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Hidden Formaldehyde Content in Cosmeceuticals Containing Preservatives that Release Formaldehyde and Their Compliance Behaviors: Bridging the Gap between Compliance and Local Regulation

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Abstract: Background: Many personal care products, and particularly cosmetic products, contain preservatives that release formaldehyde. These are potentially harmful to consumer health, especially considering that the levels of formaldehyde in some products are hidden and excessive. Objectives: To study the formaldehyde levels of preservatives in personal care products and cosmetics on the UAE market and determine the extent of compliance with health and safety requirements. Methods and Materials: Sixty-nine personal care and cosmetic product samples from the UAE market were collected and prepared to determine their formaldehyde content. According to the Second European Commission Directive 82/434/EEC of 2000 and as per the Gulf Technical Regulation, Safety Requirements of Cosmetics and Personal Care Products in GSO 1943:2016, quantitative analyses were performed to identify and quantify the content of formaldehyde as free formaldehyde. Results: With a maximum permissible limit of ≤0.2% *w*/*w*, the average formaldehyde content was found to be 0.083 with a 95% CI (0.039–0.13). Nine of the tested personal care and cosmetic products exceeded the recommended formaldehyde level, corresponding to 13% of all samples. None of these samples listed the free formaldehyde content or formaldehyde releaser. Conclusion: Applying good manufacturing practices (GMP), education, and regulatory control to improve the regulation and inspection of cosmetics containing formaldehyde releasers as preservatives, conducting research, and reporting the adverse side effects are highly recommended. There is an urgent need to monitor the incidence of skin sensitivity resulting from the use of cosmetics containing formaldehyde releasers as preservatives.

Keywords: formaldehyde releaser; contact allergy; preservatives; compliance behavior

1. Introduction

Cosmetics and personal care products are common and intended to come into contact with the body's largest organ, the skin. Their purpose is often to clean certain body parts, to minimize body odor, to perfume the body, to keep the skin in optimal condition, to change the user's appearance, and/or

to protect the skin. Generally, antibacterial preservatives are added to cosmetic products to prevent spoilage and decomposition by microbial growth. Due to the bactericidal and fungicidal properties, free formaldehyde (FA) is one of the stronger choices to preserve cosmetic products. However, it is far from the only option that can serve this purpose. Through decomposition, a number of formaldehyde releasers or donors slowly release formaldehyde under typical use conditions [1].

Formaldehyde tends to cause contact allergies; between 2–3% of European patients believed to suffer from contact dermatitis react positively to patch tests for allergies. The US reported sensitization prevalence rates of 8–9% in its patients. Formaldehyde often causes chronic allergic dermatitis, presumably because completely avoiding exposure to the allergen is difficult [2]. Unfortunately, many preservatives releasing formaldehyde used in cosmetics are also skin sensitizers. A person is likely to react to all formaldehyde releasers once he/she has become sensitized to them [3]. Concomitant allergic reactions are frequently observed when testing with formaldehyde and one or more formaldehyde releasers are activated.

In some cases, multiple releasers react in formaldehyde-sensitive patients even in the absence of a structural relation. There can also be sensitization to some releasers independent of the release of the chemical itself. Recently, research reported that, on average, between 40 and 60% of the reactions to formaldehyde donors are caused by reaction to formaldehyde. The connection with formaldehyde contact allergies was even less pronounced for 2-bromo-2-nitropropane-1,3-diol at only 15% *w*/*w* [4]. We can conclude that formaldehyde is likely the most prevalent factor behind concomitant allergic reactions between formaldehyde and its releasers. At the same time, this cannot explain why some patients are not allergic to formaldehyde, only to some releasers [3].

Formaldehyde and formaldehyde-releasing preservatives (FRPs) are used in many personal care products, particularly in shampoos and liquid baby soaps. These chemicals aid in preventing microbe growth in water-based products; however, they absorb into the skin and can create cancer and allergic skin reactions. They are found in nail polish, nail glue, eyelash glue, hair gel, hair-smoothing products, baby shampoo, body soap, body wash, color cosmetics, and personal care products. Formaldehyde can be added directly, or more often, it can be released from preservatives, such as quaternium-15, DMDM hydantoin, imidazolidinyl urea, diazolidinyl urea, polyoxymethylene urea, sodium hydroxymethylglycinate, bromopol, and glyoxal. These preservatives release small amounts of formaldehyde over time. Even low levels of formaldehyde can cause health concerns at levels as low as 250 parts per million. Even lower levels can cause sensitiveness in individuals; therefore, the slow release of small amounts of formaldehyde is also of concern [5–7].

