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RESEARCH ARTICLE

Determination of potentially toxic metals in depilatory products in the Iranian markets: human health risk assessment

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Abstract

This study aimed to investigate the concentrations of heavy metals, including lead (Pb), cadmium (Cd), chromium (Cr), zinc (Zn), cobalt (Co), and arsenic metalloid (As), to assess their health risks in the popular depilatory products of the Iranian markets. Twenty-one samples of 7 popular brands of depilatory products, inclusive of cream and powder, were examined. Selected elements were measured by inductively coupled plasma optical emission spectrometry (ICP-OES) using the appropriate procedure for acid digestion and the measurement of heavy metal contents. The differences in heavy metal concentrations were investigated according to the type of product, brand, country of production, and product price using *t* test and one-way analysis of variance and post hoc Tukey test. Finally, carcinogenic and non-carcinogenic risk assessments were calculated for the studied elements. The results showed that Pb (5.46±2.30 mg/kg) and Co (0.16±0.69 mg/kg) had the highest and lowest concentrations in these products, respectively. In general, the concentration of heavy metals in depilatory creams was less than the concentration of elements in depilatory powders and less than the maximum allowable limits as defined by the Institute of Standards and Industrial Research of Iran (ISIRI). There was a direct and significant relationship between the concentration of heavy metals in depilatory powders and the product's price. Moreover, the amount of As in one of the brands of depilatory powder was determined to exceed the standard value (2 mg/kg). Also, hazard index (HI) and lifetime cancer risk (LCR) were below 1 and 10^{-6}, respectively, which indicated that this mentioned heavy metal had no probable non-carcinogenic and carcinogenic risks for consumers. According to this study, it was evident that the chances of cancer and non-cancer risk using depilatory products were unlikely, but continuous use can be harmful due to the excessive accumulation of these heavy metals.

Keywords Heavy metals · Cosmetic products · ICP-OES · Risk assessment · Iran

Introduction

Nowadays, due to the effects of beauty, media advertising, and the increasing importance of people to maintain and improve their appearance, the consumption of various cosmetic products has significantly grown (Bilal and Iqbal 2019; Mansouri et al. 2017; Mostoli et al. 2019). One of the most common esthetic problems in recent decades, which has affected many people around the world, is the increase in hair growth due to various factors such as genetics, nutrition, hormonal disorders, and drug interventions (Grymowicz et al. 2020; Rajput 2017; Redler et al. 2017; Tewary et al. 2021). This can influence the mental health of patients by causing depression, anxiety, and distress and reduce their quality of life (Pasch et al. 2016; Rajput 2017; Tewary et al. 2021) because in the modern world, the hairless body is considered one of the ideal and healthy aspects of the body (Deslandes 2020; Grymowicz et al. 2020). Recently, various methods have been used to remove unwanted hair; the most popular of them is using depilatory products (Farzaneh et al. 2011; Fernandez et al. 2013). These products are classified into a group of cosmetics that have different types such as gels, foams,

