

Nickel and cobalt release from beauty tools: a field study in the German cosmetics trade

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Conflicts of Interest: W.U. has received travel reimbursement for the participation in an IDEA project meeting. The other authors declare no conflict of interest.

Word count: 2.390 words

Table count: 3 tables

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process which may lead to differences between this version and the [Version of Record](https://doi.org/10.1111/cod.14107). Please cite this article as doi: [10.1111/cod.14107](https://doi.org/10.1111/cod.14107)

Figure count: 2 figures

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Abstract

Background: Relevant nickel and cobalt release from hairdressing tools has recently been evidenced. Comparable data are not available for tools used in beauty salons.

Objectives: Screening of beauty tools for nickel and cobalt release.

Methods/Materials: Three hundred eight beauty tools were tested in seven beauty salons located in two North-German states. A nickel spot test and a cobalt spot test were used to test the tools for nickel release and cobalt release, respectively.

Results: 143 of 308 beauty tools overall (46.4%; 95%CI: 40.8-52.2%) released nickel and 18 of 308 beauty tools overall (5.8%; 95%CI: 3.5-9.1%) released cobalt. Nickel release was found in 22 of 99 metal tools (22.2%; 95%CI: 14.5-31.7%) and 121 of 209 tools with metallic parts (57.9%; 95%CI: 50.9-64.7%); cobalt release was detected in 3 of 99 metal tools (3.0%; 95%CI: 0.63-8.6%) and 15 of 209 tools with metallic parts (7.2%; 95%CI: 4.1-11.6%).

Conclusions: Nickel and cobalt are emitted at allergologically relevant levels by a wide range of beauty tools (i.e., metal tools and tools with metallic parts) utilized in the German cosmetics trade. Beauty tools should thus be considered occupational sources of nickel and cobalt exposure.

Keywords: aesthetician, beautician, cobalt, cosmetician, Germany, nickel, spot test, tool

1 Introduction

In the European Union (EU), the utilization of nickel in metallic objects is regulated by the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulation.¹ The use of cobalt in metallic objects is hitherto not subject to any legal regulation. Both nickel and cobalt have steadily appeared among the most common contact allergens in recent decades. Current data from the Information Network of Departments of Dermatology (IVDK) show that the current sensitization prevalence of nickel and cobalt amounts to 14.7% and 5.2%, respectively.² Nickel and cobalt release from occupationally used tools of different professional areas has been evidenced within a variety of studies conducted in the EU.³⁻⁷ In the hairdressing trade, nickel and cobalt release was found in two currently conducted studies in which “sectioning clips”, tail combs, tweezers, hair clips, crochet hooks, and straight razors have been identified as nickel and/or cobalt releasing (Table 1).^{8,9} Nickel release from scissors, which are the main working tool of hairdressers, has been identified by Thyssen *et al.* previously.³

People other than hairdressers working in beauty salons (beauticians, aestheticians, cosmeticians etc.) are subjected to a high occupational skin strain which is comparable to the skin strain of hairdressers.¹⁰ In the cosmetics trade, the skin strain mainly results from a high amount of wet work¹¹ conducted whilst performing various beauty treatments such as facial treatments or massages where also a skin contact with detergents¹² as well as other cosmetic chemicals is relevant. This exposure leads to an impairment of the epidermal barrier function concomitant with the induction of a proinflammatory skin milieu,¹¹ facilitating penetration of, and sensitization to, harmful substances. The risk of developing occupational allergic contact dermatitis of the hands is thus elevated. Considering the individual suffering as well as the socio-economic consequences – including high illness costs – that occupational hand eczema entail,¹³ the development of occupational hand eczema should strictly be prevented

Results of previous studies have shown that tweezers releasing nickel and cobalt in allergologically relevant amounts (detection limits being 0.5µg nickel/cm²/week for nickel¹⁴⁻¹⁶ and 8.3 ppm for cobalt¹⁷) are used in the hairdressing trade.^{8,9} Such tweezers are likely also used in the cosmetics trade and may be used more often in beauty salons, owing to the demand for eyebrow plucking services. As has been evidenced in a sample of Croatian beauticians, protective gloves might commonly not be worn as recommended in the cosmetics trade.¹⁸ It must be assumed that a high proportion of daily tasks of beauticians might be carried out without deploying proper skin protection measures. This led us to hypothesize that beauticians

might be exposed to nickel and/or cobalt releasing tweezers and/or other beauty tools within their daily workplace environment. Against this backdrop, the present study aims at screening a broad selection of tools used in average German beauty salons regarding nickel and cobalt release in order to determine potentially relevant sources of exposure.