For all these reasons, restrictions on exposure to formaldehyde have been imposed in the EU and GSO [8]. The use of free formaldehyde as a preservative in all cosmetic products is allowed (a maximum of 0.2% *w*/*w* concentration except in oral hygiene products, for which the maximum is 0.1% *w*/*w*), with the exception of aerosol cosmetics. According to Annex VI of the Cosmetics Directive 76/768 EC and Gulf Technical Regulation for Safety Requirements of Cosmetics and Personal Care Products (GSO 1943:2016), all finished products containing formaldehyde or its releasers must list the warning 'contains formaldehyde' on the label when the concentration of free formaldehyde in the finished product is over 0.05% *w*/*w* [9].

It is critical for consumers suffering from any kind of dermatitis or an allergy to formaldehyde to be aware of the risk of exposure to the chemical to avoid the occurrence of allergic contact dermatitis (ACD). As the presence of formaldehyde cannot be determined from the ingredient labelling with any degree of certainty, consumers allergic to formaldehyde can reasonably be expected to encounter difficulties in attempting to avoid all contact with products containing it [10]. The aim of the present investigation is to study the formaldehyde levels of preservatives in personal care products and cosmetics on the UAE market and determine the extent of their compliance with health and safety requirements.

2. Methods and Materials

2.1. Sample Collection (Sampling Method)

Local business directories containing information on all the healthcare retailers, pharmacies, and para-pharmacies in the UAE were searched to identify outlets selling cosmetics and personal care products. A total of 2183 outlets was found. A sampling framework with all the information required was created in an Excel spreadsheet, including addresses, emails, phone numbers, and business names. Then, a study sample was created using basic random sample selection based on the business ID numbers. Stratification was applied based on the location and type of cosmetic.

The main selection criterion was the cosmetic or personal care product label, which contained formaldehyde donors, such as quaternium-15 (QU), diazolidinyl urea (DU), imidazolidinyl urea (IU), 2-bromo-2-nitropropane-1,3-diol (bronopol, BP), and dimethyloldimethyl hydantoin (DMDM). Regardless of where the cosmetic and personal care products had been manufactured, the random selection of one package was made in each selected location. To avoid duplication and enable tracking, every item was provided with a code reference number.

The following details were recorded for every sample: brand name, product name, item category and subcategory, country of origin/manufacturer, dose form, barcode, batch number, size/volume, location of the shop where the item was picked, and the recommended dose. If the same product was available at more than one outlet (same name, formulation, manufacturer, barcode, and size/volume), the first-picked product was tested, while the others were returned. Products with the same names but different manufacturers or in different textures (e.g., both cream and blend) were treated as different products and underwent separate testing. All the selected products were sent for analysis to a laboratory on the same day they were collected.

2.2. Reagents

All reagents should be of analytical purity, deionized water, HPLC-grade acetonitrile, 5N Ortho-phosphoric acid prepared from stock 85% with deionized water, CRM-grade Formaldehyde (1000 mg/L) solution, and 1 mg/mL of 2,4-Dinitrophenylhydrazine (DNPH) solution prepared in acetonitrile from DNPH salt.

2.3. Apparatus and Materials

Agilent (USA) HPLC consisting of 1260 infinity series, a Diode Array Detector (DAD), and Open lab-Chemstation software with Zorbax Eclipse C-8 column (150 mm × 4.6 mm, 5 µL) having part number 699975-902 with a 10 µL sample loop, analytical balance, centrifuge, micropipette (100–1000 µL), sonicator, 0.45 µm nylon syringe filters, 20 mL test tubes with cap, and 10 mL volumetric flasks. The following are the materials used in the sample analysis with origin of purchasing, company, and country.