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creams, and powders. The powder form of this product, which is also known as "Vajebi" in Iran, is traditionally used in this country and many other eastern countries, including India, to remove unwanted hair (Farzaneh et al. 2011; Klein and Rish 1988; Mehrpour and Abdollahi 2012). In general, the chemical composition of depilatory products in the past included 65% calcium bicarbonate ($Ca(HCO_3)_2$), 25% arsenic sulfide (As_2S_3) (as an effective ingredient in hair removal), and 10% lime and moisture (Farzaneh et al. 2011). Nevertheless, in recent years, due to identifying the toxic effects of arsenic, As_2S_3 was replaced with the active ingredient calcium thioglycolate. Calcium thioglycolate destroys the disulfide bonds in hair keratin so that weakened hair can be easily removed from the follicle in the epidermis by gently rubbing the skin (Fernandez et al. 2013; Kushida et al. 1984). Among the benefits of using depilatory products are removing hair without pain and the risk of cuts and skin abrasions. This quick method can remove unwanted hair in 3 to 15 min depending on its strength, color, and thickness (Karegoudar et al. 2012; Pancar and Kalkan 2014). However, the presence of some elements, such as arsenic and heavy metals in the composition of various cosmetic products, has led to limitations in their use (Jihad 2020; Ullah et al. 2017). Heavy metals and arsenic are among the most important environmental pollutants so that even the disposal of wastewater from washing products containing these elements may contaminate groundwater sources via the septic tanks (Agoro et al. 2020; Hourieh Fallah et al. 2020; Tuzen et al. 2009). Besides, these elements can be absorbed by the body through diet, medication, the environment, or using cosmetics (Mendil et al. 2009; Meng et al. 2021; SeyyediBidgoli et al. 2020; Uluozlu et al. 2009). Because most cosmetic products are typically used on the skin, the most important route of the absorption of heavy metals in these products is the skin (Sani et al. 2016; Slodownik et al. 2008). These elements can accumulate biologically in the vital organs of the body (Zakaria and Ho 2015), which can cause cancer for a long time (Zhang et al. 2021), damage to kidney function, nervous system, and cardiovascular system (Al-Rikabi et al. 2021; Rebelo and Caldas 2016). It also causes teratogenic consequences, fetal retardation, and weight loss (Leelapongwattana and Bordeerat 2020; Zhao et al. 2020). Prolonged skin contact with cosmetics, such as depilatory agents, can aggravate the symptoms of severe skin allergies, rashes, and chemical burns (Gupta et al. 2021; Salama 2016; Tuchman et al. 2015). Therefore, it is essential to study the concentration of heavy metals in this category of popular products and assess the health risk caused by these elements because the use of depilatory products can be a possible source of human contact with various harmful substances. The Institute of Standards and Industrial Research of Iran has announced the maximum allowable concentration of As metalloid in depilatory products 2 mg/kg and for other heavy metals a maximum of 20 mg/kg (ISIRI 2003). So far, many studies have been done to measure the concentrations of heavy metals and assess the health risks of these elements in cosmetic products (Kilic et al. 2021; Lim et al. 2018; Massadeh et al. 2017; Munir et al. 2020), but despite many searches, no studies in this field were done on depilatory products.

Therefore, due to the increasing use of depilatory products to remove unwanted hair and based on the irreparable effects of heavy metals in these products on body health and the environment, this study aimed to investigate the heavy metals and assess the carcinogenic and non-carcinogenic risks of these metals in the popular brands of depilatory products in the Iranian markets.

Materials and methods

This descriptive-analytical study was conducted to measure 5 heavy metals, including Pb, Cr, Cd, Zn, Co, and As metalloid in the popular brands of depilatory powder and cream available in the Iranian markets in 2020. Samples included 15 depilatory creams and 6 depilatory powders. At first, after surveys and interviews with sellers of pharmacies and reputable cosmetics stores in provincial centers, a list of the popular brands of this product was prepared, including 5 brands of depilatory creams and 2 brands of depilatory powder. Due to the availability of these brands in Kashan, the center of Iran, all samples were collected from this city. To increase the accuracy of work, 3 samples from each brand were randomly selected from different product packages and transferred to the chemistry laboratory of the Faculty of Health of Kashan University of Medical Sciences at room temperature and without storage in special conditions.

Quality assurance (QA)/control (QC)

All chemicals used in this study were of analytical grade and purchased from Merck (Darmstadt, Germany). Nitric acid (65% HNO_3) and hydrochloric acid (37% HCl) were used to digest the samples. The accuracy was checked via the recovery test. First, the pure substance of each element was prepared, and then stock solutions were prepared for all six elements. Concentration-absorption curves of each element were performed at 3 concentrations of 300, 700, and 1000 μg/L. Based on the absorbance reading of each element in the unknown sample and the standard curve, the concentrations of elements in the samples were determined. The reference material (EnviroMAT Drinking Water, High (EP-H); Quebec, Canada) was used to evaluate the analytical process. To avoid sample contamination and increase the accuracy of results, all required glass and plastic containers were soaked in 20% HNO_3 solution for 24 h and rinsed with deionized water, and used after drying.