2 Methods/Materials

Testing was conducted in seven randomly chosen beauty salons located in Lower Saxony, Germany (n=4) and North Rhine-Westphalia, Germany (n=3) within 100 km of Osnabrück, Lower Saxony, Germany. The test solutions Chemo Nickel Test, Chemotechnique Diagnostics, Vellinge, Sweden (ingredients: water, ethanol, ammonium hydroxide, and dimethylglyoxime (DMG; CAS no. 95-45-4)) and Chemo Cobalt Test, Chemotechnique Diagnostics (ingredients: water, sodium acetate, oxalic acid, and nitroso-r salt (CAS no. 525-05-03)) were used for nickel spot testing and cobalt spot testing, respectively. In the beauty salons, all available metal tools and tools with metallic parts with which beauticians may have skin contact were included in the study. Data about the age, price, and manufacturer of the tested tools were collected in the visited salons.

To ensure uniform testing, the testing sites were chosen beforehand (Figure 1). The testing sites averaged 0.5cm² in size, depending on the tool. Depending on the size of the tools and the locations in which they have skin contact, a 2.0 x 1.25cm long strip of Leukofix, BSN medical, Hamburg, Germany, was applied between the relevant testing sites to make sure the test results were not tainted by the overlapping of the two distinct test solutions. Whenever feasible, a larger distance than 1.25cm was kept between the different testing areas. If possible, testing with the two solutions was conducted at the corresponding opposite side of the tool.

The tests were performed according to the manufacturer's recommendations. In each case, two drops (50µL) of the relevant test solution were applied to new conventional white cotton swabs made from pure cotton wool from the ebelin brand, dm-drogerie markt, Karlsruhe, Germany. The cotton swab was then rubbed for up to 60 seconds against the designated testing site. The experiment was terminated at this point if a relevant color change was noticed in due time. A positive test reaction was indicated by a color change of the previously clear nickel test solution to a reddish-pink color, whereas a negative test reaction was indicated by no color change of the test solution.^{19,20} A positive cobalt test reaction was indicated by a color shift from yellow

to reddish-brown in the test solution, whereas a negative reaction was indicated by no color change in the yellow test solution.^{17,20,21} Inconclusive test responses were identified by color shifts other than the target color for both test solutions and – as also recently recommended by Wennervaldt *et al.* –²² noted separately and neither interpreted as positive nor negative. When analyzing the color shift, the cotton swabs were put in front of a white surface for optimal color identification. The tools were examined in their natural condition, without being cleaned or manipulated in any way.

3 Results

In total, 308 beauty tools – 99 metal tools and 209 tools with metallic parts – were tested for nickel and cobalt release. The age and the price of the 308 tested tools ranged from 0.5 to 135.0 € (median: 7.00, Q1: 3.00, Q3: 12.00 €) and 1 to 30 years (median: 5, Q1: 2, Q3: 7 years). For 67 of 308 tools (21.8%), no manufacturer could be noted; the remaining 241 tools were produced by 41 different manufacturers.

The Chemo Nickel Test showed that 143 of 308 beauty tools overall (46.4%; 95%CI: 40.8-52.2%) released nickel and the Chemo Cobalt Test showed that 18 of 308 beauty tools overall (5.8%; 95%CI: 3.5-9.1%) released cobalt (Table 2, Table 3). Nickel release was found in 22 of 99 metal tools (22.2%; 95%CI: 14.5-31.7%) and 121 of 209 tools with metallic parts (57.9%; 95%CI: 50.9-64.7%); cobalt release was detected in 3 of 99 metal tools (3.0%; 95%CI: 0.63-8.6%) and 15 of 209 tools with metallic parts (7.2%; 95%CI: 4.1-11.6%). Nickel release was not related to price or age in our exploratory sample ($P \geq .1$, Wilcoxon test). Of 18 cobalt-releasing beauty tools, 16 simultaneously released nickel, see Figure 2. Nickel-releasing and cobalt-releasing beauty tools were found in every visited beauty salon (i.e., all visited beauty salons in Lower Saxony, Germany (n=4) and North Rhine-Westphalia, Germany (n=3)).

Inconclusive test results (i.e., a color change of the spot test different to the target color of the corresponding test solution) were seen in 8 tools for the Chemo Nickel Test (2.6%) – all of them with a color change of the test solution to black (100%) – and in 17 tools for the Chemo Cobalt Test (5.5%) – 14 of them with a color change of the test solution to green (82.4%) and 3 of them with a color change of the test solution to black (27.6%).