- HPLC consisting of 1260 infinity series, a Diode Array Detector (DAD), and Open lab-Chemstation software, 3000 hanover, Palo Alto, CA, USA.
- Zorbax Eclipse C-8 column (150 mm × 4.6 mm, 5 µL) having part number 699975-902 with a 10-µL sample loop, Make: Agilent, 3000 hanover, Palo Alto, CA, USA.
- Analytical balance, max 200 g range, Make: Sartorius, Germany.
- Centrifuge, Max 12000 rpm, Make: Hamilton, Reno, NV, USA.
- Micropipette (100–1000 µL), Make: Transpette, Goettingen, Germany.
- Sonicator, Make: Qualilife, Shanghai, China.
- 0.45 µm nylon syringe filters, Make Biomed Scientific Ltd., Guangdong, China.
- 20 mL test tubes with cap Make Tarsons, Kolkata, India.
- 10 mL volumetric flasks Make: Gulf scientific glass, Al Hidd, Bahrain.

2.4. Sample Preparation

We placed approximately 1× *g* of homogenous sample into a 10 mL stoppered flask, added 10 mL of acetonitrile, sonicated to complete disintegration, and then cooled to room temperature. We separated the two phases by centrifuging (3000 rpm).

2.5. Derivatization Reaction

We pipetted out 1 mL of the blank, standards, and samples into individual 20 mL glass test tubes. To each test tube, we added 0.2 mL of 5N orthophosphoric acid, added 1 mL of 1 mg/mL DNPH solution, vortexed, and kept these tubes for 30 min at room temperature. We added 1 mL of acetonitrile to all tubes. After being shaken, the sample was filtered through a filter with a pore size of 0.45 µm before injection into the HPLC system.

2.6. HPLC Quantitative Analysis of Free Formaldehyde

RP-HPLC analysis was performed with the Agilent 1260 Infinity series HPLC system, including a diode array detector. For formaldehyde quantification, the Agilent Zorbax Eclipse C8 column (150 mm × 4.6 mm, 5 µL) was used with an Acetonitrile: Water at 45:55 (*v*/*v*) solvent, UV absorbance was recorded at 360 nm. The chromatographic separation was achieved with isocratic elution (10 L of sample are injected into chromatographic system) at a flow rate of 1.0 mL/min and column temperature of 40 °C. The peaks of the determined formaldehyde were identified by their UV spectrum and by comparing the retention time with that of the standard.

2.7. Calibration

The linearity of the calibration curve was prepared between 3.0 and 100.0 mg/L, which was prepared from diluted formaldehyde stock solution of 1000 mg/L using acetonitrile as a diluent. We determined the peak area. The calibration curve was performed with the peak area Y and the concentration of solution X (mg/mL). The equation of linear regression and correlation coefficient R were obtained.

2.8. Method Validation and Detection Procedure

The detection and qualification limits, the range of linearity, and the precision of the method were determined. A series of solutions were prepared using the standard reference to reach concentrations from 3 to 100 mg/L. Based on the regression data of the slope and standard error, the limit of detection (LOD) and the limit of quantification (LOQ) were estimated. The limit of detection and limit of quantification values using this method were obtained as 10 mg/L and 30 mg/L, respectively. Method validation and quantification procedures were demonstrated by spiking with six individual spiked solutions at concentrations, including the LOQ and medium and high levels from the calibration concentrations. In this method validation, formaldehyde was spiked at 30 mg/L, 200 mg/L, and 1000 mg/L in skin care products were prepared and analyzed for each six spike levels. The Found % RSD not more than 10% and the % Recovery was 80 to 120% [11]. The method validation data and quantification data are mentioned in Table 1.

Table 1. %Recovery and %RSD values.

Spiked Level	Amount Spiked (mg/L)	Amount Recovered (mg/L)	% Recovered	% RSD
Limit of Quantification (LOQ)	30	27	90.0	8.72
Medium Level Spike	200	196	98.0	1.74
High Level Spike	1000	973	97.3	1.69

2.9. Ethical Consideration

The study was approved by the Institutional Review Board of An-Najah National University, reference number (Phd/3/20/2).

2.10. Statistical Analysis

The data were analyzed using SPSS version 24 Chicago, IL, USA. The qualitative variables were summarized using percentages. The formaldehyde content (% *w*/*w*) of each product was calculated, and comparisons were made based on European and GSO guidelines. The maximum allowed concentration in all finished cosmetic products containing formaldehyde or its releasers was 0.2% *w*/*w* (2000 ppm). In addition, all finished products containing formaldehyde or its releasers had to list the warning "contains formaldehyde" on the label in case the concentration of free formaldehyde in the finished product was more than 0.05% *w*/*w* (500 ppm). The Kruskal–Wallis test was used to compare the median values of the formaldehyde contents. Comparisons with a p value < 0.05 were considered statistically significant.

