frontiers in Public Health

ORIGINAL RESEARCH
published: 17 November 2021
doi: 10.3389/fpubh.2021.766984

Trace Metal Lead Exposure in Typical Lip Cosmetics From Electronic Commercial Platform: Investigation, Health Risk Assessment and Blood Lead Level Analysis

*Yanan Li[1,2], Yanyan Fang[1,3], Zehua Liu[1,3], Yahan Zhang[1,3], Kangli Liu[1], Luping Jiang[1,2], Boyuan Yang[1,3], Yongdie Yang[3], Yongwei Song[3] and Chaoyang Liu[1,3,4]**

[1] Research Center for Environment and Health, Zhongnan University of Economics and Law, Wuhan, China, [2] School of Business Administration, Zhongnan University of Economics and Law, Wuhan, China, [3] Department of Environmental Science and Engineering, Zhongnan University of Economics and Law, Wuhan, China, [4] Renmin Hospital of Wuhan University, Wuhan, China

OPEN ACCESS

Edited by:
*Hongtao Yi,
The Ohio State University,
United States*

Reviewed by:
*Liqin Yu,
Huazhong Agricultural
University, China
Zhihua Xiao,
Hunan Agricultural University, China*

***Correspondence:**
*Chaoyang Liu
lcy@zuel.edu.cn*

Specialty section:
This article was submitted to Environmental health and Exposome, a section of the journal Frontiers in Public Health

Received: *30 August 2021*
Accepted: *21 October 2021*
Published: *17 November 2021*

Citation:
Li Y, Fang Y, Liu Z, Zhang Y, Liu K, Jiang L, Yang B, Yang Y, Song Y and Liu C (2021) Trace Metal Lead Exposure in Typical Lip Cosmetics From Electronic Commercial Platform: Investigation, Health Risk Assessment and Blood Lead Level Analysis. Front. Public Health 9:766984. doi: 10.3389/fpubh.2021.766984

Lead (Pb) in lipstick products has become an increasing concern, which can cause safety problems to human body directly with diet. To investigate the Pb exposure and potential health risk level of typical popular lip cosmetics in Chinese e-commerce market, Python crawler was introduced to identify and select 34 typical popular lip cosmetics, including 12 lipsticks, 13 lip glosses, and 9 lip balms. And then this study used ICP-MS to determine the content of Pb. Furthermore, the ingestion health risk assessment method issued by United States Environmental Protection Agency (USEPA) and Monte Carlo simulation algorithm were applied to assess the probabilistic health risks of adults exposure. Finally, taking the possible exposure of children contacting with lip products, the health risk assessment of children blood Pb was carried out. The results showed that the concentration of Pb in lip products ranged from 0 to 0.5237 mg/kg, which was far lower than the limit set by various countries. The probabilistic non-carcinogenic risks and carcinogenic risks were $4.93 \times 10^{-7} \sim 2.82 \times 10^{-3}$ and $1.68 \times 10^{-12} \sim 9.59 \times 10^{-9}$, respectively, which were in an acceptable level. The results of blood Pb assessment suggested that the Pb content of lip cosmetics had no obvious influence on blood Pb concentration of children, and background Pb exposure is the main factor affecting children's blood Pb level (BLL). Overall, the samples of lip products are selected by Python crawler in this study, which are more objective and representative. This study focuses on deeper study of Pb, especially for the health risk assessment of blood Pb in children exposed to lip products. These results perhaps could provide useful information for the safety cosmetics usage for people in China and even the global world.

Keywords: lip cosmetics, Pb, health risk, Python crawler, Monte Carlo, Chinese e-commerce market

INTRODUCTION

In recent years, the security of cosmetics is increasingly recognized as a worldwide public health concern (1–3). The Food and Drug Administration (FDA) of the United States, the Food and Drug Safety Administration of the ROK, and the National Drug Administration of China have successively reported that the problem of excessive heavy metals in cosmetics is serious (4–7). To improve product performance, heavy metals are added to cosmetics by manufacturers. For example, the addition of Pb, Hg (mercury), and other metals makes cosmetics have the whitening function of covering or inhibiting pigment formation (8). In addition, with the aggravation of environmental pollution and the influence of some natural factors, some heavy metals widely existing in the surrounding environment will also enter people's lives with the use of cosmetic raw materials (9–11). Studies have shown that low-dose but long-term exposure of heavy metals to the human body can cause chronic poisoning or even canceration, causing irreversible adverse effects on human organs and seriously threatening human health (12–14). As one of the most commonly used cosmetics for modern women, lip cosmetics can not only moisten the lips but also improve personal performance (15). Compared with other cosmetics, lip products are easily exposed to the human body directly with the diet, and result in a higher health risk. Therefore, the assessment of exposure levels and health risks of heavy metals in lip products would be of great value to design manufacturers and relevant supervisory departments to provide scientific reference for health risk control of lip cosmetics consumers.

At present, some studies have focused on heavy metal pollution and health risks in lip products (16–18). Al-Saleh et al. measured the contents of various heavy metals in lipsticks obtained from offline markets in different years, the results indicated that the content of Pb was lower than the standard set by FDA, but special attention should be paid to the effect of Ni (nickel) and Cr (chromium) on allergic dermatitis (19, 20). Pinto et al. investigated the contents of 44 elements in 96 lipsticks from Brazil and Portugal, the results ranged from $<1\ \mu g/g$ to a few tens of $\mu g/g$ (such as Zn, Mn, Pb) (21). Gao et al. simulated the absorption of eight heavy metals in lip cosmetics by hydrochloric acid dilution method, vitro gastrointestinal method and American Pharmacopeia method, and the results suggested that Cu (copper), Pb and Cd (cadmium) were the main components of heavy metal pollution (22). Kilic et al. analyzed the lipsticks collected from the local markets in Turkey, and found the concentrations of all heavy metal were below the allowable limits (18). Although these researches are widely investigated the contents of various heavy metal, few studies focus on the deep study of a specific heavy metal element. Hence, this study attempted to select the element of Pb for deeper study. As a kind of 2B carcinogen, once Pb is absorbed by human body for about 3 months, the concentration of blood Pb will reach balance. Then, the majority of Pb is stored in the liver and the littleness left in the kidney, while the rest Pb is dispersed throughout the body (spinal cord, adrenal gland, brain, heart, etc.) (23). Excessive Pb in the human body can initiate gastrointestinal diseases, even poison the liver, central nervous system, and cause other serious harm to human health (24–27). The experts of WHO have stressed the significance of control on Pb in children, since the disadvantageous effects of Pb on central nervous system (28). Particularly for children under 6 years old, Pb is more harmful because it can damage memory, reduce intelligence, hinder growth and development (29). As mentioned above, Pb is significant among many heavy metals (30, 31), and it is high time to investigate the exposure of Pb to human body in lip products. What's more, some studies have shown that the contents of Pb and Cr in lip cosmetics exceed the standard, and it is strongly recommended to pay concern to the health risks of lip cosmetics (18, 22, 32). The contents of Pb in lip cosmetics from local supermarkets in Malaysia were 0.77–15.44 mg/kg (33). In South Korean, the maximum contents of Pb in lip products from local supermarkets were 12.77 mg/kg (34). A result, from a survey of lipstick from Portuguese and Brazilian markets, showed that the systemic exposure of lipstick was $<0.2\%$ of the daily allowable exposure, except for Pb (21). Alnuwaiser detected the content of Pb in the lipstick of Chinese products, there were only three samples above the limit, while the Pb level in other groups between 0.7 and 12.34 ppm (35). Feizi et al. found the concentrations of Pb were higher than those of Cd in lipsticks, only 33% of lipsticks had Pb contents less than the FDA limit (36). In Turkey, Kilic et al. found the concentration of Pb in Lipstick was 1.1 mg/kg (18). Obviously, the contents of Pb and corresponding health risks have been shown to vary in many different lip products and countries, and there have been little deep discussion about the health risk analysis. Therefore, this study attempts to focus on deeper study of the health risk assessment of Pb of typical popular lip cosmetics in Chinese e-commerce market.

Besides, the assessment results are uncertain due to the differences in sample distribution and exposure parameters during the actual risk assessment process (13, 37–39). To deal with the uncertainty of sample distribution, this study introduced Monte Carlo simulation to analyze the distribution of sample contents. As a statistical simulation method, the Monte Carlo simulation can descent the uncertainty of the mean value under complex condition, and get more accurate prediction results (40–42). The essence of Monte Carlo simulation is to simulate the possible random phenomena in the actual system by random numbers which obey a certain distribution. And the basic idea is to input abundant of random numbers satisfying a certain probability distribution into the model as parameters to determine the probability distribution of the concerned variables (43, 44). Combined with the Monte Carlo simulation and the health risk assessment model recommended by USEPA, the corresponding probability risk assessment range is further obtained.