Retesting of randomly selected 31 (10.1%) of the previously tested tools with a time lag of two weeks revealed a reproducibility of the results of 100% (95%CI: 88.8-100%).

4 Discussion

In this paper we have shown that people working in beauty salons (beauticians, aestheticians, cosmeticians etc.) are exposed to a wide range of beauty tools releasing nickel and/or cobalt at allergologically relevant levels. “Relevance” is assumed as the sensitivity of the spot tests is such that detected release is likely to elicit allergic contact dermatitis with sufficient (be it repeated, short-term) contact,^{14,17} in case of nickel release likely exceeding regulatory threshold levels.^{1,23} This applies for a wide range of metal tools (i.e., nail clippers, corner pliers, tweezers, cuticle scissors, and cuticle removers/pushers) and tools with metallic parts (i.e., foundation brushes, eyeshadow applicators, contour brushes, lip brushes, eyeliner brushes, mask brushes, eyeshadow brushes, eyebrow brushes, nail art brushes, highlighter brushes, eyebrow spoolies, concealer brushes, blusher brushes). Because the tested metal tools are sold nationally and nickel and cobalt release was identified in all visited beauty salons spanning two German federal states, the findings of this study are likely to be representative for Germany. Further to that, since a proportion of the evaluated metal tools is marketed all over the EU, our study findings might be transferrable to other European countries. Certainly, the results might stimulate further such investigations in the cosmetics trade, which in Germany comprises about 22.800 beauty salons and 54.000 workers, mostly in small enterprises.²⁴ It additionally should be considered to establish technical rules on hazardous substances (TRGS) in the cosmetics trade, which could be derived and refined from the German TRGS 530 for the hairdressing trade: Working tools releasing nickel – especially when in prolonged skin contact – are not suitable to use.²⁵

To the best of our knowledge, this is the first field study investigating nickel and cobalt release from a wide range of beauty tools in the cosmetics trade. The share of 46.4% nickel-releasing and 5.8% cobalt-releasing beauty tools – which has to be described as particularly high compared to previous studies on nickel and/or cobalt spot testing in the related hairdressing trade^{3,8,9} might be due to the broad range of beauty tools tested in the current investigation.

Interestingly, the identification of tweezers as especially problematic regarding nickel release in two previous studies conducted in the hairdressing trade^{8,9} was confirmed by the present findings in the cosmetics trade. As both hairdressers and beauticians oftentimes suffer from a

high occupational skin strain¹⁰ caused by a significant amount of wet work¹¹ as well as by working with detergents and salon chemicals,¹² skin contact with nickel-releasing beauty tools, such as tweezers, should be strictly prevented since the induced damage of the skin barrier homeostasis facilitates the penetration of allergens into the skin.¹¹ This is of particular importance because previous research has shown that the share of beauticians actually wearing protective gloves as recommended is disenchanting.¹⁸ Tweezers should thus be in the focus of dermatologists searching for occupational relevance in case of nickel and/or cobalt allergy in employees in the beauty industry. Further, this particular item should be included in educating nickel and/or cobalt allergic patients, especially in terms of adequate allergen avoidance. Evidently, (self-)screening with the DMG test of all metallic items with potential skin contact is an important part of secondary prevention for every nickel-allergic patient.

It should, however, be mentioned that some nickel releasing beauty tools for very specific purposes likely do not provide prolonged and direct contact with the skin, mainly because it is to be expected that gloves usually are worn when performing certain procedures, namely, tools for conducting pedicures. However, if no gloves are worn during pedicures, these particular tools become problematic. It should further be noted that – even though it is expected for brushes to be held at the metallic part – it cannot be fully excluded that beauticians hold brushes on the other – often wooden – components, reducing skin contact to potentially nickel and/or cobalt releasing parts. Nevertheless, as has been described in previous studies, even a short (and repetitive) contact with nickel and/or cobalt ions can be harmful – especially in already sensitized individuals.^{26,27} Because there is a link between nickel and cobalt sensitization²⁸ and nickel acts as adjuvant in the mechanism of cobalt sensitization, co-exposure to nickel and cobalt – as observed in some of the examined beauty tools and in fashion jewelry –²⁹ should be averted to obviate sensitization and elicitation of contact allergy.³⁰ Further, the results of this study point out that beauty tools of different ages, prices and by diverse manufacturers release nickel and/or cobalt. This shows that beauty tools that are supposed to comply with the current EU nickel regulation¹ may nonetheless be considered relevant sources of nickel exposure.

