longer in a water bath until the volume is reduced to a few milliliters. Add another 10 mL H_2O_2 to the mixture and repeat the heating procedures as described above. After cooling, add 50 mL CH_3COONH_4 (1.0 mol/L, adjusted to pH 2 with HNO_3) and shake for 16 h at 20 ± 2 °C; the residual fraction (F4)-is held in the crystal lattice of the original mineral, and is identified as the "inactive" fraction. In this research, extraction solution was added to lip cosmetics according to the order of digestion capacity from weak to strong. Trace metal concentrations in different combination states were obtained. The residual fractions of trace metals required for extraction in a closed and high-temperature environment were determined under the condition of strong acid (digestion procedure was the same as that for the total metal concentration). Strong concentrated nitric acid was used as the extraction solvent. The acidic extraction environment was much higher than that inside the human body (e.g., stomach). It is difficult to dissolve residual trace metals inside the human body, therefore, they do not form a potential risk to human health. After each successive extraction, separation was performed by centrifugation at 4000 rpm for 20 min, and the concentrations of different metals were analyzed by ICP-MS. The bioaccessible concentration is the sum of F1, F2 and F3 of a metal (Li et al., 2013; Feng et al., 2009; Zhang and Wang, 2009). The bioaccessible concentration is often considered the direct and potentially hazardous fraction to organisms as F1, F2 and F3 bond much less strongly with the lip cosmetic phases than F4.

2.4. Quality assurance/quality control

An internal check was performed on the results of the sequential extraction by comparing the total metal concentrations extracted by different reagents during the sequential extraction procedure with the results of total digestion. The recovery of the sequential extraction method was calculated as follows (Li et al., 2013):