Of particular concern is Pb mainly existing in the form of blood Pb in the human body (45). Kinds of pollution factors in the environment may result in the increase of blood Pb concentration, such as the Pb pollution in soil (46, 47). In recent years, some studies have begun to pay attention to the blood Pb problem of children caused by the use of lip cosmetics (48). Among them, there are mainly two pathways for children to expose. One is that children directly use lip balm, and the other is that Pb in lip products will also be released into children through maternal transmission (49). At present, several methods currently exist for the measurement of health risks of blood Pb, mainly include Adult Lead Model (ALM) and Integrated Exposure Uptake Biokinetic Model (IEUBK) (48, 50, 51). Among them, the IEUBK mainly involves children aged 0∼7. These two models not only consider the existence and quantity of corresponding harmful substances in the health risk assessment of blood Pb, but also combine the estimated background exposure and the comparison with the basic health standards (52). Through the health risk assessment of adults and blood Pb in children exposed to lip products, this study perhaps could provide useful information for the safety cosmetics usage for people in China and even the global world.

In brief, this study selected 34 typical best-selling lip cosmetics from Chinese e-commerce market based on Python crawler technology, and analyzed the health risk level of adults and children caused by Pb exposure of lip products. The main objectives were (i) to investigate the popular lip cosmetics in Chinese e-commerce market, and determine the content of heavy metal Pb; (ii) to estimate the non-carcinogenic and carcinogenic risks of lipstick users with different frequencies using the health risk assessment model recommended by USEPA; (iii) to evaluate the effects of lip cosmetics on children's blood Pb content by ALM and IEUBK.

MATERIALS AND METHODS

Samples Selection

With the generality of online shopping in Chinese market, this study used Python crawler technology to select the most popular lip products in Chinese typical e-commerce market. JingDong, as one of Chinese top ten e-commerce markets, was selected as the research object of this study. The main Python crawler steps were shown in **Figure 1**. The first step was to establish the initial URL link: www.jingdong.com. Links unrelated to the topic were filtered based on the webpage analysis algorithm, while the useful links were retained and put into the URL pool. The second step was to start the crawler scheduler and initialize the Python crawler. Then, the crawler program simulated the browser to send a request "response" to obtain the HTML file of the corresponding link in the URL pool, and the server sent the "response" file object back to the browser. Python crawler called the BeautifulSoup library to parse HTML in "response." Next, it parsed the Web page according to HTML syntax and accessed valuable data. The third step, Pandas was used to analyze and obtain the value data after the end of the crawler data process, and got the analysis results finally.

As shown in **Figure 2**, the box price distribution of lip cosmetics was obtained on the basis of crawler data. The price distribution of lip cosmetics mainly ranged from 0 to 400 RMB, so the study classified the unified brand of lip cosmetics according to the 33th percentiles and the 66th percentiles, 0∼95 RMB, 96∼266 RMB, and more than 267 RMB, respectively.

Samples Collection and Analysis

Samples Collection

Based on the crawler analysis results above, the top lipstick brands were selected from each section by combining market share and commodity reviews. A total of 34 samples were purchased in this study, including lipsticks (LS, $n = 12$), lip glosses (LG, $n = 13$) and lip balms (LB, $n = 9$). Detailed information involves sample number, brand, origin, color, and price are shown in **Table 1**.

Sample Determination

The sample pretreatment experiment was carried out by wet digestion method according to *Safety specification for cosmetics* (2015 edition) (53). Firstly, 0.5000∼1.0000 g of samples were weighed using EL204 electronic balance (Mettler-Toledo Co., Ltd.) and placed in the crucible. The samples were heated at 100°C using a DK-98-11A electrothermal constant temperature water bath (Tianjin Tester Instrument Co., Ltd.) to make all the samples flow into the bottom of the crucible. 10∼15 ml mixed acid were added, which was mixed with high grade pure nitric acid (Kaifeng Dongda Chemical Co., Ltd.) and high grade pure perchloric acid (Tianjin Zhengcheng Chemical Products Co., Ltd.) at a ratio of 3:1. Heating digestion was carried out on DB-4A stainless steel electric heating plate (Changzhou Boyuan Experimental Analysis Instrument Factory) to produce white smoke in the digestion solution, and the crucible was shaken slowly from time to time to make the digestion solution uniform. When the acid solution is pale yellow or colorless, turn off the power supply of the electric heating plate. The liquid was diluted with ultra-pure deionized water to

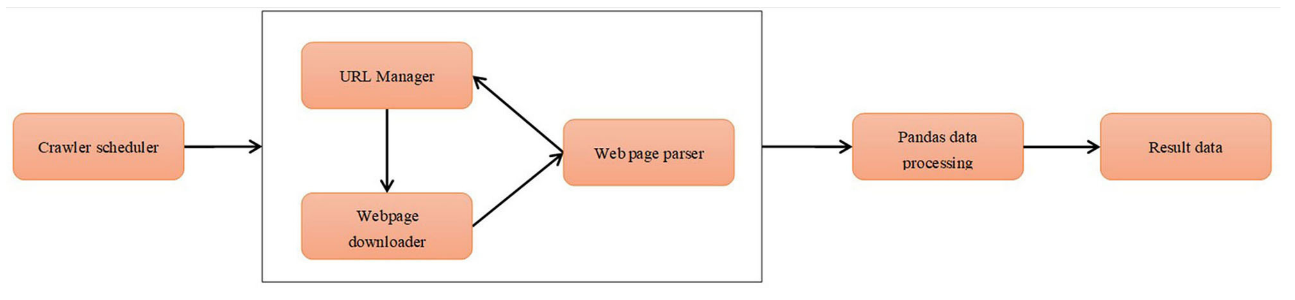

FIGURE 1 | The crawling process by Python.

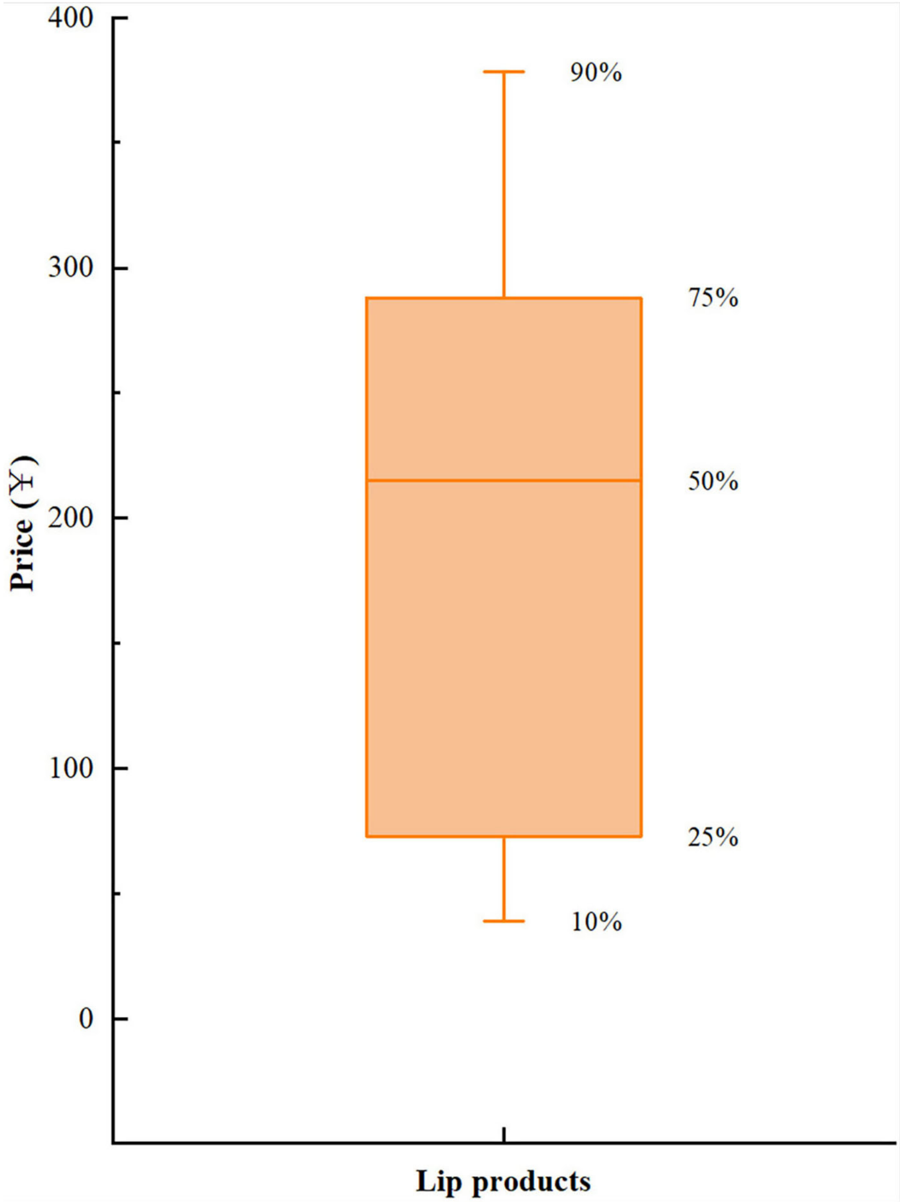

FIGURE 2 | The boxplot of price distribution.

a final volume of 25 ml when the remaining solution was only about 2∼3 ml. In this study, Pb in lip cosmetics was selected for determination. The pretreated samples, parallel samples, and blank samples were put into the preheating inductively coupled plasma mass spectrometer (Nexlon350x, PE, USA) to determine the concentrations of heavy metals. The instrument was calibrated with 187Re in the determination of heavy metals by ICP-MS.

