

Jewellery: alloy composition and release of nickel, cobalt and lead assessed with the EU synthetic sweat method

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Summary

Background. Several studies have shown nickel and cobalt release from jewellery by using spot tests, but the metal composition of jewellery is largely unknown.

Objectives. To evaluate the metal composition of a large worldwide sample of mainly inexpensive jewellery items, and investigate the release of nickel, cobalt and lead from a subsample by using EN 1811:1998-required methods.

Methods. A total of 956 metallic jewellery components were examined with X-ray fluorescence spectroscopy. A subsample of 96 jewellery items purchased in the United States were investigated for nickel, cobalt and lead release by the use of artificial sweat immersion and plasma optical emission spectroscopy.

Results. Eighteen elements were detected. The 10 most frequently occurring were, in order of frequency, copper, iron, zinc, nickel, silver, chromium, tin, manganese, lead, and cobalt. Release of nickel was noted from 79 of the 96 US samples (0.01–98 µg/cm²/week), release of cobalt from 35 samples (0.02–0.5 µg/cm²/week), and release of lead from 37 samples (0.03–2718 µg/cm²/week).

Conclusions. We present here a comprehensive list of the most frequently encountered metals in jewellery and fashion accessories. Different allergenic and non-allergenic metals are utilized. We also report the frequent release of nickel, cobalt and lead from these objects, despite legislative restrictions.

Key words: chromium; cobalt; dermatitis; earrings; jewellery; lead; nickel.

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Conflict of interests: J. P. Thyssen participated in the development of the cobalt spot test, which was sold to SmartPractice (Phoenix, Arizona) after its development, and will receive royalty fees for annual net sales of the spot test. D. Hamann D and C. R. Hamann are the sons of C. Hamann, owner and CEO of SmartPractice, which manufactures and sells patch test products. The remaining authors have no conflict of interest to declare.

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Earrings and other metallic fashion accessories are important sources of human metal exposure. In particular, pierced earrings expose the host's immune cells directly to metal ions and promote skin absorption of skin-sensitizing metal ions, both prior to healing of the newly pierced hole and following micro-traumatization in healed piercing sites during re-insertion. Nickel was identified in crusts and blood from the pierced region of the earlobe in 1 of 3 nickel-allergic patients with earlobe dermatitis (1), and ear piercing is the strongest risk factor for nickel allergy (2, 3). Besides earrings, other accessories and fashion items, such as bracelets, rings, necklaces, watches, and spectacle frames, come into prolonged or persistent skin contact, potentially releasing metal ions causing dermatitis.

The composition of nickel-containing or gold-containing alloys and plating frequently used in jewellery has previously been described (4–6), and patents concerning jewellery materials have been reported (7). Jewellery composition has been partly described in studies performed to evaluate heavy metal content in jewellery (8–10). Although nickel, cobalt and chromium are the most frequent metal contact sensitizers, copper, aluminium, palladium, rhodium, gold and others have also been reported.

Nickel is relatively inexpensive, light, and corrosion-resistant. It is for these reasons that nickel is frequently used in high quantities for the production of earrings and jewellery, resulting in a high prevalence of nickel sensitization among those who wear jewellery (11). Even today, after regulation of nickel release from jewellery in the EU and China (12), nickel is frequently released in excessive amounts from items purchased in these countries, as assessed by spot test screening (13–16). Although exposure to cobalt and nickel often has been considered to be concomitant, owing to their frequent co-existence in nature, the higher price of cobalt has led to more efficient refining, limiting dual exposure to these metals in recent years. Nevertheless, cobalt is sometimes used for jewellery manufacturing, and may indeed cause allergic contact dermatitis (4, 17, 18).

In addition to legislation limiting nickel release, there are legislative restrictions on lead, which include EU and California state laws. These restrictions were formulated largely in response to enteral exposure, such as ingestion of lead-containing items by young children. One recent study identified persistent lead content in costume and imported jewellery (8); however, to our knowledge, lead release from jewellery, as opposed to lead content, has not previously been widely assessed with artificial sweat analysis.