Method validation

In the analytical procedure, the limit of detection (*LOD*) was considered as the lowest amount of analyte, which can be quantified with a known degree of reliability. In contrast, the limit of quantitation (*LOQ*) refers to the concentration at which quantitative results can be produced at a sufficient amount of confidence. *LOD* and *LOQ* were determined using a statistical approach based on measuring replicate blank samples or through the measurement of progressively dilute concentrations of the analyte (Armbruster et al. 1994).

Two samples were used to analyze the recovery of each element. The first sample (*A*) contained 25 g/mL of each element's standard solution, and the second sample (control one) (A_1) was cleared out and unspiked. A_1 is the same blank sample that has no analytes. Two parts were independently taken by a similar process which will be mentioned later for sample digestion. Both samples were separately acid digested and finally analyzed using inductively coupled plasma optical emission spectrometry (ICP-OES). These two samples' acid digestion and analysis methods were the same as the samples of depilatory products. The recovery percentage (*%R*) of the studied elements was regulated compared to each element's concentration values from the spiked and unspiked samples utilizing Eq. 1 (Miranzadeh et al. 2021).

$$\%R = \frac{A - A_1}{B} \quad (1)$$

where *A* is the trace element concentration in the spiked sample, A_1 is the trace element concentration in the unspiked sample, and *B* is the amount of trace element utilized for spiking.

The respective wavelength, recovery percentage values (*R %*, *RSD %*), *LOD*, and *LOQ* for the heavy metals experimentally determined using ICP-OES are shown in Table 1. The heavy metals' recovery percentage was from 89.31 to 98.99%, which were considered acceptable values.

Sample preparation

Solid and powdered samples were first placed in an 80 °C oven for 12 h to reach a constant dry weight. Finally, 1 g of each dried sample was acid digested. Depilatory cream samples could not be easily processed by drying, so they were directly digested as wet.

Digestion

One gram of any sample was transferred into a beaker containing 20 mL of a 1:3 ratio of the acid mixture (HNO_3:HCl), and after mixing completely, it was given 15 min to pre-digest. The beakers were then placed on a hot plate at 100 °C to digest. This was continued until the sample size reached one-fifth of the original volume. Then, removing the beakers from the hot plate, and after cooling, the contents of the beakers were filtered with Whatman No. 42 filter paper. Finally, the volume of the filtered sample was increased to 50 mL using deionized water (Baird 2017).

Measurement of elements

The measurements of Pb, Cr, Cd, Zn, Co, and As in all samples were performed by ICP-OES (Perkin Elmer Optima 2100 DV model, USA). The power of this device was 1300 W to generate radio frequency, plasma gas flow rate of 15 L/min, the auxiliary gas flow rate of 0.2 L/min, and nebulizer gas flow of 0.8 L/min. The concentrations of mentioned heavy metals in all samples were measured based on the standard curve, and the results were reported in mg/kg.

Health risk assessment

Toxic metals can enter the human body mainly through three pathways: ingestion, inhalation, and dermal contact, and cause carcinogenic and non-carcinogenic health risks. In the present study, the dermal-only contact method was considered to assess the health risk associated with the regular use of depilatory products. The average daily exposure to heavy metals was determined using chronic daily intake (CDI) (mg/(kg day)), and the dose received through dermal routes was calculated by Eq. 2 (USEPA 2011).

$$CDI_{\text{derm}} = \frac{C \times SA \times AF \times ABS \times EF \times ED}{BW \times AT} \times CF \quad (2)$$

Table 1 Recovery, *LOD*, and *LOQ* for six target elements

Element	Wavelength (nm)	*R%*	*RSD%*	*LOD* (mg/kg)	*LOQ* (mg/kg)
Pb	220.353	91.25%	5.45%	0.042	0.12
Cd	228.802	98.99%	6.65%	0.0027	0.01
Zn	213.857	91.41%	6.32%	0.0018	0.016
Co	228.616	89.31%	7.58%	0.007	0.02
Cr	267.716	97.55%	3.86%	0.0071	0.069
As	228.812	94.23%	5.84%	0.083	0.06

where C is the heavy metal concentration in depilatory powder and cream (mg/kg); SA is the exposed skin area (cm^2). In this study, SA is calculated for total body area (17,500 cm^2); AF is the adherence factor (0.07 mg/cm^2); ABS is the dermal absorption factor (unit less); EF is the exposure frequency (24 days/year); ED is the exposure duration (30 years); CF is unit conversion factors (10^{-6} kg/mg); BW is the body weight (70 kg); AT is the averaging time for non-carcinogen effects: ED×365 (day); AT is the averaging time for carcinogen effects: 365×70 (day).