In order to remove the background values of heavy metals in the reagents and containers, the samples were not exposed to metal containers during the experiment, and the required experimental containers were soaked in nitric acid for more than 24 h before drying and using. Besides, parallel samples were more than 20% level and set blank control throughout the experiment. In the determination experiment, Pb standard solution and blank solution were selected to control the metal concentration of the sample. The whole blank test results are less than the detection limit of the method to ensure that the sample is not contaminated during digestion and determination. The standard curve was drawn for each sample test, and the correlation coefficient of the standard curve was ≥0.995, and the relative deviation of the parallel sample test results was controlled within 10%.

TABLE 1 | The basic information for all samples ($N = 34$).

Category	Number	Brand	Production Country	Color	Price (RMB)
Lipsticks	LS1	Chanel	France	Orange red	320
($n = 12$)	LS2	YSL	France	True red	320
	LS3	Armani	France	True red	320
	LS4	Dior	France	True red	330
	LS5	Dhc	Japan	Orange	158
	LS6	Mac	Canada	Brick red	185
	LS7	L' Oreal	China	Orange red	135
	LS8	Maybelline	China	Orange red	120
	LS9	Carslan	China	Cameo brown	139
	LS10	Revlon	America	Orange red	78
	LS11	Kiko	Italy	Cameo brown	90
	LS12	Zeesea	China	Brick red	70
Lip glosses	LG1	YSL	France	Cameo brown	320
($n = 13$)	LG2	Armani	France	Orange red	310
	LG3	Chanel	France	Purplish red	330
	LG4	Dior	France	True red	330
	LG5	Mac	Canada	Pink	170
	LG6	Maybelline	China	True red	122
	LG7	L' Oreal	China	Cameo brown	145
	LG8	Carslan	China	Orange red	109
	LG9	Revlon	America	Cameo brown	48
	LG10	Chioture	China	Cameo brown	60
	LG11	Zeesea	China	Brick red	80
	LG12	Kiko	Italy	Pink	90
	LG13	Kiko	Italy	Colorless	90
Lip balms	LB1	Dhc	Japan	Colorless	78
($n = 9$)	LB2	Uriage	France	Colorless	78
	LB3	Maybelline	China	Light red	30
	LB4	Mentholatum	China	Colorless	35
	LB5	Vaseline	America	Colorless	25
	LB6	Vaseline	America	Light red	25
	LB7	Herbacin	Germany	Colorless	45
	LB8	Mentholatum	China	Light red	36
	LB9	Burt's bees	America	Colorless	70

TABLE 2 | Parameter selection and references of health risk assessment model for oral ingestion.

Parameter type	Parameter value	References
Intake rate of average users IR(g/d)	0.02578	(54)
Intake rate of high users IR(g/d)	0.14902	(54)
Exposed frequency EF(d/a)	365	(55)
Exposure duration ED(a)	70	(55)
Turnover rate CF	0.001	(56)
Average exposure time AT(d)	25550	(56)
Body weight BW(kg)	60	(57)
Non-carcinogenic reference dose RfD (mg/(kg·d))	0.0004	(67)
Cancer slope factors SF ((kg·d)/mg)	0.0085	(67)

Health Risk Assessment of Pb Exposure

Carcinogenic and Non-carcinogenic Health Risk Assessment Models

Considering the particularity of lip products exposed to the human body through diet, this study selected the health risk assessment model recommended by USEPA for oral ingestion (54, 55). The calculation formula was shown in Equations (1-3).

$$\text{ADDing} = \text{C}\times\text{IR}\times\text{EF}\times\text{ED}\times\text{CF}/\text{BW}/\text{AT} \quad (1)$$

$$\text{HQ} = \text{ADD}/\text{RfD} \quad (2)$$

$$\text{LCR} = \text{ADD}\times\text{SF} \quad (3)$$

Where ADD represents the average daily dose of Pb in lip products, mg/(kg·d). C is the concentration of Pb in lip products, mg/kg. All parameters are shown in **Table 2**, IR represents the intake rate of lip products, g/d. The Intake rate of average users and high users was 0.02578 and 0.14902 g/d, respectively (54). EF is the exposure frequency, set as 365 d/a (55). ED represents the exposure duration, 70a (55). CF represents the conversion rate, set to 0.001 (56). AT is the average exposure time, 25,550 d (56). BW is the average body weight of the exposed population, which is 60 kg (57). RfD is the non-carcinogenic reference dose, mg/(kg·d). The general toxicity data of IRIS of USEPA, shown in plenty of researches, can be applied not only for food (58–60), but also for soil (61, 62), dust (63, 64) or other media, such as lip products (22, 33, 65). Therefore, according to the previous studies (22, 66), it is appropriate to cite the general toxicity data of IRIS of USEPA as the reference dose (RfD) of metals in lip products. The RfD was set to 0.0004 in this study (67). SF is carcinogenic slope factor, (kg·d)/mg, set to 0.0085 (67). HQ and LCR are the non-carcinogenic risk value and carcinogenic risk value of oral intake of Pb, respectively. The reference values of non-carcinogenic risk and carcinogenic risk are 1 and 10^{-6}, respectively. If the calculated results are greater than the corresponding value, it is considered that the risk is large, and certain control measures are needed to reduce the risk. Otherwise, it is considered that the risk is at an acceptable level (56, 57, 67).

Blood Lead Level Model

ALM is mainly composed of three parts: namely soil exposure, lip cosmetics exposure, and reference value. The detailed expression is shown in formula (4).

$$\begin{aligned}\text{PbB} = {} & (\text{Pbs}\times\text{BKSF}\times\text{IR}_{\text{S+D}}\times\text{AF}_{\text{S,D}}\times\text{EFs}/\text{AT}_{\text{S,D}}) \\ & +(\text{Pb}_{\text{L}}\times\text{BKSF}\times\text{IR}_{\text{L}}\times\text{AF}_{\text{L}}\times\text{EF}_{\text{L}}/\text{AT}_{\text{L}}) + \text{PbB}_0 \end{aligned} \quad (4)$$

In the formula, PbB represents adult blood Pb concentration, μg/dl. Pbs and Pb_L are BLL in soil and lip cosmetics, respectively, μg/g. According to the research results of scholars on the soil Pb reference value in China, the value of Pbs was set as 282 μg/g (68). Based on the experimental data in this study, the average concentration of Pb in three kinds of lip cosmetics was set to 0.05791 μg/g. PbB_0 was taken 1.62μg/dl as the reference blood Pb content. BKSF is the biokinetic slope factor, set as 0.4 d/dl. IR represents daily intake, and soil intake $\text{IR}_{\text{S+D}}$ is 0.05 g/d. For lip cosmetics intake, average users was 0.0258 g/d and high users was 0.1490 g/d (67). AF represents the absorption rate, $AF_{S,D}$ for soil is 0.12. AF_L for lip cosmetics is conservatively considered to be 1. EF represents the contact frequency. EFs for soil is set to 220 d/year, and EF_L for lip cosmetics is set to 365 d/year (69). AT represents the average contact time, which is 365 d/year (69). When blood Pb in adults is transmitted through the mother, the transmission rate is 0.85 in ALM and 0.9 in IEUBK (48).

The IEUBK model for children exposed to Pb was developed by USEPA to predict the blood Pb concentration of children under 7 years old (0∼84 months) and the possibility of Pb poisoning in children after a certain degree of Pb exposure (70–72). This model can set up integral and external parameters with the consideration of soil, water, food, air and conditions of Pb exposure. The integral parameters can't be changed arbitrarily, while the external parameters can be modified based on local actual data at the input interface to simulate the relationship between Pb absorption efficiency and blood Pb concentration in the human body (68, 73). Taking the actual situation of children's use of lip cosmetics into account, this study defaulted that children were exposed only to lip balms, and Pb exposure in other types of lip cosmetics was transmitted by the mother (48). The reference value of Pb concentration in soil in China is set at 282 mg/kg, and the default absorption rate of Pb in soil and dust by children is 45% (68, 69). In accordance with the national revised limit of Pb concentration in the atmosphere in 2012, the background value of Pb concentration in the air was set as an annual average of 0.5 $\mu g/m^3$ (GB3095-2012) (74), and the default absorption rate was 30%. The background value of Pb in drinking water was 0.01 µg/L (GB5749-2006) (75), and the default values of 0∼7 years old were 0.2, 0.5, 0.52, 0.53, 0.55, 0.58, and 0.59 L/day (69). The blood Pb concentration in pregnant women was set based on the results of the ALM model. In accordance with China standard on the limit of pollutant content in food (GB2762–2017) (76), the limit of Pb content in infant formula foods was 0.15 and 0.02 mg/kg with solid and liquid food, respectively. The limit of Pb content in infant auxiliary food was 0.2∼0.3 mg/kg, and the limit of Pb content in food was below 0.5 mg/kg except for seafood. According to the pyramid distribution of children's food intake, the background value of Pb intake in children aged 0∼3 was set to 8 µg/day, and 20 µg/day in children aged 3∼7 (68, 69). The statistical software is IEUBK win1.1_Build 11 (77).

Statistical Analysis

Microsoft Excel 2019 was used for data processing. The correlation analysis was performed in SPSS (20.0), and the significance level was $P < 0.05$. In order to quantify the uncertainty of sample content distribution, Crystal Ball software (16.0) was used for Monte Carlo simulation in this study, and the number of iterations was set to be 10,000. The box diagrams of probability risk were drawn in Origin Pro 8.0.