As it is difficult and expensive for patch testers to easily determine the metallic content of and metal release

from jewellery items, there is a continuous need for insights into their composition. Only with up-to-date information can patch testers determine relevant contact allergens for their patch test trays. In this study, we determined the composition of jewellery that was purchased from cities in the United States, Poland, the United Kingdom, Denmark, and Japan. Nickel and cobalt release has been well described for earrings by the use of colorimetric spot tests, including some of the earrings investigated in this study. These tests are also clinically helpful. However, the EU nickel regulations mandate that compliance be assessed with a standardized synthetic sweat assay: European Standard EN 1811:1998. A comprehensive evaluation of nickel, cobalt and lead release from a large sample of earrings with this synthetic sweat and inductively coupled plasma optical emission spectroscopy (ICP-OES) method has not been undertaken.

Materials and Methods

Here, we provide a brief description of the jewellery samples that were analysed for their metal content in this study. Except for the earrings purchased in Japan, the jewellery and spot-test data have been detailed previously, and we refer interested readers to these publications (14, 15, 19). Testing was, in all cases, restricted to components that come into contact with the skin with normal use. The sample sizes differed from those in the original publications, as some jewellery items have since been used for other research purposes and destructive analyses (20).

Samples

Denmark. Between December 2008 and March 2009 in Copenhagen, inexpensive jewellery and hair clasps were purchased from 36 stores, street vendors, and a jewellery web page (15). Approximately €3000 (range €5–50) was spent buying 354 metallic jewellery items and hair clasps. A total of 308 items were available for the present study: 167 earrings, 15 bracelets, 15 rings, and 111 hair clasps.

Poland. In January 2010, in Warsaw, inexpensive earrings were purchased from 20 stores and street markets (14). Approximately €700 (range €1–12) was spent buying 206 earrings. A total of 188 earrings were available for the present study.

United Kingdom. In January 2010, in London, inexpensive earrings were purchased from 23 stores and street

markets (14). Approximately €1100 (range €1–10) was spent buying 205 earrings. A total of 205 earrings were available for the present study.

United States. In October 2007, in San Francisco, California, 277 earrings were purchased from 34 stores and street markets. Approximately €2003 (range €3–25) (19) was spent. A total of 73 earrings were selected for metal release and X-ray fluorescence (XRF) spectroscopy, as previously described, to validate the dimethylglyoxime (DMG) spot test (20). Earrings composed of different parts were dismantled, leaving 96 sets of metallic parts for the present study (73 pairs of posts and hooks, and 23 pairs of decorative attachments).

Japan. Between June 2010 and October 2012, in Tokyo and Hiroshima, 159 earrings and other body piercing items were purchased from six stores and markets, including: InFox (Mizonokuchi), Ni Shop (Hiroshima), Stone House (Hiroshima), Daiso Shop (Hiroshima), and Claire's (Hiroshima). Approximately €700 (range €2–14) was spent.

XRF spectroscopy

XRF spectroscopy is a non-destructive analytical technique that is widely used for elemental and chemical analysis. Briefly, high-energy X-rays bombard the outer layers of an object. The excitation leads to emission of characteristic fluorescent X-rays that are registered by a detector. Spectra are evaluated with calibrated software for alloy analysis. The composition of the outer layers of the samples was determined with handheld XRF analysers. An Innov-X Alpha 4000 (Innov-X Europe, The Netherlands, Hertogenbosch) was used for the US samples, and a Bruker S1 Sorter X-Ray Fluorescence Spectrometer (Bruker Elemental, Billerica, MA, USA) was used for the samples from Poland, Denmark, the United Kingdom, and Japan. The metallic portion inserted into the pierced hole was analysed for each earring. Additionally, decorative parts from a subset of US earrings with a high likelihood of skin contact were also evaluated. For other metallic accessories, such as hair clasps, the most significant metallic site of skin exposure was tested. X-ray bombardment was conducted for at least 30 seconds. Only elements with an estimated elemental content of >0.5% are reported. Also, content below 0.5% was assessed using the Innov-X spectrometer in US samples, however content below 0.5% was not assessed using the Bruker Elemental spectrometer in other samples. Thus, content below 0.5% is not reported in this joint study. If the cumulative content of a sample was >100%, it was retested, and

the sample was discarded from the study if the result remained >100%.