In general, the hazard quotient (HQ) describes the non-carcinogenic risk calculated by Eq. 3.

$$HQ = \frac{CDI}{RfD_{\text{derm}}} \quad (3)$$

where RfD_{derm} is the absorbed reference dose (for dermal exposure, mg/(kg day)). Its value could be calculated from the value of oral reference dose, RfD_{O} using Eq. 4.

$$RfD_{\text{derm}} = RfD_{\text{O}} \times ABS_{\text{GI}} \quad (4)$$

where RfD_{O} is the oral reference dose (mg/(kg day)) and ABS_{GI} is the gastrointestinal absorption factor (unitless).

Equation 5 was used to estimate the hazard index (HI). HI has been proposed to assess the overall risk of non-cancerous health effects from exposure to several heavy metals and/or different exposure pathways (USEPA 1989).

$$HI = \sum HQ = HQ_{\text{Pb}} + HQ_{\text{Cd}} + HQ_{\text{Zn}} + HQ_{\text{Co}} + HQ_{\text{Cr}} + HQ_{\text{As}} \quad (5)$$

When HQ and HI levels are less than 1, there is no potential risk to consumers, but if these levels are more than one, there may be concerns about potential non-carcinogenic effects (USEPA 2004).

Equation 6 was used to calculate the LCR (lifetime cancer risk). LCR is determined by calculating the probability of developing cancer over a lifetime due to exposure to carcinogens. Slope factor (SF) indicates the maximum carcinogenicity in people who have been exposed to specific doses of toxins (USEPA 1989).

$$LCR = CDI \times SF_{\text{derm}} \quad (6)$$

where CDI is the chronic daily intake (mg/(kg day)) and SF_{derm} is the carcinogenicity slope factor (for dermal exposure, mg/(kg day)). The SF_{derm} is determined by the Eq. 7.

$$SF_{\text{derm}} = \frac{SF_{\text{O}}}{ABS_{\text{GI}}} \quad (7)$$

where SF_{O} is the oral SF (mg/(kg day)).

According to the US EPA, an LCR of more than $1{\times}10^{-4}$ is considered an unacceptable risk, and a tolerable risk has been reported between 1×10^{-4} and 1×10^{-6}. Values less than $1{\times}10^{-6}$ are not considered as significant health effects.

The required parameters to calculate the health risk of exposure to the studied elements are shown in Table 2. Because SF_{O} levels were not available for cobalt and zinc, the carcinogenic risk assessment for these two metals was not calculated.

Statistical analysis

For statistical analysis of obtained results, SPSS software version 22 was used. Mean ± SD was used to describe the data, and t test, Mann-Whitney, one-way analysis of variance, Kruskal-Wallis, and post hoc Tukey test were used to investigate the differences among the heavy metal concentrations according to the type of product, brand, country of production, and product price. The significance level was considered less than 0.05.

Results and discussion

The results showed that the concentrations of studied heavy metals in depilatory powders and creams are Pb>Zn>Cr>As>Cd>Co, respectively. The concentrations of Cd (0.72±0.06 mg/kg), Co (0.17±0.05 mg/kg), Cr (2.65 ±0.24 mg/kg), and As (2.17±0.37 mg/kg) in depilatory powders are higher than in cream-type samples (Table 3). The results of statistical tests indicate a significant relationship among the concentrations of Cd, Cr, and As with the product type. Using depilatory powders is widely used in Asian countries, including India (Farzaneh et al. 2011, Klein and Rish 1988, Mehrpour &Abdollahi 2012). Studies showed that most cosmetic products made in India contain significant amounts of As (ALqadami et al. 2013; Salama 2016). Though using toxic elements such as As in cosmetics is prohibited (Kohli 2017), many studies have proven the presence of these elements in cosmetics (Ababneh and Al-Momani 2018; Bund 2017; Li et al. 2015; Mohiuddin 2019).