3. Results

3.1. Sample Description

A total of 69 cosmetics and personal care products were analyzed in this study. Of the 69 samples, 12 (17.4%) were body care preparations, five (7.2%) were face and neck preparations, and 52 (75.4%) were hair and scalp products. Regarding the country of origin, six (8.7%) were manufactured in Brazil, eight (11.6%) in China, 23 (33.3%) in the EU, nine (13.0%) in India, nine (13.0%) in the Middle East, seven (10.1%) in the United Arab Emirates, and seven (10.1%) in the United States (Table 2).

Table 2. The number and percentages of cosmetics products (n = 69).

Characteristics	Groups	Frequency	Percentage
Categories	Body Care Preparations	12	17.4%
	Face and Neck Preparations	5	7.2%
	Hair and scalp products	52	75.4%
Country of origin	Brazil	6	8.7%
	China	8	11.6%
	EU	23	33.3%
	India	9	13.0%
	Middle East	9	13.0%
	United Arab Emirates	7	10.1%
	United States	7	10.1%

3.2. Assessment of the Formaldehyde Content of the Cosmetics and Personal Care Products

Estimates of the mean concentrations with confidence intervals (CIs) and standard deviations of the formaldehyde content of the cosmetics and personal care products are summarized in Table 3. The estimated average formaldehyde content was 0.083 (95% CI [0.039–0.13]) compared to the maximum allowable limit of ≤0.2% *w*/*w*. Of the 69 tested cosmetics and personal care products, 9 (13%) exceeded the recommended formaldehyde level (≤0.2% *w*/*w*) Figure S1. The results of the formaldehyde content stratified by the sample characteristics of each sample are provided in Table 4. Supplementary Materials shows the chromatogram for the formaldehyde standard solution, chromatograph for formaldehyde in a sample product and the linearity plot of formaldehyde Figures S2–S4.

Table 3. Estimates of the concentration of formaldehyde from cosmetics and personal care products and the maximum allowable limit (n = 69).

Parameters	Maximum Allowable Limit	Products Exceeding the Maximum Limit		Estimates of Concentration (% *w*/*w*)				
		N	%					
				Mean	±SD	95% CI		Median
Formaldehyde	≤0.2% *w*/*w*	9	13%	0.083	0.18	0.039	0.13	0.021

Maximum allowable limits according to the EU regulation and GSO 1943:2016.

Table 4. List of tested cosmetics and personal care products according to the formaldehyde content and sample characteristics.

Sample Code	Cosmetic Category	Country of Origin	Formaldehyde Content (% *w*/*w*)
1	Hair and scalp products	India	0.94
2	Body Care Preparations	United Arab Emirates	0.046
3	Face and Neck Preparations	Middle East	0.021
4	Face and Neck Preparations	Middle East	0.021
5	Face and Neck Preparations	Middle East	0.021
6	Body Care Preparations	China	0.021
7	Body Care Preparations	China	0.021
8	Body Care Preparations	China	0.34
9	Face and Neck Preparations	EU	0.021
10	Hair and scalp products	EU	0.021
11	Hair and scalp products	EU	0.021
12	Hair and scalp products	EU	0.021
13	Hair and scalp products	EU	0.021
14	Hair and scalp products	China	0.021
15	Body Care Preparations	United Arab Emirates	0.003
16	Hair and scalp products	India	0.021
17	Hair and scalp products	Brazil	0.021
18	Hair and scalp products	Middle East	0.003
19	Hair and scalp products	United Arab Emirates	0.021
20	Hair and scalp products	Brazil	0.021
21	Hair and scalp products	EU	0.021
22	Body Care Preparations	EU	0.035
23	Hair and scalp products	EU	0.021
24	Body Care Preparations	Middle East	0.021
25	Hair and scalp products	EU	0.021
26	Hair and scalp products	EU	0.45
27	Hair and scalp products	EU	0.72
28	Hair and scalp products	EU	0.021
29	Hair and scalp products	EU	0.021
30	Hair and scalp products	India	0.021
31	Hair and scalp products	EU	0.021
32	Hair and scalp products	India	0.021
33	Face and Neck Preparations	EU	0.003
34	Hair and scalp products	Brazil	0.009
35	Hair and scalp products	Brazil	0.048
36	Hair and scalp products	United States	0.021
37	Hair and scalp products	United States	0.021
38	Hair and scalp products	EU	0.021
39	Hair and scalp products	Brazil	0.021
40	Hair and scalp products	EU	0.001
41	Body Care Preparations	United Arab Emirates	0.021
42	Body Care Preparations	China	0.021
43	Hair and scalp products	United States	0.0025