Metal release and chemical analysis according to EN 1811

To determine release of metal from the US sample, the European Standard EN 1811:1998 for control of compliance with the EU nickel regulations was followed (20, 21). All 96 pairs of earring parts were investigated in this manner for nickel, cobalt and lead release by immersion in artificial sweat consisting of deionized and aerated water containing sodium chloride 0.5%, lactic acid 0.1%, and urea 0.1%, as previously published and described (20). The pH was adjusted to 6.5. Each pair of earring components was totally immersed in ~1 ml of artificial sweat/cm² sample area. The minimum volume of artificial sweat required by the analytical laboratory for this chemical analysis was 6 ml. The vessels were left untouched in an oven at 30°C for 1 week. ICP-OES (Optima 5300DV; PerkinElmer Waltham, MA, USA) was used for the analysis of nickel, cobalt and lead in the artificial sweat extracts. The reporting limits were 0.01 mg/l for nickel and cobalt, and 0.02 mg/l for lead. The final results were expressed as µg/cm²/week. We reported the analytical values of metal release, and did not multiply the values by 0.1 as described in the version of EN 1811 for nickel release available at the time of the investigation.

Results

XRF results

A total of 956 items of jewellery were examined by XRF spectroscopy (Table 1 and Fig. 1). Eighteen elements were detected (Table 1). The 10 most frequently occurring were, in order of frequency, copper, iron, zinc, nickel, silver, chromium, tin, manganese, lead, and cobalt. Little variation was observed across the countries of purchase, except for titanium, which was more frequently found in earrings from Japan. It should be noted that elements with a smaller atomic mass than titanium, such as aluminium, are not detected by the two XRF instruments used.

Examples of the composition of jewellery items with high contents of nickel or lead are given in Tables 2 and 3. It should be noted that the composition determined by XRF is indicative, being semiquantitative, and it does not show whether an item is made of one base alloy with or without surface coating (plating, flash, or lacquer), or whether it is composed of several parts with possibly different compositions.

Table 1. Metal composition of randomly purchased inexpensive earrings and other fashion jewellery determined with X-ray fluorescence spectroscopy

Metal	United States			United Kingdom			Poland			Denmark			Japan			Total		
	n = 96			n = 205			n = 188			n = 308			n = 159			n = 956		
	No. +	Concentration, median (minimum–maximum) (%)		No. +	Concentration, median (minimum–maximum) (%)		No. +	Concentration, median (minimum–maximum) (%)		No. +	Concentration, median (minimum–maximum) (%)		No. +	Concentration, median (minimum–maximum) (%)		No. +	Concentration, median (minimum–maximum) (%)	
Ag	28	8 (<0.5–84)		57	20 (1–93)		39	13 (1–95)		52	18 (1–91)		10	1 (1–5)		187	15 (<0.5–95)	
Au	0	–		0	–		0	–		0	–		2	1		2	1	
Cd	3	1 (<0.5–1)		0	–		0	–		0	–		0	–		3	1 (<0.5–1)	
Co	9	<0.5 (<0.5–1)		4	1		4	3 (1–6)		14	1 (1–3)		4	1 (1–2)		38	1 (<0.5–6)	
Cr	12	6 (1–13)		40	14 (1–46)		28	14 (1–44)		40	12 (1–39)		61	15 (1–20)		181	13 (1–46)	
Cu	93	61 (1–98)		201	57 (1–98)		174	55 (1–97)		247	58 (1–98)		143	39 (1–96)		865	54 (1–98)	
Fe	57	17 (<0.5–57)		82	40 (1–99)		123	35 (1–95)		173	38 (1–96)		90	56 (1–88)		526	38 (<0.5–99)	
Mn	16	<0.5		19	5 (1–18)		22	3 (1–17)		40	3 (1–3)		24	3 (1–17)		121	3 (<0.5–18)	
Mo	2	<0.5		1	4		0	–		1	3		4	2		8	2 (<0.5–4)	
Nb	0	–		11	2 (1–6)		5	2 (1–3)		17	7 (1–19)		3	1 (1–2)		36	4 (1–19)	
Ni	61	18 (<0.5–65)		30	22 (1–76)		62	27 (1–64)		106	29 (1–90)		73	25 (1–72)		338	25 (<0.5–90)	
Pb	16	9 (<0.5–60)		24	5 (1–21)		5	1 (1–2)		30	9 (1–62)		20	5 (1–18)		95	7 (<0.5–62)	
Sb	3	2 (1–4)		10	2 (1–12)		0	–		15	8 (1–31)		1	1		29	5 (1–31)	
Sn	20	3 (<0.5–33)		33	11 (1–78)		14	9 (1–54)		51	10 (1–94)		19	19 (1–100)		137	10 (<0.5–100)	
Ti	0	–		7	1 (1–2)		4	7 (2–21)		10	21 (1–95)		14	41 (1–96)		36	23 (1–96)	
W	1	<0.5		0	–		1	6.9		10	11 (1–34)		3	1 (1–2)		15	8 (<0.5–34)	
Zn	71	18 (<0.5–46)		106	21 (2–88)		65	16 (1–43)		113	14 (1–84)		62	17 (1–52)		424	17 (<0.5–84)	
Zr	0	–		0	–		0	–		0	–		2	1		2	1	