The concentration of heavy metals in all samples of depilatory cream was less than standard values (20 mg/kg). Furthermore, Pb (5.46±2.30 mg/kg) and Co (0.16±0.69 mg/kg) had the highest and lowest concentrations among all samples, respectively (Table 3). Heavy metals can be found as preservatives or as residual contaminants in the raw materials of cosmetics. For example, compounds containing Pb (white lead) are used to exfoliate and whiten the skin (Burger et al. 2016; Lim et al. 2018). Heavy metals can be detected in samples of eye and face cosmetics, toothpaste, and lipsticks (Li et al. 2015). Vella and Attard (2019) reported that the presence of Pb in toothpaste exceeded the standard of the USA and the European Union (Vella and Attard 2019). In addition to industrial cosmetics, products that are traditionally produced also contain significant amounts of heavy metals. The results

Table 2 Oral and dermal adsorbed reference doses (RfD_o and RfD_{derm}), the fraction of contaminant absorbed in gastrointestinal tract (ABS_{GI}), the dermal absorption fraction for a given metal (*ABS*), and oral and dermal slope factor (SF_o and SF_{derm}) (USEPA 2020)

Metal	RfD_O (mg/kg day)	ABS_{GI}	RfD_{derm} (mg/kg day)	$ABS^{b,c}$	SF_O (mg/kg day)[d]	SF_{derm} (mg/kg day)
As	0.0003	1.0	0.0003	0.03	1.5	1.5
Cd	0.0005	0.025	0.0000125	0.001	6.7	268
Co	0.0003	1.0	0.0003	0.001	-	-
Cr	1.5	0.013	0.0195	0.001	0.5	38.46154
Pb	-	-	0.04[a]	0.001	0.0085	0.0085
Zn	0.3	1.0	0.3	0.001	-	-

[a] (USEPA 2015)

[b] (Cao et al. 2014)

[c] (Jiang et al. 2020)

[d] (Lim et al. 2018)

of studies showed that Kohl (surma) (Gupta et al. 2021; Lim et al. 2017), Tiro, a cosmetic similar to kohl in Nigeria (Boisa 2016; Schwarcz et al. 2013), Sindoor corrective powder used in Hindu religious and cultural ceremonies (Shah et al. 2017), and henna (Yahya et al. 2021) have dangerous levels of Pb. According to studies, the concentration of Pb in cosmetics is directly related to the blood lead level of consumers (Goswami 2013). High concentrations of this toxic element can cause severe damage to the brain and kidneys, increase mortality in pregnant women, abortion (Al Jameil 2014; Bakhireva et al. 2013; Taylor et al. 2015), and decrease fertility in men (Rehman et al. 2018; Wani et al. 2015). Zinc oxide (ZnO) is an inorganic compound used as a sunscreen (Kim et al. 2017). The symptoms of Zn poisoning were reported to be very similar to lead poisoning and can easily be identified as lead poisoning (Martin et al. 2004). Besides, some heavy metals such as Co and its salts are used as coloring agents in cosmetics and light brown hair dyes (Fischer et al. 2017), which due to the non-color of the depilatory products, the low concentration of the element Co is expected.

The results of the analysis with Kruskal-Wallis statistical tests and one-way analysis of variance showed that even though the amounts of Pb, Cd, Cr, and Co in brand # C5 are higher than other brands, only Cr concentration in different brands of depilatory cream is significantly different ($p = 0.003$). The results of post hoc Tukey test also showed that the concentration of Cr in brand # C5 with brand # C1 ($p = 0.007$), brand # C2 ($p = 0.009$), brand # C3 ($p = 0.007$), and brand # C4 ($p = 0.004$) is significantly higher. Cr is one of the most widely used heavy metals in cosmetics (Ideriah et al. 2016; Odukudu et al. 2014; Orisakwe et al. 2016). Lim et al. (2018) evaluated the concentration of heavy metals in 14 types of cosmetic products. The results of this study showed that Cr was present in most of the samples. Moreover, this element's highest and lowest concentrations were found in facial make-up and body lotion, respectively (Lim et al. 2018).