The occurrence of inconclusive test results should be considered from a methodological perspective. Because inconclusive test reactions of the nickel spot test^{5,7,9} and the cobalt spot test^{5,9} have been reported in earlier research, inconclusive test findings – which indicate release of other than the targeted metals – were not unexpected to occur. The importance of neither interpreting inconclusive test results as negative nor positive reactions has been stressed before,

as the outcome of these reactions remains unclear.⁵ A green color change of a cobalt spot testing solution has been described as indicating iron release.²³ Additionally, Wennervaldt *et al.* currently described the issue of copper release potentially masking positive nickel spot test results (i.e., brown-yellow discolorations).²²

A limitation of this field study is that the nickel spot testing as well as cobalt spot testing have a limited use for research (e.g., low sensitivity of the nickel spot test, meaning that some cases might be overlooked and that the figures might even be higher).³¹ Beyond semi-quantitative methods used in the current field study, quantitative approaches may be used to identify the precise quantity of nickel^{5,29} and cobalt^{5,27,29,32} emitted by beauty tools in the cosmetics trade in future research. Further, there was a potential risk of contamination of the tested metallic parts, e.g., transferred from cosmetics or by contaminated hands, although a random sample of tools (10.1%) were re-tested and the reproducibility was 100%, why this is not thought to be an issue.

According to the findings of this field study, employees working in beauty salons are not adequately protected from nickel and/or cobalt emission from beauty tools. Setting threshold limits for the use of cobalt, in addition to stringent compliance with the REACH nickel regulation, appears appropriate. When confronted with a nickel or cobalt allergic beauty salon employee, dermatologists and occupational health physicians may initiate comprehensive testing of occupationally used beauty tools for nickel or cobalt release. In this context, not only metal tools but also tools with metallic parts should be paid attention to. In the sense of primary prevention of occupational dermatoses in the cosmetics trade, general preventive advice, as e.g., wearing gloves whilst handling beauty tools, should be integrated into health education programs in order to prevent hand eczema in employees working in beauty salons.

5 References

1. REACH. Commission Regulation (EC) No. 552/2009 of June 2009 amending Regulation (EC) No. 1907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards Annex XVII. Off J Eur Union. 2009;L64:7-31.
2. Uter W, Gefeller O, Mahler V, Geier J. Trends and current spectrum of contact allergy in Central Europe: results of the Information Network of Departments of Dermatology (IVDK) 2007-2018. *Br J Dermatol*. 2020;183(5):857-865.

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3. Thyssen JP, Milting K, Bregnhøj A, Sosted H, Duus Johansen J, Menne T. Nickel allergy in patch-tested female hairdressers and assessment of nickel release from hairdressers' scissors and crochet hooks. *Contact Dermatitis*. 2009;61(5):281-6.
 4. Thyssen JP, Menne T, Johansen JD. Identification of metallic items that caused nickel dermatitis in Danish patients. *Contact Dermatitis*. 2010;63(3):151-6.
 5. Kettelarij JA, Lidén C, Axén E, Julander A. Cobalt, nickel and chromium release from dental tools and alloys. *Contact Dermatitis*. 2014;70(1):3-10.
 6. Kicking-Lörsch A, Bruckner T, Mahler V. Nickel and cobalt release from metal alloys of tools—a current analysis in Germany. *Contact Dermatitis*. 2015;73(5):289-95.
 7. Ringborg E, Lidén C, Julander A. Nickel on the market: a baseline survey of articles in 'prolonged contact' with skin. *Contact Dermatitis*. 2016;75(2):77-81.
 8. Symanzik C, John SM, Strunk M. Nickel release from metal tools in the German hairdressing trade-A current analysis. *Contact Dermatitis*. 2019;80(6):382-385.
 9. Symanzik C, Skudlik C, John SM. Experimental evaluation of nickel and cobalt release from tools and self-reported prevalence of nickel and cobalt allergy in the German hairdressing trade. *J Eur Acad Dermatol Venereol*. 2021;35(4):965-972.
 10. Babić Ž, Samardžić T, Macan J. Comparison of beautician and hairdressing apprentices with regard to skin health and skin barrier function. *Arh Hig Rada Toksikol*. 2020;71(3):190-196.
 11. Kieć-Swierczyńska M, Chomiczewska D, Kręcisz B. Wet work. *Med Pr*. 2010;61(1):65-77.
 12. Antonov D, Schliemann S, Elsner P. Hand dermatitis: a review of clinical features, prevention and treatment. *Am J Clin Dermatol*. 2015;16(4):257-270.
 13. Carøe TK, Ebbelhøj NE, Bonde JP, Agner T. Occupational hand eczema and/or contact urticaria: factors associated with change of profession or not remaining in the workforce. *Contact Dermatitis*. 2018;78(1):55-63.
 14. Thyssen JP, Skare L, Lundgren L, et al. Sensitivity and specificity of the nickel spot (dimethylglyoxime) test. *Contact Dermatitis*. 2010;62(5):279-88.
 15. Menné T, Brandup F, Thestrup-Pedersen K, et al. Patch test reactivity to nickel alloys. *Contact Dermatitis*. 1987;16(5):255-9.
 16. Menné T, Andersen KE, Kaaber K, et al. Evaluation of the dimethylglyoxime stick test for the detection of nickel. *Derm Beruf Umwelt*. 1987;35(4):128-30.
 17. Thyssen JP, Menné T, Johansen JD, et al. A spot test for detection of cobalt release - early experience and findings. *Contact Dermatitis*. 2010;63(2):63-9.