–, not detected.

Metal release

Release of nickel after immersion for 1 week in artificial sweat was detected from 79 of the US samples, ranging from 0.01 to 598 $\mu\text{g}/\text{cm}^2/\text{week}$; release of cobalt was detected from 35 samples, ranging from 0.02 to 0.5 $\mu\text{g}/\text{cm}^2/\text{week}$, and release of lead was detected from 37 samples, ranging from 0.03 to 2718 $\mu\text{g}/\text{cm}^2/\text{week}$. Examples of the metal composition, according to XRF spectroscopy, of items with high release of nickel or lead are given in Tables 2 and 3, which show that there were different compositions and that there was no direct relationship between content and release.

Discussion

This study provides an overview of commonly used metals in inexpensive jewellery, mainly earrings. Many different metals are used; copper, iron, nickel, and zinc are the most frequent. Also, the composition seemed not to depend on the country of purchase, although titanium was more commonly used in earrings from Japan. Based on experience from previous studies, it is our impression that much cheap jewellery is often produced in Asian countries, especially China, Thailand, Indonesia, and the Philippines. It is therefore not surprising that the composition is similar.

However, at present, we know very little about the number and size of wholesale producers.

In this study, we contribute a large new dataset on the composition of jewellery; particularly helpful are the data on nickel, cobalt and lead release determined by laboratory analysis, which is mandatory for assessing compliance with EU nickel regulations. Here, we will present a brief discussion of some of the metals and their potential role in allergic contact dermatitis. Iron, tin, zinc, silver and other metals will not be discussed, as these are considered only to cause contact allergy in very rare cases, and not to represent general contact allergy risk factors. Lead is well known to cause systemic toxicity, but it is seldom discussed in a dermatological context, although it is present in jewellery.

As expected, nickel was frequently found in the different samples of earrings. We have previously investigated the same items as used in this study with the DMG spot test, and found nickel release from a substantial proportion of them (14, 15, 19). Although XRF analysis does provide good semiquantitative data on the composition of base alloys without surface coating, it does not predict nickel release. Clinically, many nickel-allergic patients can tolerate earrings and jewellery that contain stainless steel, an alloy that generally contains nickel but