RESULTS AND DISCUSSION

Pb Content Characteristics in Lip Cosmetics

The Pb content in 34 lip products was determined in this study, as shown in **Figure 3**; **Table 3**. It can be seen from **Figure 3** that the Pb content varies greatly among different lip products. In this study, the Pb element was not detected in about 41.18% lip products. At present, different countries, including China, the United States and Canada, have set limits for Pb in cosmetics, which are 10 mg/kg. The contents of lip products in this study

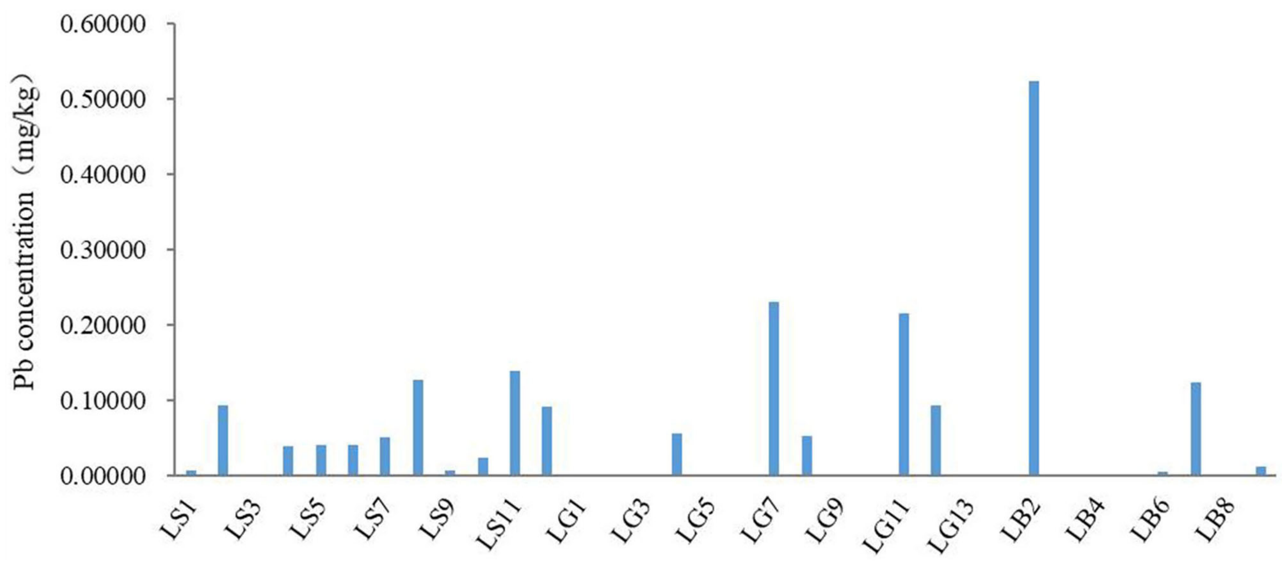

FIGURE 3 | The contents of Pb in typical popular lip cosmetics ($N = 34$).

TABLE 3 | The contents of Pb in various lip products (mg/kg).

Parameter	Lipstick (n = 12)	Lip glosses (n = 13)	Lip balms (n = 9)	Totals (N = 34)
Average value	0.05482	0.04976	0.07380	0.05791
Standard deviation	0.04506	0.07922	0.16358	0.10146
Maximum value	0.13849	0.23093	0.52470	0.52370
Minimum value	0.00000	0.00000	0.00000	0.00000

were far below the limit. Therefore, the trace metal Pb element in lip cosmetics is at an acceptable level.

According to **Table 3**, the content of Pb in lip products (N = 34) ranged from 0 to 0.5237 mg/kg, which was far lower than that reported in previous studies such as South Korea (34), the United States (78), Iran (65), Saudi Arabia (20) and Turkey (18). This may be related to the batch, color, raw materials, and ratio of lip cosmetics (36, 79, 80). The average Pb content of all kinds of lip products decreased in the following order: lip balms ($n = 12$) > lipsticks ($n = 13$) > lip glosses ($n = 9$), while the result of Iwegbue et al. showed that the content of Pb in lipsticks is more than in lip glosses/lip balms (17). Probably, it reflected differences in the origin, color, brand and batch of lip cosmetics. In addition, in order to investigate the relationship between the content of Pb, the category and the price of lip products, this study carried out correlation analysis in SPSS. The results showed that the correlation coefficient between Pb content and category was 0.067 ($P = 0.707 > 0.05$), and the correlation coefficient between Pb content and price was −0.136 ($P = 0.443 > 0.05$). Therefore, there is no significant correlation among the content of Pb, the category and the price of lip products, which corroborate the findings of little relevance between the cost of cosmetics and the concentration of heavy metals (81). However, these results differ from some published studies which indicated that the concentration of Pb in cheaper brands was higher than the expensive brands (82, 83). This discrepancy could be attributed to the differences in limited sample selection.

Carcinogenic and Non-carcinogenic Health Risk Assessment

To evaluate the uncertainty caused by the difference in sample content, Monte Carlo algorithm was introduced for analysis. The results showed that the Pb content in lip cosmetics in this study was in line with the lognormal distribution. Combined with the health risk assessment model, 10,000 iterations were carried out to predict the final non-carcinogenic and carcinogenic risks, as shown in **Figures 4**, **5**.

The non-carcinogenic risk prediction results of Pb in lip cosmetics showed that the 95th percentiles of high users and average users were 2.82×10^{-3} and 4.88×10^{-4}, respectively, which were far below the threshold 1. Thus, the non-carcinogenic risk of exposure to Pb in lip products is acceptable, this result is consistent with previous research conclusions (33, 34, 84).

From **Figure 5**, it appeared that the carcinogenic risk of Pb in lip cosmetics was between 10^{-12} and 10^{-8}. The 95th percentiles of high users and average users were 9.59×10^{-9} and 1.66×10^{-9}, respectively, which were far lower than the threshold of 10^{-6}. Therefore, it can be considered that the carcinogenic risk of Pb in contact with lip products is at a safe level. Though the carcinogenic risk of Pb in contact with lip products and other cosmetics, in many previous studies, is lower than the threshold of 10^{-6} (34), there will be a requirement for attention if the risk is above 10^{-4}. In this study, the exposure of Pb may be considered safe currently. However, with daily using of the cosmetics, the heavy metals may poison and accumulate in human body. Therefore, the data provided in this study may be important to the managerial organization of cosmetic safety.

In this study, the exposure and health risks of Pb in lip products are the concerned objects. Exposure of hazardous substances in lip products is the result of interaction of various heavy metals and pollutants (22, 78), and this comprehensive exposure may have higher health risks, which need to be further enriched and deepened in the following studies.

Blood Lead Level Analysis of Blood Lead

The use of lip cosmetics may affect the blood Pb content in children, especially through maternal transmission. Hence, based on the calculation results of different data parameters of the ALM model, the influence of adult exposure on blood Pb concentration in infants was obtained, as shown in **Table 4**.

The left half of the table shows the corresponding adult blood Pb concentration of every part with low background value, which the reference value 1.62 μg/dl. And the other half of that displays the blood Pb content affected by high background value, which is 2.03 μg/dl with the combination of soil and reference exposure. And line labeled "Lip cosmetic" presents the blood Pb content affected by lip products exposure, which is 0.0006 and 0.0035 for average and high users, respectively. Subsequently, the adults blood Pb concentration could be summarized, as shown in the next line of the table. Finally, based on the fact that the transmission rate, in general, can be set as 0.85 or 0.9, the blood Pb concentrations from the mother to the fetus can be obtained. The results showed that under the condition of low background value and the transmission rate was 0.85, the blood Pb concentrations from the mother to the fetus of the average user and the high user were 1.3775 and 1.3799 μg/dl, respectively. While the transmission rate under the children's blood Pb pharmacokinetic model was 0.9, the blood Pb concentrations from the mother to the fetus of the average user and the high user were 1.4585 and 1.4611 μg/dl, respectively. Similarly, under the condition of high background value, the blood Pb concentrations from maternal to fetal were 1.7260 and 1.7284 μg/dl for both average and high users at adult blood Pb transmission rate, respectively. Under the condition of IEUBK for children, the blood Pb concentrations from maternal to fetal were 1.8275 and 1.8301 μg/dl for both average users and high users, respectively. No matter the concentration of Pb in lip cosmetics under average or high exposure, there is little difference in blood Pb content from mother to fetus. Hence, the main factor affecting fetal blood Pb concentration is the maternal background environment.