- Accepted Article
18. Macan J, Babić Ž, Samardžić T. Skin health and protection at work in Croatian beautician apprentices. *Contact Dermatitis*. 2017;76(3):178-179.
 19. Thyssen JP, Menné T, Johansen JD. Nickel release from inexpensive jewelry and hair clasps purchased in an EU country - Are consumers sufficiently protected from nickel exposure? *Sci Total Environ*. 2009;407(20):5315-8.
 20. Thyssen JP, Jensen P, Lidén C, et al. Assessment of nickel and cobalt release from 200 unused hand-held work tools for sale in Denmark - Sources of occupational metal contact dermatitis? *Sci Total Environ*. 2011;409(22):4663-6.
 21. Midander K, Julander A, Skare L, Thyssen JP, Lidén C. The cobalt spot test--further insights into its performance and use. *Contact Dermatitis*. 2013;69(5):280-7.
 22. Wennervaldt M, Ahlström MG, Menné T, Thyssen JP, Johansen JD. Copper release from metals may mask positive nickel spot test results. *Contact Dermatitis*. 2022:Epub ahead of print. doi: 10.1111/cod.14049.
 23. DIN EN 1811:2021-11. Reference test method for release of nickel from all post assemblies which are inserted into pierced parts of the human body and articles intended to come into direct and prolonged contact with the skin. 2022:1-63.
 24. German Federal Statistical Office. Unternehmen und Arbeitsstätten. Kostenstruktur bei Frisör- und Kosmetiksalons. Available at: https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Dienstleistungen/Publikationen/Downloads-Dienstleistungen-Kostenstruktur/kostenstruktur-frisoer-kosmetik-2020164189004.pdf;jsessionid=C5102B9410520152FE48E79BE47E3CEF.live711?__blob=publicationFile (last accessed 4 February 2022).
 25. Committee for Hazardous Substances of the German Federal Agency for Industrial Health and Safety. Technical Rules on Hazardous Substances (TRGS) 530 for the Hairdressing Trade. Available at: <https://www.bgw-online.de/resource/blob/20628/5f65bd1bb394e88d7ba969b57d2d26e5/trgs530-gefahrstoffe-friseurhandwerk-data.pdf> (last accessed 8 February 2022).
 26. Ahlström MG, Thyssen JP, Menné T, Lidén C. Short contact with nickel is not harmless. *Contact Dermatitis*. 2019;80(4):259-260.
 27. Midander K, Julander A, Skare L, Lidén C. Cobalt skin dose resulting from short and repetitive contact with hard metals. *Contact Dermatitis*. 2014;70(6):361-8.
 28. Rystedt I, Fischer T. Relationship between nickel and cobalt sensitization in hard metal workers. *Contact Dermatitis*. 1983;9(3):195-200.

- Accepted Article
29. Uter W, Wolter J. Nickel and cobalt release from earrings and piercing jewellery - analytical results of a German survey in 2014. *Contact Dermatitis*. 2018;78(5):321-328.
 30. Bonefeld CM, Nielsen MM, Vennegaard MT, Johansen JD, Geisler C, Thyssen JP. Nickel acts as an adjuvant during cobalt sensitization. *Exp Dermatol*. 2015;24(3):229-31.
 31. Wennervaldt M, Ahlström MG, Menné T, Thyssen JP, Johansen JD. Nickel release from metallic earrings: A survey of the Danish market and validation of the nickel spot test. *Contact Dermatitis*. 2021.
 32. Julander A, Hindsén M, Skare L, Lidén C. Cobalt-containing alloys and their ability to release cobalt and cause dermatitis. *Contact Dermatitis*. 2009;60(3):165-70.