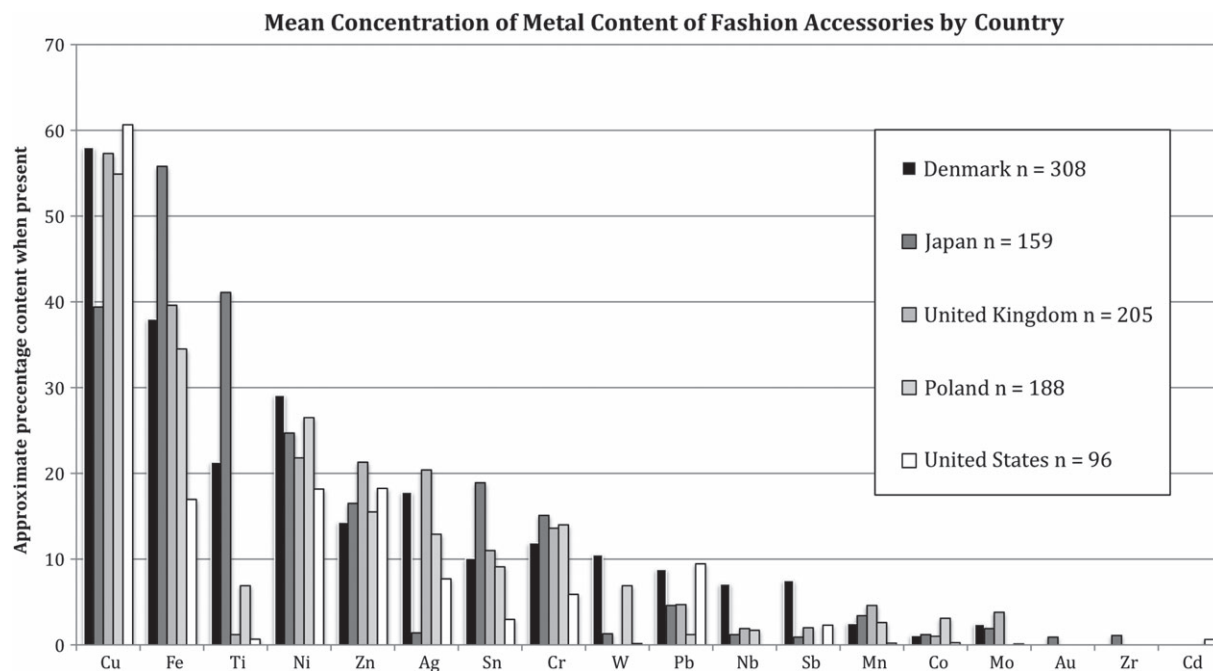


Fig. 1. Metal composition of randomly purchased inexpensive earrings and other fashion jewellery determined with X-ray fluorescence spectroscopy, arranged by relative approximate percentage and stratified by country of purchase.

generally does not release substantial amounts of nickel ions. In our study, nickel was often released in high amounts from the US samples, reaching up to $598 \mu\text{g}$ nickel/ cm^2 /week. We have not determined the rates of nickel release from the remaining jewellery. Nonetheless, it is alarming that nickel release from earrings is still so prevalent. It shows that the many advantageous properties of this metal, which is inexpensive, corrosion-resistant, and light, and has a silvery appearance, continue to motivate manufacturers to use this metal.

As assessed by XRF spectroscopy, cobalt was present in few jewellery items (<3%), and, when present, was found at low concentrations. However, cobalt release from approximately one-third of the San Francisco subsample was detected, ranging between 0.02 and $0.5 \mu\text{g}/\text{cm}^2$ /week. We have previously shown, with the cobalt spot test, that cobalt is infrequently released from fashion jewellery (22, 23). Nonetheless, we provide here an explanation for why cobalt may sometimes cause allergic cobalt dermatitis (17, 18), as cobalt-allergic individuals could potentially react to earrings that were investigated in the San Francisco study. We remind readers that previous studies have suggested that some jewellery with a dark appearance may release cobalt (22, 23). Cobalt is also used in gold jewellery to alter the gold colour, and in cobalt–chromium jewellery,

and it may be used as a substitute for nickel (4). It is suggested that cobalt-containing jewellery is more expensive than the relatively cheap items in the present study.