Table 4. *Cont.*

Sample Code	Cosmetic Category	Country of Origin	Formaldehyde Content (% *w*/*w*)
44	Hair and scalp products	United States	0.0025
45	Hair and scalp products	United States	0.0025
46	Hair and scalp products	EU	0.021
47	Hair and scalp products	India	0.021
48	Hair and scalp products	Brazil	0.021
49	Hair and scalp products	India	0.021
50	Hair and scalp products	EU	0.021
51	Hair and scalp products	United States	0.034
52	Hair and scalp products	United States	0.003
53	Hair and scalp products	India	0.021
54	Hair and scalp products	India	0.021
55	Hair and scalp products	EU	0.021
56	Hair and scalp products	EU	0.021
57	Hair and scalp products	EU	0.021
58	Hair and scalp products	United Arab Emirates	0.32
59	Body Care Preparations	India	0.021
60	Body Care Preparations	China	0.021
61	Hair and scalp products	United Arab Emirates	0.54
62	Hair and scalp products	United Arab Emirates	0.63
63	Hair and scalp products	China	0.031
64	Hair and scalp products	Middle East	0.021
65	Hair and scalp products	Middle East	0.021
66	Hair and scalp products	China	0.021
67	Body Care Preparations	EU	0.021
68	Hair and scalp products	Middle East	0.26
69	Hair and scalp products	Middle East	0.33

3.3. Comparison of Formaldehyde Content According to Sample Characteristics

Table 5 presents the distribution of the formaldehyde content according to sample characteristics. The table also provides the estimates along with *p*-values. These *p*-values were obtained from the results of the Kruskal–Wallis test.

Table 5. Comparison of the formaldehyde content according to the sample characteristics.

Sample Characteristics	Groups	Formaldehyde Content (% *w*/*w*)				
		N	Mean	Median	±SD	*p*-Value
Categories	Body Care Preparations	12	0.049	0.023	0.092	0.214
	Face and Neck Preparations	5	0.017	0.021	0.008	
	Hair and scalp products	52	0.097	0.026	0.203	
Country of origin	Brazil	6	0.024	0.023	0.013	0.129
	China	8	0.062	0.028	0.11	
	EU	23	0.069	0.029	0.17	
	India	9	0.12	0.051	0.32	
	Middle East	9	0.079	0.031	0.12	
	United Arab Emirates	7	0.23	0.046	0.27	
	United States	7	0.012	0.003	0.013	

p-value reported above for comparisons between variable level "category-levels" using the Kruskal–Wallis test.

Comparisons between the groups did not reveal any statistically significant differences in relation to the formaldehyde content.

Though not statistically significant, there was a tendency toward a higher formaldehyde content in the hair and scalp products (0.097% *w*/*w*) than in the body care preparations (0.049% *w*/*w*) and face and neck preparations (0.017% *w*/*w*). A tendency toward an increased formaldehyde content

was observed in products made in the United Arab Emirates (0.23% *w*/*w*), India (0.12% *w*/*w*), and the Middle East (0.079% *w*/*w*).

4. Discussion

Formaldehyde is difficult to avoid considering how often it is found in the environment. It is not always listed on product labels because it can stem from hidden sources of which manufacturers are not aware. Today, formaldehyde itself is very rarely used in cosmetics, but this is not true for preservatives that release it when they come into contact with water. These preservatives are widely used in many household products and topical medications as well. These preservatives are also known as formaldehyde releasers or formaldehyde donors [10]. The present study investigated formaldehyde released by personal care products and cosmetic preservatives on the UAE market to determine the extent of their compliance with health and safety requirements.

In our study, nine of the tested personal care and cosmetic products exceeded the recommended formaldehyde level (≤0.2% *w*/*w*), corresponding to 13% of all samples. The migration of formaldehyde from the plastic package, contaminated raw material, or degradation of surfactants in the final product could account for the higher levels of formaldehyde detected in the study. Alternatively, it could have been added intentionally [10].