6 Tables

Table 1: Results of two currently conducted studies regarding nickel and cobalt release from tools in the German hairdressing trade

Tools	Symanzik <i>et al.</i> 2019 ⁸		Symanzik <i>et al.</i> 2021 ⁹			
	Nickel positive		Nickel positive		Cobalt positive	
	%	n/n _{total}	%	n/n _{total}	%	n/n _{total}
Scissors	0	0/62	0	0/116	0	0/116
Hair rollers	0	0/45	0	0/60	0	0/60
Whisks	0	0/20	0	0/22	0	0/22
Hand showers	0	0/13	0	0/20	0	0/20
Tail combs	7.4	2/27	8.9	4/45	0	0/45
Straight razors	n/t	n/t	15.6	5/32	3.1	1/32
Sectioning clips	17.8	8/45	44.0	33/75	2.7	2/75
Tweezers	64.7	11/17	60.0	24/40	7.5	3/40
Crochet hooks	n/t	n/t	100	5/5	0	0/5
Hair clips	n/t	n/t	100	60/60	6.7	4/60
All	9.2	21/229	27.6	131/475	2.1	10/475

n/t, not tested

Table 2: Positive nickel and cobalt test results of the tested metal tools in the present study alongside with characteristics of the tools with positive test results (age, price, and manufacturers)

Metal tools	Category†	Direct and prolonged contact likely?‡	Nickel positive					Cobalt positive				
			%	n/n _{total}	Age range (M±SD) in years	Price range (M±SD) in Euro	No. of manufacturers§	%	n/n _{total}	Age range (M±SD) in years	Price range (M±SD) in Euro	No. of manufacturers
Nail clippers	Pedicure	no	100	9/9	9.0-20.0 (12.2±3.7)	3.0-10.0 (5.7±2.3)	1+x	11.1	1/9	15.0 (15.0±0)	7.0 (7.0±0)	1
Corner pliers	Pedicure	no	40.0	2/5	15.0-15.0 (15.0±0)	10.0-10.0 (10.0±0)	1+x	0	n/a	n/a	n/a	n/a
Tweezers	Facial	yes	28.6	6/21	7.0-30.0 (13.7±8.4)	2.0-15.0 (7.5±4.5)	3+x	4.8	1/21	10.0 (10.0±0)	5.0 (5.0±0)	1
Cuticle scissors	Pedicure	no	25.0	2/8	10.0-20.0 (15.0±7.1)	10.0 (10.0±0)	2	0	n/a	n/a	n/a	n/a
Cuticle remover/pusher	Pedicure	no	21.4	3/14	2.0-7.0 (5.3±2.9)	3.0-5.0 (4.0±1.0)	3	0	n/a	n/a	n/a	n/a
Tip cutter	Manicure	yes	0	0/1	n/a	n/a	n/a	100	1/1	7.0 (7.0±0)	10.0 (10.0±0)	1
Corner file	Pedicure	no	0	0/2	n/a	n/a	n/a	0	0/2	n/a	n/a	n/a
Foot scraper	Pedicure	no	0	0/1	n/a	n/a	n/a	0	0/1	n/a	n/a	n/a
Comedo extractor	Facial	yes	0	0/3	n/a	n/a	n/a	0	0/3	n/a	n/a	n/a
End cutter	Pedicure	no	0	0/9	n/a	n/a	n/a	0	0/9	n/a	n/a	n/a
Nail file	Pedicure	no	0	0/2	n/a	n/a	n/a	0	0/2	n/a	n/a	n/a
Cuticle nippers	Pedicure	no	0	0/10	n/a	n/a	n/a	0	0/10	n/a	n/a	n/a
Scalpel holder	Pedicure	no	0	0/4	n/a	n/a	n/a	0	0/4	n/a	n/a	n/a
Edge lifter	Pedicure	no	0	0/10	n/a	n/a	n/a	0	0/10	n/a	n/a	n/a
All tools	n/a	n/a	22.2	22/99	2.0-30.0 (12.2±5.8)	2.0-15.0 (6.7±3.3)	10+x	3.0	3/99	7.0-15.0 (10.7±4.0)	5.0-10.0 (7.3±2.5)	3