Copper was the most common metal found in our jewellery samples across all of the countries. Although copper is a weak contact sensitizer (24), relatively little is known about its role in allergic contact dermatitis. In Sweden, 1190 dermatitis patients were routinely patch tested with copper sulfate 2% in petrolatum (24). Only 13 had some test reactivity to copper sulfate, and 9 of these had concomitant allergy to nickel, cobalt, and/or chromium. The reactions to copper sulfate were considered to be non-relevant and not conclusive for true sensitivity to copper. No isolated reactions to copper were observed in that study. In Austria, 2260 patients were routinely tested with copper sulfate 2% in pet., and 3.5% of these had positive test reactions (25). These were also strongly associated with nickel, cobalt and chromium allergy, and, additionally, palladium allergy. Retesting of copper patch test-positive patients showed that only 38% of positive reactions could be reproduced in subsequent patch testing. An isolated patch test reaction to copper was found in an electrician with hand eczema, and was judged to be of clinical relevance. Moreover, 1 patient reacted to a gold ring that probably also contained copper (25). Another case report also suggested that exposure to

Table 2. Examples showing the broad variation in metal composition of fashion jewellery with high nickel content or high nickel release, according to X-ray fluorescence spectroscopy and immersion in artificial sweat

Item ID	Concentration of metals (%)											Ni release ($\mu\text{g}/\text{cm}^2/\text{week}$)
	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sb	Sn	Ti	Zn	
DK 1493	–	1	1	6	–	89	–	–	–	–	–	NA
UK 444	–	–	9	5	–	76	–	–	–	–	–	NA
DK 1363	–	–	16	4	–	71	–	–	–	–	–	NA
JP 45	–	–	22	1	–	67	–	–	–	–	–	NA
US 32	–	–	29	<1	–	65	–	–	<1	–	6	4
JP 146	–	–	34	–	–	64	–	–	–	–	–	NA
PL 858	–	–	–	35	–	64	–	–	–	–	–	NA
UK 424	–	–	34	–	–	64	–	–	–	1	–	NA
PL 864	–	–	22	24	–	63	–	–	–	–	–	NA
UK 459	–	2	6	31	1	62	–	–	–	–	–	NA
DK 1392	1	1	–	32	1	61	–	–	–	–	–	NA
PL 791	–	–	17	23	–	61	–	–	–	–	–	NA
JP 153	–	1	21	3	–	60	–	–	–	5	–	NA
US 55	–	–	5	42	<1	53	–	–	–	–	–	1.6
US 17	–	8	17	24	–	43	–	–	–	–	7	38
US 26	–	–	36	2	–	42	–	–	–	–	21	410
US 8	–	–	43	–	<1	38	–	–	–	–	19	204
US 51	–	–	73	–	–	18	5	1	1	–	1	598

–, not detected; DK, Denmark; JP, Japan; NA, not analysed; PL, Poland; UK, United Kingdom; US, United States. Items were purchased in Denmark, Japan, Poland, the United Kingdom, and the United States.

Table 3. Examples showing the broad variation in metal composition of fashion jewellery with high lead content or high lead release, according to X-ray fluorescence spectroscopy and immersion in artificial sweat

Item ID	Concentration of metals (%)												Pb release ($\mu\text{g}/\text{cm}^2/\text{week}$)
	Ag	Cr	Cu	Fe	Mn	Mo	Nb	Ni	Pb	Sb	Sn	Zn	
DK 1218	1	–	15	–	–	–	–	–	62	4	15	4	NA
US 23	–	1	1	1	–	–	–	31	60	4	1	<1	2718
DK 1197	4	–	38	–	–	–	–	–	40	–	17	–	NA
DK 1425	–	–	70	–	–	–	–	2	25	–	–	–	NA
DK 242	–	–	70	–	–	–	–	2	25	–	–	–	NA
DK 1285	6	–	66	–	–	–	3	–	23	1	10	–	NA
US 46	1	–	60	–	–	–	–	13	23	–	<1	2	0.2
US 52	–	–	75	–	–	–	–	–	23	1	–	<1	200
JP 1431	–	–	81	–	–	–	–	–	21	1	–	–	NA
UK 413	3	–	68	–	–	–	–	–	21	1	1	–	NA
JP 53	–	–	72	–	–	–	–	–	18	–	10	–	NA
UK 391	2	–	65	–	–	–	–	12	18	–	5	3	NA
UK 421	8	–	59	–	–	4	–	–	16	–	6	12	NA
UK 730	5	–	74	–	–	–	2	–	15	–	4	6	NA
DK 1284	–	–	25	22	1	–	–	24	14	2	–	–	NA
DK 1129	–	–	90	–	–	–	–	–	8	–	2	4	NA
US 73	–	–	69	<1	<1	–	–	5	1	–	1	24	13