Among the samples of depilatory cream collected, 3 samples were made in France, and 12 samples are made in Iran. Although the concentration of heavy metals in products made in Iran is higher than products made in France, this difference was not significant (Table 4). Furthermore, the concentrations

Table 3 Average concentration of potentially toxic metals in depilatory products by product type (mg/kg)

Element	Cream				Powder				*p* value**
	N	Min	Max	Mean±SD	*N*	Min	Max	Mean ±SD	
Pb*	15	3.55	12.95	5.46±2.30	6	4.45	5.05	4.85±0.21	0.68
Cd	15	0.25	0.9	0.39±0.19	6	0.65	0.8	0.72±0.06	0.001
Zn	15	1.05	12	3.06±2.88	6	2	4.3	2.85±0.92	0.87
Co	15	0.1	0.35	0.16 ±0.069	6	0.1	0.25	0.17±0.05	0.72
Cr	15	1.2	2.85	1.53±0.48	6	2.4	2.95	2.65±0.24	<0.001
As	15	0.9	1.4	1.11±0.17	6	1.75	2.7	2.17±0.37	0.001

* Based on Mann-Whitney analysis and other variables based on *t* test

** Significance level: $p<0.05$

Table 4 Distribution of potentially toxic metal concentrations of depilatory products by studied variables (mg/kg)

Product type	Variable		Target element					
			Pb	Cd	Zn	Co	Cr	As
Cream	**Brand** (Mean±SD)	**Brand C1**	4.21±0.61	0.28±0.02	2.28±1.70	0.13±0.028	1.33±0.07	1.08±0.07
		Brand C2	4.01±0.20	0.26±0.02	2.88±2.05	0.15±0.05	1.38±0.02	1.18±0.22
		Brand C3	6.36±0.75	0.55±0.21	6.33±5.16	0.16±0.05	1.35±0.08	0.93±0.05
		Brand C4	4.78±0.25	0.31±0.02	2.28±1.74	0.11±0.02	1.25±0.05	1.23±0.17
		Brand C5	7.91±4.44	0.55±0.30	1.51±0.02	0.25±0.1	2.35±0.58	1.15±0.18
		Total	5.46±2.30	0.39±0.19	3.06±2.88	0.16±0.69	1.53±0.48	1.11±0.17
		p* value	0.07	0.14	0.29	0.13	0.003	0.24
	Country (Mean±SD)	**France**	4.21±0.61	0.28±0.02	2.28±1.70	0.13±0.02	1.33±0.07	1.08±0.07
		Iran	5.77±2.48	0.42±0.21	3.25±3.14	0.17±0.07	1.58±0.53	1.12±0.18
		p* value	0.17	0.292	0.621	0.422	0.443	0.720
	Price Pearson correlation (*p* value)		0.07 (0.8)**	0.06(0.82)	-0.31(0.25)	0.02(0.93)	0.05(0.84)	0.09(0.74)
Powder	**Brand** (Mean±SD)	**Brand P1**	4.9±0.13	0.76±0.02	3.63±0.58	0.21±0.28	2.86±0.10	1.85±0.1
		Brand P2	4.8±0.30	0.68±0.05	2.08±0.07	0.13±0.02	2.45±0.08	2.5±0.18
		Total	4.85±0.21	0.72±0.06	2.85±0.92	0.17±0.05	2.65±0.24	2.17±0.37
		p* value	0.83	0.09	0.04	0.024	0.006	0.005
	Price Pearson correlation (*p* value)		0.098(0.854)***	0.738(0.094)	0.878***(0.21)	0.905***(0.013)	0.891***(0.017)	0.87***(0.021)
	ISIRI (ISIRI 2003)		**< 20**	**< 20**	**< 20**	**< 20**	**< 20**	**< 2**