When running the IEUBK program, the maternal body was set to 0, 1.41925, and 1.77800 μg/dl, respectively. Under the background of average exposure, 0.00190 μg/d Pb was ingested from lip cosmetics and 0.07819 μg/d Pb was ingested from lip

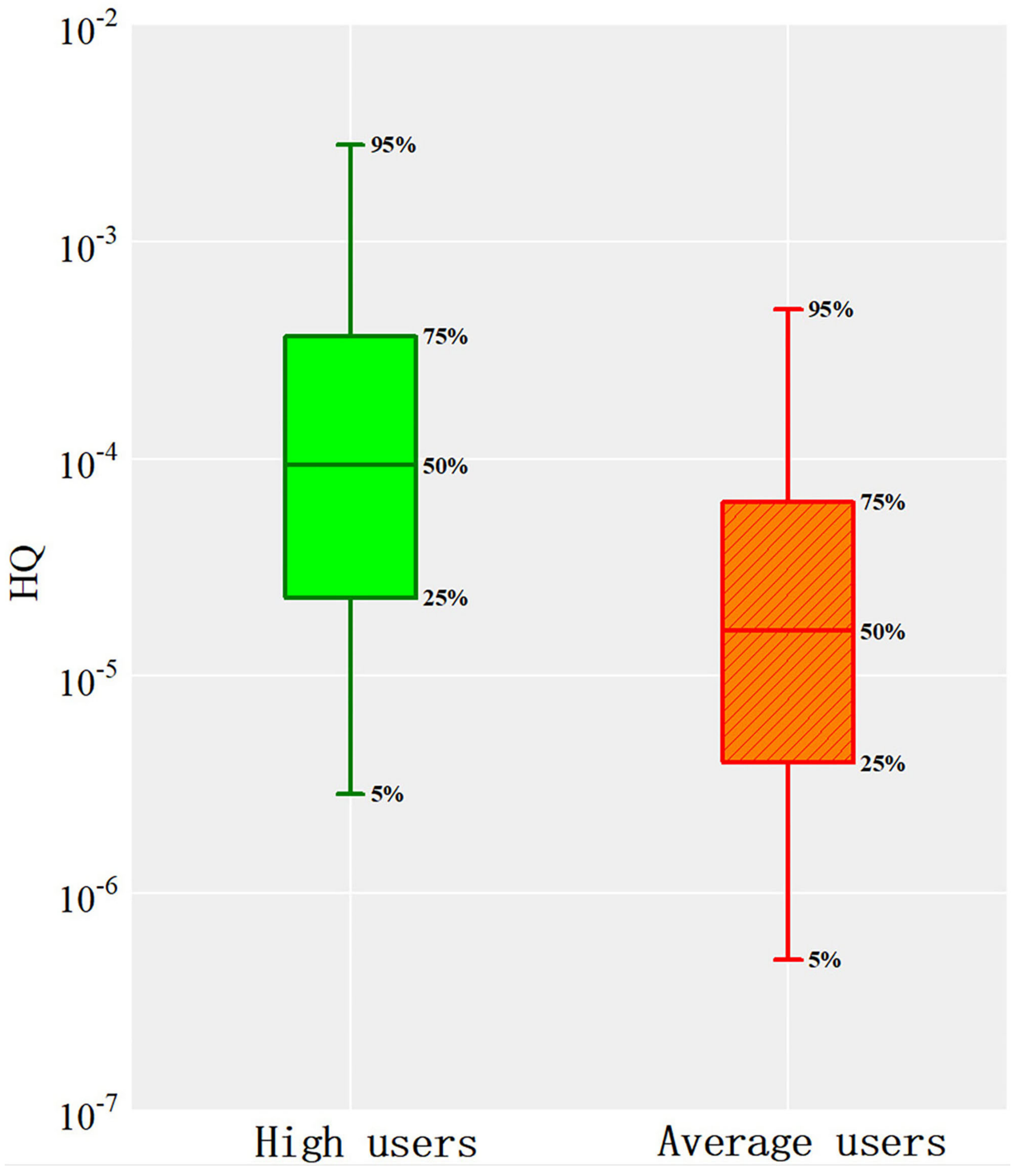

FIGURE 4 | The non-cancer health risk assessment of Pb.

cosmetics under the condition of high exposure. The changes of blood Pb concentration in 0∼7 years old children under the above six conditions were found, as shown in **Table 5**. Even if the total intake of Pb content changed slightly, the operation results of blood Pb concentration under the six conditions were the same.

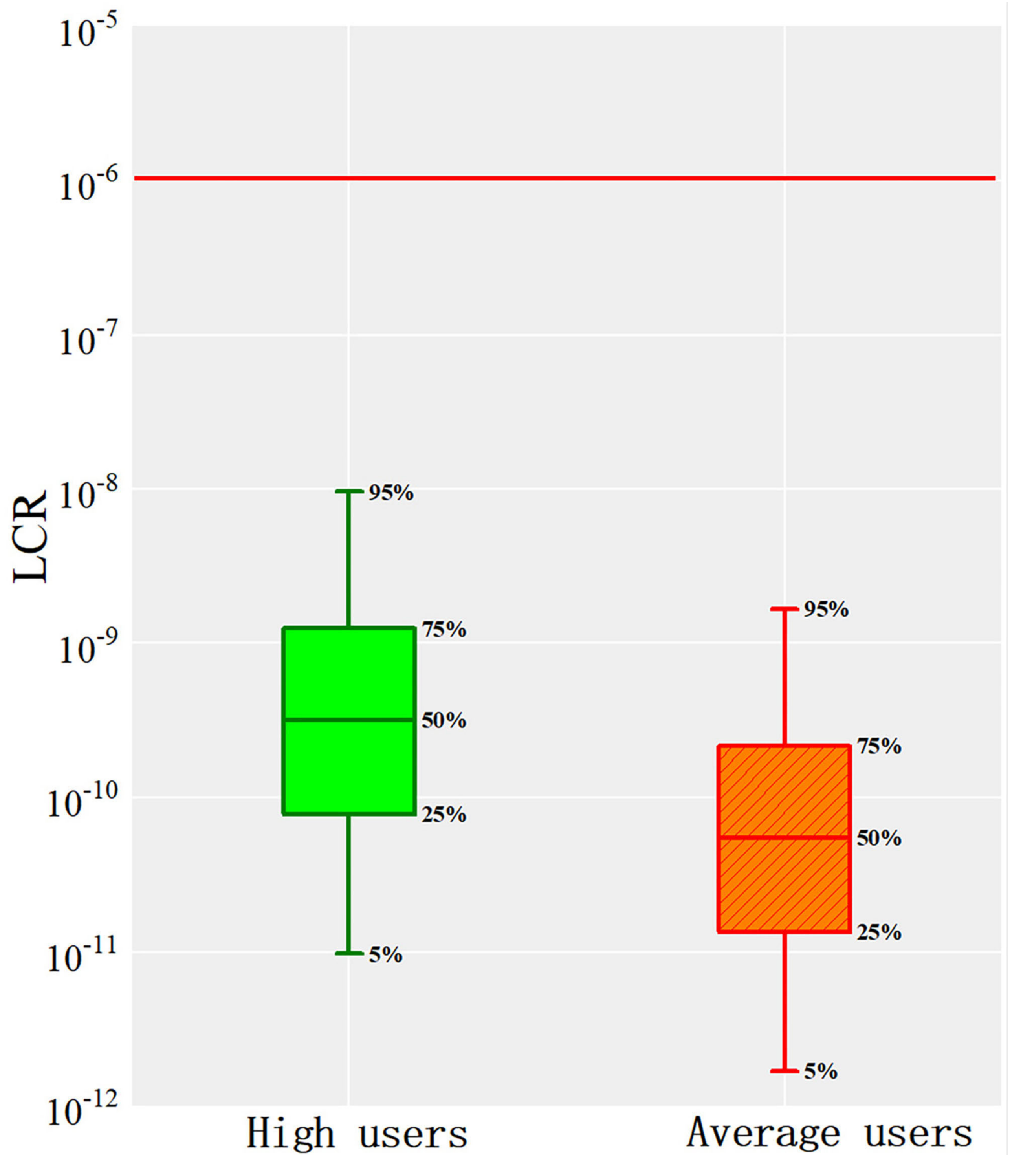

FIGURE 5 | The cancer health risk assessment of Pb.

In developed countries, the BLL of children <6 μg/dl are considered to be relatively safe (85), and the international threshold for children's blood Pb is 10 μg/dl (86). There would exist embryonic development toxicity and the pregnant women are prone to miscarriage when the concentration of blood Pb reach the standard. With the rise of BLL, people gradually experience the impact of heme metabolism, which can lead to renal dysfunction and even death (48, 87). Based on the data

TABLE 4 | The running results for adult blood Pb model.

Exposure scenarios	Blood Pb levels BLL(μg/dl)							
Background	1.62				2.03			
Lip cosmetic	0.0006		0.0035		0.0006		0.0035	
PB_L	1.6206		1.6235		2.0306		2.0335	
From mother to fetus	1.3775	1.4585	1.3799	1.4611	1.7260	1.8275	1.7284	1.8301

TABLE 5 | The running results for the IEUBK model.

Age (years)	Total Pb absorption (μg/d)	Blood Pb levels (μg/dl)
0.5∼1	9.694 ± 0.002	5.2
1∼2	13.224 ± 0.002	5.9
2∼3	13.574 ± 0.002	5.1
3∼4	18.684 ± 0.001	6.0
4∼5	16.679 ± 0.002	5.7
5∼6	16.294 ± 0.002	5.1
6∼7	16.048 ± 0.002	4.6

obtained in this study, although the blood Pb concentration in children did not exceed the international threshold, the blood Pb content of children aged 3∼4 years old had reached the standard value in developed countries. In addition, there was little difference between the blood Pb data from the mother and the lipstick separately and the total of them. The results indicated that whether the average-exposed or the high-exposed population, the background Pb exposure is the main factor affecting the BLL of children. The Pb exposure of lip cosmetics did not significantly increase the blood Pb content of children, this conclusion is consistent with previous studies (48, 88). Compared with previous study, Monnot et al. found that the baseline BLLs of child born to mothers with high BLLs were 0.04 μg/dl higher than the BLLs of children born to mothers with average BLLs, and the lipstick exposure has little contribution to resulting in a higher level of BLLs than the dose of background exposure (48). Hence, more attention should be paid to the Pb content of air and soil around the living environment of children, as well as the safety of food and drinking water for adults and children.