†categories: body, facial, manicure, pedicure; ‡categories: yes, no; §+x indicates that a share of tools in this line could not be attributed to a manufacturer and thus a more exact specification is not possible; n/a, not applicable

Table 3: Positive nickel and cobalt test results of the tested tools with metallic parts in the present study alongside with characteristics of the tools with positive test results (age, price, and manufacturers)

Tools with metallic parts	Category†	Direct and prolonged contact likely?‡	Nickel positive						Cobalt positive				
			%	n/n _{total}	Age range (M±SD) in years	Price range (M±SD) in Euro	No. of manufacture rs§	%	n/n _{total}	Age range (M±SD) in years	Price range (M±SD) in Euro	No. of manufacture rs§	
Foundation brush	Facial	yes	100	7/7	2.0-10.0 (5.4±2.9)	10.0-29.0 (15.4±6.9)	4	14.3	1/7	10.0 (10.0±0)	20.0 (20.0±0)	1	
Eyeshadow applicator	Facial	yes	100	4/4	2.0-12.0 (5.3±4.7)	4.0-4.0 (4.0±0)	1	0	0/4	n/a	n/a	n/a	
Contour brush	Facial	yes	100	1/1	5.0 (5.0±0)	12.0 (12.0±0)	1	0	0/1	n/a	n/a	n/a	
Lip brush	Facial	yes	78.6	11/14	2.0-12.0 (5.5±3.9)	1.5-6.0 (3.2±1.5)	2	0	0/14	n/a	n/a	n/a	
Eveliner brush	Facial	yes	75.0	6/8	2.0-7.0 (3.5±2.3)	1.0-5.0 (3.5±1.5)	2	12.5	1/8	7.0 (7.0±0)	1.0 (1.0±0)	1	
Mask brush	Facial	yes	75.0	3/4	7.0-10.0 (9.0±1.7)	4.0-4.0 (4.0±0)	2	25.0	1/4	10.0 (10.0±0)	4.0 (4.0±0)	1	
Eyeshadow brush	Facial	yes	73.8	31/42	2.0-12.0 (5.3±3.0)	1.5-14.0 (6.7±3.0)	5	14.3	6/42	2.0-7.0 (5.8±1.9)	2.0-10.0 (5.8±2.7)	2+x	
Eyebrow brush	Facial	yes	60.0	3/5	5.0-12.0 (7.3±4.0)	6.0-8.0 (7.3±1.2)	2	20.0	1/5	5.0 (8.0±0)	8.0 (8.0±0)	1	
Nail art brush	Manicure	yes	57.0	49/86	1.0-10.0 (4.3±3.0)	1.0-22.0 (9.7±6.2)	5+x	4.7	4/86	1.0-8.0 (4.0±3.6)	6.0-15.0 (10.8±4.9)	2+x	
Highlighter brush	Facial	yes	50.0	1/2	5.0 (5.0±0)	12.0 (12.0±0)	1	0	0/2	n/a	n/a	n/a	
Eyebrow spoolie	Facial	yes	37.5	3/8	2.0-9.0 (6.0±3.6)	1.0-3.0 (1.8±1.0)	3	0	0/8	n/a	n/a	n/a	
Concealer brush	Facial	yes	20.0	1/5	5.0 (5.0±0)	11.0 (11.0±0)	1	20.0	1/5	5.0 (5.0±0)	11.0 (11.0±0)	1	
Blusher brush	Facial	yes	16.6	1/6	10.0 (10.0±0)	4.0 (4.0±0)	1	0	0/6	n/a	n/a	n/a	
Milling handpiece	Pedicure	no	0	0/3	n/a	n/a	n/a	0	0/3	n/a	n/a	n/a	

Body brush	Body	yes	0	0/2	n/a	n/a	n/a	0	0/2	n/a	n/a	n/a
Fen brush	Facial	yes	0	0/3	n/a	n/a	n/a	0	0/3	n/a	n/a	n/a
Powder brush	Facial	yes	0	0/6	n/a	n/a	n/a	0	0/6	n/a	n/a	n/a
Stippling brush	Facial	yes	0	0/3	n/a	n/a	n/a	0	0/3	n/a	n/a	n/a
All	n/a	n/a	57.9	121/209	1.0-12.0 (5.0±3.1)	1.0-29.0 (7.8±5.5)	14+x	7.2	15/209	1.0-10.0 (5.9±2.8)	1.0-20.0 (8.1±5.2)	6+x