* Significance level: $p<0.05$

** Based on Spearman correlation

*** Correlation is significant at the 0.05 level (2-tailed)

of heavy metals (Pb, Zn, Cr, Co, and Cd) in foreign and Iranian products are less than the values recommended (20 mg/kg) by the ISIRI. In a study, Zafarzadeh et al. (2018) evaluated the concentration of lead and cadmium in 11 types of cosmetics made in different countries in Iran. The results of this study showed that the highest mean concentrations of Cd and Pb were found in cosmetics made in China followed by Iran and Turkey. In contrast, French and German products had the lowest concentration of elements (Zafarzadeh et al. 2018), which was consistent with the present study results. Moreover, similar results were found in the Gunduz and Akman study, which showed the highest levels of lead in products made in China and Taiwan and the lowest levels in products made in the United States and France (Gunduz and Akman 2013). The cost of buying depilatory creams ranged from $ 1 to $ 3. The results of Pearson correlation indicate that the price of the product has no significant relationship with the concentrations of these heavy metals which is in line with the results of the study of Sani et al. (Sani et al. 2016). Moreover, Al-saleh et al. (2009) and Gondal et al. (2010) reported that high levels of Cd and Pb in low-cost products belong to Chinese and Indian companies (Al-Saleh et al. 2009; Gondal et al. 2010). Meanwhile, Al-Qahtani et al. (2016) examined the relationship between the content of heavy metals in cosmetics at different prices in a study and concluded that there is no significant difference between the concentration of heavy metals and the price of lipstick (Al-Qahtani et al. 2016). Therefore, the results of a study conducted in Malaysia indicate a significant relationship between lead content and the price of lipstick samples, but such a result was not observed for Cr and Cd (Zakaria and Ho 2015).

The results of a one-sample *t* test indicate that the concentration of As in different brands of depilatory cream is significantly less than the recommended limit of 2 mg/kg. Therefore, these products contain safe levels of As.

The results also indicate a significant relationship between the brand type of depilatory powders and the concentration of heavy metals, and in general, the concentrations of these elements in brand # P1 were higher than brand # P2 (Table 4). The present study showed a direct and significant relationship between the price of depilatory powders and the concentration of elements which means that with increasing prices, the concentration of heavy metals in these products also increases, but in general, these values did not exceed the standard. This is consistent with the study by Ahmed et al. (2017) on the concentration of As in eye shadows (Ahmed et al. 2017). Sani et al. (2016) also achieved similar results (Sani et al. 2016). Due to the fact that all brands of depilatory

Table 5 The HQ and HI calculated for depilatory products

Product type	Brand	HQ						HI
		Pb	Cd	Zn	Co	Cr	As	
Cream	**C1**	1.21E−07	2.58E−05	8.75E−09	4.99E−07	7.85E−08	1.24E−04	1.51E−04
	C2	1.15E−07	2.39E−05	1.10E−08	5.75E−07	8.14E−08	1.36E−04	1.60E−04
	C3	1.83E−07	5.06E−05	2.43E−08	6.14E−07	7.97E−08	1.09E−04	1.61E−04
	C4	1.38E−07	2.85E−05	8.75E−09	4.22E−07	7.38E−08	1.42E−04	1.71E−04
	C5	2.28E−07	5.06E−05	5.79E−09	9.59E−07	1.39E−07	1.32E−04	1.84E−04
Powder	P1	1.41E−07	7.00E−05	1.39E−08	8.05E−07	1.69E−07	2.13E−04	2.84E−04
	P2	1.38E−07	6.26E−05	7.98E−09	4.99E−07	1.45E−07	2.88E−04	3.51E−04

powder in question were made in Iran, the relationship among the concentrations of heavy metals in terms of the manufacturing country was not raised in this case.

The statistical test showed that the concentration of As in the top-selling brands of depilatory powder is significant, and brand # P2 contains significantly more As than the standard value (2 mg/kg). Arsenic was negatively known as a "king of poisons" for centuries due to its colorless, odorless, and tasteless properties (Akhtar et al. 2017; Frith 2013). So far, many studies have proven the presence of this element in various cosmetic products including depilatory products (Mohammed et al. 2017; Ozakın et al. 2013); due to using depilatory powders for suicidal purposes, arsenic was removed and replaced with calcium thioglycolate (Farzaneh et al. 2011; Ozakın et al. 2013).