Uncertainty Analysis

A large number of studies have shown that heavy metal content in different lip products varies greatly, which may be related to origin, brand, color, price, raw materials and ratio (55, 63). Therefore, there is great uncertainty in sample selection. The selection of samples plays a fundamental role in the investigation of lip products, to effectively reduce the uncertainty of sample selection, Python crawler technology, is innovatively introduced in this study to select the best-selling brands in typical e-commerce platforms, which is in accord with the reality of market and consumers, making sample selection more objective and representative (89–91). The data of the e-commerce platform are updated in real-time observation. In order to carry out long-term effective risk control, it is necessary to continuously monitor the pollution levels of Pb and other heavy metals in lip cosmetics.

Furthermore, the risk levels appeared to be affected by metal contents. In the process of implementing risk assessment, this study introduces Monte Carlo simulation and predicts the risk assessment results through 10,000 iterations, which can reduce the uncertainty of risk assessment to some extent. Further investigations can obtain reliable data through short-term observation experiments on population exposure parameters, and more accurately measure the health risk of lip cosmetics.

Finally, it should be noted that this study assumes that the smeared lipstick is human intake, the absorption rate is 100%. In fact, due to the limitation of human body absorption, it is difficult to reach 100%. There are few existing studies regarding human body absorption, which brings certain uncertainty to risk assessment. Further work on human body absorption rate is particularly important.

CONCLUSIONS

This study intends to investigate the heavy metal Pb content, assess health risks and analysis blood Pb level in popular lip cosmetics across Chinese e-commerce market. Python crawler technology, particularly, was introduced to identify and select the most popular 34 lip cosmetics. The findings clearly found that the average content of Pb in the tested lip products is 0.05791 mg/kg, far below the limit value. And the contents of Pb in various lip products decreased in the following order: lip balms > lipstick > lip glosses. There is no significant non-carcinogenic and carcinogenic risk caused by adult exposure to lip cosmetics. Furthermore, blood Pb model analysis showed that the exposure of Pb in lip cosmetics had little effect on children's blood Pb health. Compared with the Pb content of lip cosmetics, it is necessary to pay more attention to the safety of children's diet, drinking water and living environment to prevent the heavy metals from causing health damage.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

YL organized study, prepared datasets, performed the statistical analysis, and drafted the manuscript. CL designed the study, organized study, prepared datasets, and revision of the manuscript. YF contributed to organize study, prepare datasets, and draft the manuscript. ZL contributed to study design and revision of the manuscript. YZ contributed to prepare datasets, perform the statistical analysis, and draft the manuscript. KL, LJ, and YY organized study and revision of the manuscript. BY and YS contributed to datasets prepare and revision of the manuscript. All authors read and approved the final manuscript.

FUNDING

This study was financially supported by National Social Science Foundation of China (19FJYY02), China Postdoctoral Science Foundation (2020M672420), and Special Fund for the Reform of Education and Teaching in Central Universities, Zhongnan University of Economics and Law (YZKC202143).

REFERENCES

1. Choi CM, Hwang YS, Park AS, Jung SJ, Kim HJ, Kim JH. A study on heavy metal concentrations of color cosmetics in Korea market. *J Soc Cosmet Sci Korea.* (2014) 40:269–78. doi: 10.15230/SCSK.2014.40.3.269
2. Borowska S, Brzoska MM. Metals in cosmetics: implications for human health. *J Appl Toxicol.* (2015) 35:551-72. doi: 10.1002/jat.3129
3. Salama AK. Assessment of metals in cosmetics commonly used in Saudi Arabia. *Environ Monitor Assess.* (2015) 188:553. doi: 10.1007/s10661-016-5550-6
4. CCTV Finance. *Heavy Metals in 13 Kinds of Cosmetics Exceeded the Standard*. CCTV Finance (2018). Available online at: http://baijiahao.baidu.com/s?id=1595517502888349927&wfr=spider&for=pc (accessed June 2020).
5. SFDA (State Food and Drug Administration). *Notice of the State Food and Drug Administration on 8 Batches of Unqualified Cosmetics*. SFDA (2020). Available online at: https://www.nmpa.gov.cn/xxgk/ggtg/hzhpchj/hzhpgjjgg/20201013172259176.html (accessed December 2020).
6. Matta MK, Zusterzeel R, Pilli NR, Patel V, Volpe DA, Florian J, et al. Effect of sunscreen application under maximal use conditions on plasma concentration of sunscreen active ingredients: a randomized clinical trial. *JAMA*. (2019) 321:2082–91. doi: 10.1001/jama.2019.5586
7. Liu XS, Zhang HL, Zhang HL, Jiang YH, Lv L, Zu J, et al. Assessment of heavy metal content in cosmetics of Chinese market. *Basic Clin Pharmacol Toxicol.* (2021) 128:151.
8. Bocca B, Pino A, Alimonti A, Forte G. Toxic metals contained in cosmetics: a status report. *Regulat Toxicol Pharmacol.* (2014) 68:447–67. doi: 10.1016/j.yrtph.2014.02.003
9. Peng G, Sa L, Zhaohan Z, Ping M, Nan L, Binyu L, et al. Health impact of bioaccessible metal in lip cosmetics to female college students and career women, northeast of China. *Environ Pollut.* (2015) 197:214–20. doi: 10.1016/j.envpol.2014.11.006
10. Zhang J, Jiang L, Liu Z, Li Y, Liu K, Fang R, et al. A bibliometric and visual analysis of indoor occupation environmental health risks: development, hotspots and trend directions. *J Clean Product*. (2021) 300:126824. doi: 10.1016/j.jclepro.2021.126824
11. Chen Y, Wang J, Shi G, Sun X, Chen Z, Xu S. Human health risk assessment of lead pollution in atmospheric deposition in Baoshan District, Shanghai. *Environ Geochem Health.* (2011) 33:515–23. doi: 10.1007/s10653-010-9368-9
12. Zhang J, Li Y, Liu C, Li F, Zhu L, Qiu Z, et al. Concentration levels, biological enrichment capacities and potential health risk assessment of trace elements in eichhornia crassipes from Honghu Lake, China. *Sci Rep.* (2019) 9:2431. doi: 10.1038/s41598-018-36511-z
13. Li F, Lu Y, Zhang J, Wang Y, Chen X, Yan J, et al. Investigation and regional fuzzy health risk management of lead and cadmium in best-selling cigarettes across China. *J Clean Product.* (2020) 261:121005. doi: 10.1016/j.jclepro.2020.121005
14. Zhao J, Jiang JC, Hu JJ, Wang YF, Jian XD, Ge HH. Pollution status and control countermeasures for pharmaceutical and personal care products in China. *Asian J Ecotoxicol.* (2020) 15:21–7. doi: 10.7524/AJE/1673-5897.20191030002
15. Iwegbue CMA, Bassey FI, Tesi GO, Onyeloni SO, Obi G, Martincigh BS. Safety evaluation of metal exposure from commonly used moisturizing and skin-lightening creams in Nigeria. *Regulat Toxicol Pharmacol.* (2015) 71:484–90. doi: 10.1016/j.yrtph.2015.01.015
16. Escher K, Shellock FG. Evaluation of MRI artifacts at 3 Tesla for 38commonly used cosmetics. *Magn Reson Imaging*. (2013) 31:778-82. doilink[10.1016/j.mri.2012.11.002]10.1016/j.mri.2012.11.002
17. Iwegbue CMA, Bassey FI, Obi G, Tesi GO, Martincigh BS. Concentrations and exposure risks of some metals in facial cosmetics Nigeria. *Toxicol Rep.* (2016) 3:464–72. doi: 10.1016/j.toxrep.2016.04.004
18. Kilic S, Kilic M, Soylak M. The determination of toxic metals in some traditional cosmetic products and health risk assessment. *Biol Trace Elem Res.* (2021) 199:2272–7. doi: 10.1007/s12011-020-02357-8
19. Al-Saleh I, Al-Enazi S, Shinwari N. Assessment of lead in cosmetic products. *Regulat Toxicol Pharmacol.* (2009) 54:105–13. doi: 10.1016/j.yrtph.2009.02.005
20. Al-Saleh I, Al-Enazi S. Trace metals in lipsticks. *Toxicol Environ Chem.* (2011) 93:1149–65. doi: 10.1080/02772248.2011.582040
21. Pinto E, Paiva K, Carvalhido A, Almeida A. Elemental impurities in lipsticks: results from a survey of the Portuguese and Brazilian markets. *Regul Toxicol Pharmacol.* (2018) 95:307–13. doi: 10.1016/j.yrtph.2018.04.009
22. Gao P, Lei T, Jia L, Yury B, Zhang Z, Du Y, et al. Bioaccessible trace metals in lip cosmetics and their health risks to female consumers. *Environ Pollut.* (2018) 238:554–61. doi: 10.1016/j.envpol.2018.03.072
23. Sirivarasai J, Kaojarern S, Chanprasertyothin S, Panpunuan P, Petchpoung K, Tatsaneeyapant A, et al. Environmental lead exposure, catalase gene, and markers of antioxidant and oxidative stress relation to hypertension: an analysis based on the EGAT study. *Biomed Res Int.* (2015). 2015:856319. doi: 10.1155/2015/856319
24. Wei YH, Huang QC. The toxicological effect of lead on the human health and its measures of prevention. *Stud Trace Elem Health.* (2008). 25:62–64. doi: 10.3969/j.issn.1005-5320.2008.04.026
25. Yue QL, Huo J, Cao MS, Chen JY, Zhang LS. Research progress in neurobehavioral toxicity of lead. *J Food Saf Qual.* (2018) 9:3567–72. doi: 10.3969/j.issn.2095-0381.2018.14.003
26. Flora SJS. Lead exposure: health effects, prevention and treatment. *J Environ Biol.* (2002) 23:25–41. doi: 10.1016/S0169-7722(01)00143-7
27. Debnath B, Singh WS, Manna K. Sources and toxicological effects of lead on human health. *Indian J Med Special.* (2019) 10:66–71. doi: 10.4103/INJMS.INJMS_30_18
28. WHO (World Health Organization). *WHO Expert Consultation: Available Evidence for the Future Update of the WHO Global Air Quality Guidelines (AQGs).* (2016). Available online at: https://www.euro.who.int/__data/assets/pdf_file/0013/301720/Evidence-future-update-AQGs-mtg-report-Bonn-sept-oct-15.pdf (accessed August 2020).
29. Charkiewicz AE, Backstrand JR. Lead toxicity and pollution in Poland. *Int J Environ Res Public Health.* (2020) 17:4385. doi: 10.3390/ijerph171 24385
30. Dong ZM, Wu SM, Hu JY. Health risk assessment for children due to lead exposure in some region of China. *Zhongguo Huanjing Kexue/China Environ Sci.* (2011) 31:1910–6.
31. Wang B, Zhang J, Zhang Y, Pan L, Liu L, Zhao X, et al. Health risk assessment for lead exposure of children in China. *Acta entiae Circumstantiae.* (2013). 33:1771–79. doi: 10.13671/j.hjkxxb.2013.06.007