An alarming finding of this study is that cosmetic products made in the Middle East, more specifically the United Arab Emirates, had an increased risk of formaldehyde contamination To complicate matters further, the formaldehyde content in all of the cosmetic products tested in the study and manufactured in this region exceeded the maximum of ≤0.2% *w*/*w* allowed in finished cosmetics products. Variations in the quality levels most likely account for the degree of noncompliance. These, in turn, can be due to the manufacturer's engagement in unethical practices and/or other failures to comply with good manufacturing practices (GMPs). It is necessary to address the technical challenges that undermine measurement and test accuracy. Manufacturers of cosmetics and personal care products need to ensure they comply with the specifications and conduct reliable tests to determine the content of formaldehyde. Where necessary, they should entrust a suitable laboratory with testing and certification.

The average formaldehyde content was found to be 0.083% *w*/*w* (830 ppm), which was among the more significant findings of this study. None of the tested cosmetic product labels indicated the presence of formaldehyde. This violates the health and safety requirements of the European Union. According to Directive 76/768/EC and GSO 1943:2016, all finished products with concentrations of free formaldehyde above 0.05% *w*/*w* (500 ppm) must be labeled with the warning "contains formaldehyde" [9,12–14].

Up to 30% of cosmetics products in Denmark and Sweden and approximately 20% of cosmetics in the USA are reported to contain formaldehyde releasers [15–17]. One study in Sweden showed that 48% of leave-on and 70% of rinse-off products containing free formaldehyde were not labelled accordingly [18]. Another study revealed that 5 of every 67 creams purchased in Denmark contained formaldehyde releasers, but this was not stated on the label [19].

Most of these products contained more than 0.004% *w*/*w* (40 ppm) formaldehyde, which is a high amount for consumers allergic to this chemical. According to US, EU, and GSO legislations, a maximum of 0.2% *w*/*w* (2000 ppm) of free formaldehyde concentration is allowed in cosmetics and household products [20]. However, even this level is sufficient to provoke ACD in those allergic to formaldehyde when applied on healthy skin [21]. Research also demonstrated that in cases where allergic individuals have irritant contact dermatitis, they are at risk if they use products even with low formaldehyde content (10–40 ppm) because their condition will become exacerbated [21].

Individuals may reasonably desire to avoid using cosmetic products containing formaldehyde or its releasers on damaged skin due to a compromised barrier function. Individuals who are allergic to formaldehyde should only use cosmetics packaged in glass, not plastic. No tests to check cosmetics for formaldehyde content are currently available to consumers [10].

For these and other reasons, a systematic investigation of the formaldehyde release in cosmetic products is highly desirable. Such research has been scarce to date, with the exception of a study on bronopol [22]. It is necessary to test formaldehyde-containing products more extensively to determine the level at which there is no risk of allergic contact dermatitis arising from single product use [2].

Further areas of concern include the absence of systematic data on the actual use concentrations of preservatives in personal care and cosmetic products, and the lack of information regarding the sensitization frequency to formaldehyde releasers in cosmetics on the UAE market. It is advisable to update the regulations for improving the compliance of cosmetics and personal care products by including the following measures.

1. Include accurate and reliable details of product ingredients on labels.
2. Implement a system to inspect and license manufacturing plants.
3. Implement laboratory-based analysis and testing procedures through an accredited laboratory applying standard methodology within a predetermined tolerance framework.

5. Conclusions

The effects of formaldehyde as a contact allergen are well documented. Applying good manufacturing practice (GMP), education, and regulatory control to improve the regulation and inspection of cosmetics containing formaldehyde-releasers as preservatives, conducting research, and reporting use and adverse side effects are highly recommended. There is an urgent need to monitor the incidence of skin sensitivity resulting from the use of cosmetics containing formaldehyde releasers as preservatives.

Supplementary Materials: The following are available online at http://www.mdpi.com/2079-9284/7/4/93/s1, Figure S1: Histogram of the estimated formaldehyde content (%) for cosmetics and personal care products (n = 69). The vertical dashed line is the maximum allowable limit of the formaldehyde according to EU regulations, Figure S2: Chromatogram of the standard at 20 mg/L, Figure S3: Chromatogram of the Sample spike at 20 mg/L, Figure S4: Linearity plot of formaldehyde.

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