Tables 5 and 6 present the calculated non-carcinogenic and carcinogenic risk values for depilatory products, respectively. Based on the results, the highest *HQ* values for arsenic were observed in the depilatory powder samples, but in general, the *HQ* and *HI* values for all samples were much less than 1, indicating no potential non-carcinogenic risk to consumers. In addition, the calculated values of carcinogenic risk for all elements were less than the allowable limit stated in the instructions (one person per million), which indicates that carcinogenicity of these metals is not possible in the studied samples (Table 6). Heavy metal health risk assessment of cosmetics sold in Iran showed that HI was less than 1 in 80% of samples (Ghaderpoori et al. 2020). Shomar and Rashkeev (2021), in a study, evaluated the risk assessment of toxic elements in an international brand of face foundation powders (Shomar and Rashkeev 2021). The results of this study indicate that the calculated *HI* for all considered samples is much lower than 1. Alam et al. (2019) also achieved similar results in examining the heavy metals' concentration in beauty creams and its health risk assessment (Alam et al. 2019), consistent with the present study.

Conclusion

This study's results showed that all samples of depilatory powder and creams examined contained heavy metals Pb>Zn>Cr>As>Cd>Co, respectively. The concentration of elements found in depilatory cream samples was less than depilatory powder samples and within the allowable range recommended by the ISIRI. Thus, the concentration of heavy metals in depilatory products made in Iran was higher than in products made in France. The concentration of elements and the price of depilatory powders have a significant relationship which means that as the price of the product increases, the

Table 6 The *LCR* calculated for depilatory products

Product type	Brand	LCR					
		Pb	Cd	Zn	Co	Cr	As
Cream	**C1**	1.76E−11	3.70E−08	-	-	2.52E−08	2.39E−08
	C2	1.68E−11	3.43E−08	-	-	2.61E−08	2.61E−08
	C3	2.66E−11	7.26E−08	-	-	2.56E−08	2.10E−08
	C4	2.00E−11	4.09E−08	-	-	2.37E−08	2.72E−08
	C5	3.31E−11	7.26E−08	-	-	4.45E−08	2.55E−08
Powder	P1	2.05E−11	1.00E−07	-	-	5.42E−08	4.10E−08
	P2	2.01E−11	8.98E−08	-	-	4.64E−08	5.54E−08

concentration of heavy metals in it increases. In addition, the concentration of As in one of the brands of depilatory powder is above the standard (2 mg/kg). The results of carcinogenic and non-carcinogenic risk assessments in depilatory products showed that both *HI* and *LCR* indices were lower than the recommended limits in the guidelines, which indicates that these products are safe to use. However, heavy metals can pose a risk to human health because they are widely used in cosmetics every day and accumulate and concentrate in the human body.

This study showed that even though the statement "this product is free of arsenic and any other toxic elements" is inserted on the packaging of depilatory powders, some heavy metals and As were found in these compounds. Therefore, you should be cautious of the continuous use of depilatory powders. Regular monitoring of toxic metals in depilatory products, along with increasing public awareness, is essential to ensure a level of public health protection.

Author contribution MM: investigation, sample preparation and analysis, data curation and analysis, writing original draft, formal analysis methodology, review & editing. NM: writing, review, and editing. GRM: sample analysis, review, and editing. FA: statistical analysis, review, and editing. MBM: review and editing. RD: supervision, writing original draft, data analysis, review, & editing.

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Availability of data and materials The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability Not applicable.

Declarations

Ethics approval This research project was approved by the ethics committee of Kashan University of Medical Sciences. The ethics code of this study was IR.KAUMS.NUHEPM.REC.1399.009.

Consent to participate Not applicable (The manuscript does not report on or involve the use of any animal or human data or tissue).

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Conflict of interest The authors declare no competing interests.

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