32. Zhao D, Li J, Li C, Juhasz AL, Scheckel KG, Luo J, et al. Lead relative bioavailability in lip products and their potential health risk to women. *Environ Sci Technol.* (2016) 50:6036-43. doi: 10.1021/acs.est.6b01425
33. Zakaria A, Ho YB. Heavy metals contamination in lipsticks and their associated health risks to lipstick consumers. *Regul Toxicol Pharmacol.* (2015) 73:191–5. doi: 10.1016/j.yrtph.2015.07.005
34. Lim DS, Roh TH, Kim MK, Kwon YC, Choi SM, Kwack SJ, et al. Non-cancer, cancer, and dermal sensitization risk assessment of heavy metals in cosmetics. *J Toxicol Environ Health A.* (2018) 81:432–52. doi: 10.1080/15287394.2018.1451191
35. Alnuwaiser MA. Determination of As, Hg, Pb, Cd and Al in the lipsticks in the kingdom of Saudi Arabia. *Int J Pharm Sci Res.* (2018) 9:4750–58. doi: 10.13040/IJPSR.0975-8232.9(11).4750-58
36. Feizi R, Jaafarzadeh N, Akbari H, Jorfi S. Evaluation of lead and cadmium concentrations in lipstick and eye pencil cosmetics. *Environ Health Eng Manag J.* (2019) 6:277–82. doi: 10.15171/EHEM.2019.31
37. Chen D, Zhang ZJ, Gao FL, Li QQ, Wang BG. Study on health risk assessment of aromatic hydrocarbons from a typical oil refinery in Pearl River Delta, China. *China Environ Science.* (2017) 37:1961–70. doi: 10.3969/j.issn.1000-6923.2017.05.045
38. Yang LH, Zhao-Yue KE, Xie ZY, Qun YU. The heavy metal content of atmospheric-particulates and the risk assessment of exposed people in the surrounding area of a lead-zinc mine in Guangdong. *Environ Monitor China.* (2015). 31:48–53.doi: 10.19316/j.issn.1002-6002.2015.04.008
39. Li F, Wang Y, Zhang J, Lu Y, Zhu X, Chen X, et al. Toxic metals in top selling cigarettes sold in China: pulmonary bioaccessibility using simulated lung fluids and fuzzy health risk assessment. *J Clean Product*. (2020) 275:124131. doi: 10.1016/j.jclepro.2020.124131
40. Chaudhary A, Hantush MM. Bayesian Monte Carlo and maximum likelihood approach for uncertainty estimation and risk management: application to lake oxygen recovery model. *Water Res.* (2017) 108:301–11. doi: 10.1016/j.watres.2016.11.012
41. Seifi A, Dehghani M, Singh VP. Uncertainty analysis of water quality index (WQI) for groundwater quality evaluation: Application of Monte-Carlo method for weight allocation. *Ecol Indicat.* (2020) 117:106653. doi: 10.1016/j.ecolind.2020.106653
42. Zhu H, Liu X, Xu C, Zhang L, Chen H, Shi F, et al. The health risk assessment of Heavy Metals (HMs) in road dust based on Monte Carlo simulation and bio-toxicity: a case study in Zhengzhou, China. *Environ Geochem Health.* (2021). 021:00922. doi: 10.1007/s10653-021-00922-1
43. Guo P, Li H, Zhang G, Tian W. Contaminated site-induced health risk using Monte Carlo simulation: evaluation from the brownfield in Beijing, China. *Environ Sci Pollut Res Int.* (2021) 28:25166–78. doi: 10.1007/s11356-021-12429-4
44. Qiu H, Gui H, Fang P, Li G. Groundwater pollution and human health risk based on Monte Carlo simulation in a typical mining area in Northern Anhui Province, China. *Int J Coal Sci Technol.* (2021) 8:118–29. doi: 10.1007/s40789-021-00446-0
45. Zhang Y, Geng. Review on models for lead exposure on human health risk assessment. *Environ Chem.* (2013) 32:943-51. doi: 10.7524/j.issn.0254-6108.2013.06.004
46. Zhou XY, Lei M, Yang J. Effect of lead on soil quality and human health around a lead smeltery. *China Environ Science*. (2013) 34:3675-8. doi: 10.13227/j.hjkx.2013.09.051
47. Ren HM, Wang JD, Wang GP, Zhang XL, Wang CM. Influence of soil lead upon children blood lead in Shenyang City. *China Environ Science.* (2005) 26:153-8. doi: 10.13227/j.hjkx.2005.06.032
48. Monnot AD, Christian WV, Abramson MM, Follansbee MH. An exposure and health risk assessment of lead (Pb) in lipstick. *Food Chem Toxicol.* (2015) 80:253–60. doi: 10.1016/j.fct.2015.03.022
49. O'Halloran K, Spickett JT. The interaction of lead exposure and pregnancy. *Asia Pac J Public Health.* (1992) 6:35–9. doi: 10.1177/101053959300600206
50. Yang KL, Zhang HZ, Zhang ZG, Yan PS. Localization study of environmental health risk assessment model for lead exposure. *China Popul Resources Environ.* (2016). 26:163–9. doi: 10.3969/j.issn.1002-2104.2016.02.020
51. Yang Y, Li X, Wang Q, Li D, Yu Y. Lead benchmarks for soil based on human health model (IEUBK and ALM) in Wenling region. *Huanjing Kexue Xuebao/Acta entiae Circumstantiae.* (2014) 34:1808–17. doi: 10.13671/j.hjkxxb.2014.0526
52. Delgado-Caballero MR, Valles-Aragon MC, Millan R, Alarcon-Herrera MT. Risk assessment through ieubk model in an inhabited area contaminated with lead. *Environ Prog Sustainable Energy.* (2018) 37:391-8. doi: 10.1002/ep.12692
53. National Medical Products Administration (NMPA). *Safety and Technical Standards for Cosmetics*. NMPA (2015). Available online at: http://mpa.gd.gov.cn/zwgk/zcfg/bmgz/content/post_1841027.html (accessed July 2020).
54. Zhou JM, Jiang ZC, Guang-Li XU, Qin XQ, Huang QB, Zhang LK. Distribution and health risk assessment of metals in groundwater around iron mine. *China Environ Sci.* (2019) 39:1934–44. doi: 10.19674/j.cnki.issn1000-6923.2019.0230
55. Gao RZ, Qin ZY, Zhang S, Jia DB, Wang XX. Health risk assessment of Cr6+, As and Hg in groundwater of Jilantai salt lake basin, China. *Zhongguo Huanjing Kexue/China Environ Sci.* (2018) 38:2353–62. doi: 10.19674/j.cnki.issn1000-6923.20180305.004
56. USEPA (United States Environmental Protection Agency). *Risk Assessment Guidance for Superfund. Volume I: (Part A: Human Health Evaluation Manual; Part E, Supplemental Guidance for Dermal Risk Assessment; Part F, Supplemental Guidance for Inhalation Risk Assessment).* Washington DC, USEPA (2011).
57. USEPA (United States Environmental Protection Agency). *Risk Assessment Guidance for Superfund. Volume? (Part A: Human Health Evaluation Manual; Part E, Supplemental Guidance for Dermal Risk Assessment; Part F, Supplemental Guidance for Inhalation Risk Assessment).* Washington DC, USEPA (1999).
58. Hosseini Koupaie E, Eskicioglu C. Health risk assessment of heavy metals through the consumption of food crops fertilized by biosolids: a probabilistic-based analysis. *J Hazard Mater.* (2015) 300:855–65. doi: 10.1016/j.jhazmat.2015.08.018
59. Peng Q, Nunes LM, Greenfield BK, Dang F, Zhong H. Are Chinese consumers at risk due to exposure to metals in crayfish? A bioaccessibility-adjusted probabilistic risk assessment. *Environ Int.* (2016) 88:261-8. doi: 10.1016/j.envint.2015.12.035
60. Wang J, Shan Q, Liang X, Guan F, Zhang Z, Huang H, et al. Levels and human health risk assessments of heavy metals in fish tissue obtained from the agricultural heritage rice-fish-farming system in China. *J Hazard Mater.* (2020) 386:121627. doi: 10.1016/j.jhazmat.2019.121627
61. Yang S, Zhao J, Chang SX, Collins C, Xu J, Liu X. Status assessment and probabilistic health risk modeling of metals accumulation in agriculture soils across China: a synthesis. *Environ Int.* (2019) 128:165–74. doi: 10.1016/j.envint.2019.04.044
62. Wu J, Li J, Teng Y, Chen H, Wang Y. A partition computing-based positive matrix factorization (PC-PMF) approach for the source apportionment of agricultural soil heavy metal contents and associated health risks. *J Hazard Mater.* (2020) 388:121766. doi: 10.1016/j.jhazmat.2019.121766
63. Kurt-Karakus PB. Determination of heavy metals in indoor dust from Istanbul, Turkey: estimation of the health risk. *Environ Int.* (2012) 50:47-55. doi: 10.1016/j.envint.2012.09.011
64. Sun G, Feng X, Yang C, Zhang L, Yin R, Li Z, et al. Levels, sources, isotope signatures, and health risks of mercury in street dust across China. *J Hazard Mater.* (2020) 392:122276. doi: 10.1016/j.jhazmat.2020.122276
65. Malvandi H, Sancholi F. Assessments of some metals contamination in lipsticks and their associated health risks to lipstick consumers in Iran. *Environ Monit Assess.* (2018) 190:680. doi: 10.1007/s10661-018-7065-9
66. Arshad H, Mehmood MZ, Shah MH, Abbasi AM. Evaluation of heavy metals in cosmetic products and their health risk assessment. *Saudi Pharm J.* (2020) 28:779–90. doi: 10.1016/j.jsps.2020.05.006
67. Sook KJ. Study on the intake amount of lipstick and lip-gloss and content monitoring focusing on butylparaben and tar color. *J Korean Soc Cosmetol.* (2013) 19:54–61. https://www.kci.go.kr/kciportal/ci/sereArticleSearch/ciSereArtiView.kci?sereArticleSearchBean.artiId=ART001744376&locale=en&SID=8EpyLIo1RyrJNORrVms (accessed May 2020).
68. Zhang HZ, Luo YM, Zhang HB, Song J, Xia JQ, Zhao QG. Development of lead benchmarks for soil based on human blood lead level in China. *China Environ Science.* (2009) 30:3036–42. doi: 10.13227/j.hjkx.2009.10.051