†categories: body, facial, manicure, pedicure; ‡categories: yes, no; §+x indicates that a share of tools in this line could not be attributed to a manufacturer and thus a more exact specification is not possible; n/a, not applicable

7 Figures



Figure 1: Tested instruments alongside with pre-determined testing sites. Nickel spot test testing sites are marked with an x, whereas cobalt spot test testing sites are marked with a circle (o). Asterisks (*) indicate testing sites where nickel and cobalt spot tests were performed on the corresponding opposite sides of the metal tool. a) tweezers (customary models as well as automatic tweezers, displayed in the middle), b) tools for conducting nail treatments (manicures), c) makeup brushes for application of liquid/cream products (concealer, foundation, liquid bronzer, liquid blush etc.) and powder products (setting powder, blusher, bronzer etc.), d) makeup brushes for application of eyeshadow (powder or liquid/cream) and/or eyebrow and eyelash products (mascara, eyebrow gel etc.) as well as a so-called blackhead remover (displayed on the right outer side), e) nail design/art brushes used for conducting nail treatments (mostly acrylic nails and gel nails), f) tools used for conducting pedicures

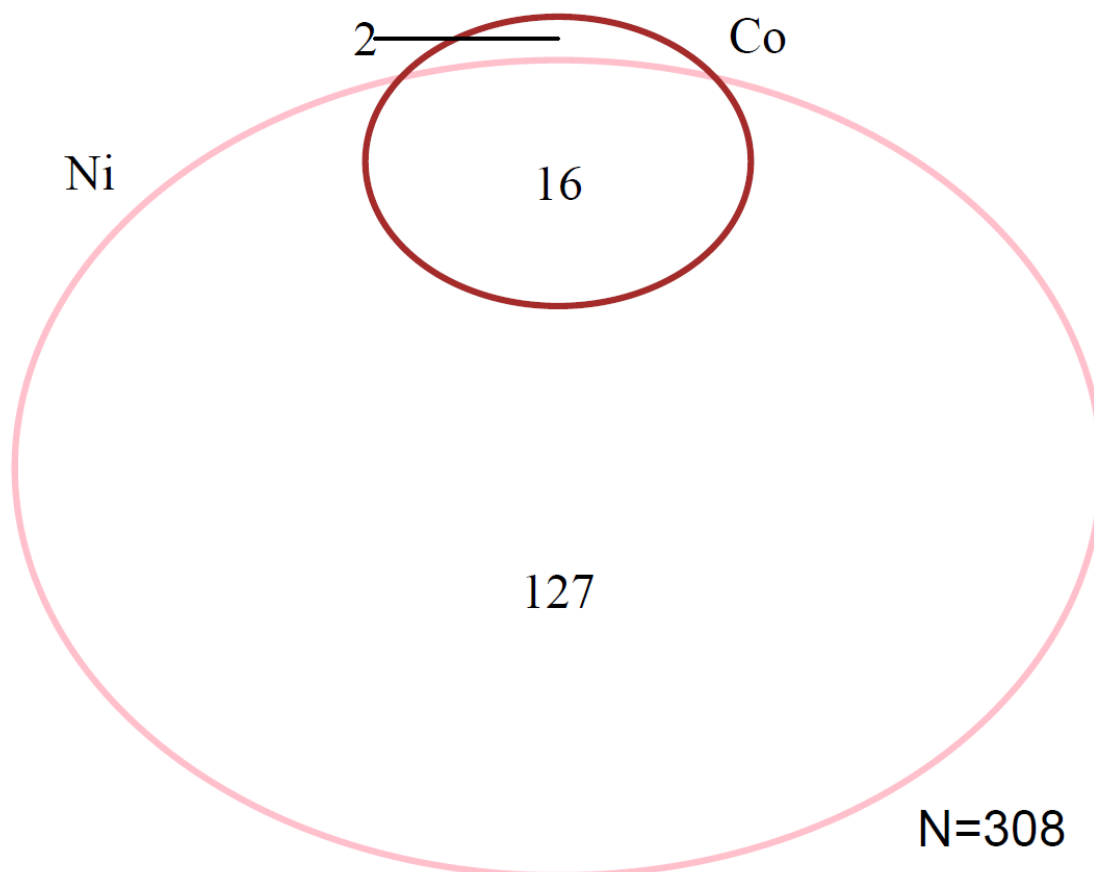


Figure 2: Area-proportionate Venn diagram showing the number of samples testing positive to nickel and/or cobalt (created with the R package “VennDiagram” v. 1.7.1)