69. Can LI, Zeng Y, Liu SY, Wang Q. Lead benchmarks for soils based on blood lead model for children and adult in China. *J Environ Health.* (2017). 34:789–93, doi: 10.16241/j.cnki.1001-5914.2017.09.010
70. USEPA (United States Environmental Protection Agency). *Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children*; *Chapter 1*. Washington DC, USEPA (1994).
71. White PD, Van Leeuwen P, Davis BD, Maddaloni M, Hogan KA, Marcus AH, et al. The conceptual structure of the integrated exposure uptake biokinetic model for lead in children. *Environ Health Pers.* (1998) 106(Suppl 6):1513–30. doi: 10.1289/ehp.98106s61513
72. Li YY, Hu J, Wu W, Liu SY, Li M, Yao N, et al. Application of IEUBK model in lead risk assessment of children aged 61-84 months old in central China. *Sci Total Environ.* (2016) 541:673–82. doi: 10.1016/j.scitotenv.2015.09.103
73. Heusinkveld D, Ramirez-Andreotta MD, Rodriguez-Chavez T, Saez AE, Betterton E, Rine K. Assessing children's lead exposure in an active mining community using the integrated exposure uptake biokinetic model. *Expo Health.* (2021) 13:517–33. doi: 10.1007/s12403-021-00400-0
74. Ministry of Environmental Protection of China. *Ambient Air Quality Standards*. Beijing: Standards Press of China (2012).
75. MOHC (the Minister of Health of the People's Republic of China). *Standards for Drinking Water Quality*. Beijing: Standards Press of China (2006).
76. CFDA (China Food and Drug Administration). *National Standards for Food Safety Limits of Pollutants in Food.* Beijing: Standards Press of China (2017).
77. Gulson B, Taylor A, Stifelman M. Lead exposure in young children over a 5-year period from urban environments using alternative exposure measures with the US EPA IEUBK model – a trial. *Environ Res.* (2018) 161:87–96. doi: 10.1016/j.envres.2017.10.040
78. Liu S, Hammond SK, Rojas-Cheatham A. Concentrations and potential health risks of metals in lip products. *Environ Health Perspect.* (2013) 121:705–10. doi: 10.1289/ehp.1205518
79. Mattioli M, Giordani M, Dogan M, Cangiotti M, Avella G, Giorgi R, et al. Morpho-chemical characterization and surface properties of carcinogenic zeolite fibers. *J Hazard Materials.* (2016) 306:140–8. doi: 10.1016/j.jhazmat.2015.11.015
80. Janetos TM, Akintilo L, Xu S. Overview of high-risk food and drug administration recalls for cosmetics and personal care products from 2002 to 2016. *J Cosmet Dermatol.* (2019) 18:1361–5. doi: 10.1111/jocd.12824
81. Sani A, Gaya MB, Abubakar FA. Determination of some heavy metals in selected cosmetic products sold in kano metropolis, Nigeria. *Toxicol Rep.* (2016) 3:866–9. doi: 10.1016/j.toxrep.2016.11.001
82. Malakootian M, Mazandarany MP, Eskandari M, Pourmahyabady R. Determination of lead concentration in solid and liquid lipsticks available in Iran-Kerman. *Trans Chin Soc Agri Eng.* (2012) 25:21–6. doi: 10.3969/j.issn.1002-6819.2009.09.004
83. Sharafi K, Fatahi N, Yarmohammadi H, Moradi M, Dargahi A. Determination of cadmium and lead concentrations in cosmetics (lipstick and hair color) in Kermanshah Markets. (2017) 8:143–50. http://healthjournal.arums.ac.ir/article-1-1180-en.html (accessed June 2020).
84. Ghaderpoori M, Kamarehie B, Jafari A, Alinejad AA, Hashempour Y, Saghi MH, et al. Health risk assessment of heavy metals in cosmetic products sold in Iran: the Monte Carlo simulation. *Environ Sci Pollut Res Int.* (2020) 27:7588-95. doi: 10.1007/s11356-019-07423-w
85. USEPA (United States Environmental Protection Agency). *Region 6 Human Health Medium-Specific Screening Levels*. Washington DC, USEPA (2009).
86. Jusko TA, Henderson CR, Lanphear BP, Cory-Slechta DA, Parsons PJ, Canfield RL. Blood lead concentrations < 10 microg/dL and child intelligence at 6 years of age. *Environ Health Perspect.* (2008) 116:243–8. doi: 10.1289/ehp.10424
87. Zhu H, Yang ZJ. Effect of lead exposure during pregnancy on mother and infants and the related factors. *Hainan Med J.* (2011) 22:12–5. doi: 10.3969/j.issn.1003-6350.2011.24.005
88. Gonzalez Valdez E, Gonzalez Reyes E, Bedolla Cedeno C, Arrollo Ordaza EL, Manzanares Acuna E. Blood lead levels and risk factors for lead poisoning in mexican children. *Revista Facultad De Ingenieria-Universidad De Antioquia.* (2008) 43:114–9. http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S0120-62302008000100010 (accessed July 2020).
89. Tao Y, Zhang F, Shi C, Chen Y. Social media data-based sentiment analysis of tourists' air quality perceptions. *Sustainability.* (2019) 11:5070. doi: 10.3390/su11185070
90. Li Y, Liu Z, Zhang Y, Jiang L, Cai Y, Chen X, et al. Investigation and probabilistic health risk assessment of trace elements in good sale lip cosmetics crawled by Python from Chinese e-commerce market. *J Hazard Materials.* (2021) 405:124279. doi: 10.1016/j.jhazmat.2020.124279
91. Wu Z, Wang X, Pan R, Huang X, Li Y. Study of the relationship between ICU patient recovery and TCM treatment in acute phase: a retrospective study based on python data mining technology. *Evid Based Complement Alternat Med.* (2021) 2021:5548157. doi: 10.1155/2021/5548157

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.