–, not detected; DK, Denmark; JP, Japan; NA, not analysed; PL, Poland; UK, United Kingdom; US, United States. Items were purchased in Denmark, Japan, Poland, the United Kingdom, and the United States.

copper-containing jewellery (brass) caused dermatitis in a copper patch test-positive patient (26). Given all these findings, copper allergy seems to be an infrequent cause of allergic contact dermatitis, but should not be discounted in rare cases.

Simultaneous reactions to nickel and copper have been proposed to be explained by cross-reactivity. This has been shown both in clinical material and at the receptor level (27–29). In a copper migration study in which coins (95% Cu), copper-coated paper clips (0.005% Cu) and

copper thread (99.99% Cu) were left in artificial sweat for 24 hr, a final concentration of only 0.01% copper was found in the solution, under the conditions of the experiment. Release per surface area was not reported (30). The authors concluded that the concentration was too low to give positive test reactions, and that only highly sensitized individuals would react. Interestingly, a study investigating gold release from 13 different gold-containing jewellery materials showed high copper release from gold-plated brass (290 µg/cm²/week), and relatively low copper release from white gold and red gold alloys (range 0.05–0.72 µg/cm²/week) (6). No gold release was detected, although the utility of the analysis used for gold is now in question (31). As little is known about eventual cross-reactivity to gold and copper, this could potentially be of importance in cases with reactions to jewellery or other items made of gold alloys. At present, there is no evidence to support advising nickel-allergic individuals against wearing copper-containing earrings. Release studies are warranted to learn more about this.

Alarming, lead was identified in 10% of the earrings and other jewellery items that were assessed with XRF. Lead toxicity from ingestion of lead-containing items is far more common; however, percutaneous absorption of lead has been well described in both clinical cases and animal models (32). Lead toxicity is classically associated with neurological and renal dysfunction, sideroblastic anaemia, and non-specific complaints such as gastrointestinal disturbance and headaches. Of particular note, there was a very high level of lead release from an earring purchased in 2007 in the United States (2718 µg lead/cm²/week). However, this release figure cannot be reliably compared with other lead release values or limit values. Our method utilized immersion in artificial sweat for 1 week at 30°C for assessing compliance with the EU nickel regulation, and this is not a common method for assessing lead release (8–10). Although lead has traditionally been used in jewellery to make the articles heavier or to brighten colours, its use in jewellery in California, where the earring was purchased, has been restricted since 2006, because of health concerns (<http://www.leginfo.ca.gov/cgi-bin/displaycode?section=hsc&group=25001-26000&file=25214.1-25214.4.2>). Similarly, the use of cadmium is restricted by California's metal-containing jewellery law, as children may suck, chew or bite on such jewellery, and thus be exposed.

The authorities are aware of the problem, and, during 2009–2012, the California Department of Toxic Substances Control visited 11 stores and warehouses, and discovered >340 jewellery items containing lead levels exceeding regulatory limits (<http://www.leginfo.ca.gov/cgi-bin/displaycode?section=hsc&group=25001-26000&file=25214.1-25214.4.2>). At present, under California state law, lead levels in children's jewellery must be <0.06%. In adult jewellery, permissible lead levels are set as high as 6% or as low as 0.06%, depending on the type of material used in the jewellery. In 2012, it was likewise decided to prohibit jewellery articles in the EU if the lead concentration is ≥0.05% by weight of any individual part thereof. The restriction is part of the European chemicals regulation REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) (33).

Palladium and platinum, which are expensive metals, were not identified in the present study, but are found in high-end jewellery. Gold, which is a potential allergen that has been much debated, was incidentally found in two earrings from Japan. On the basis of our composition data, patch testers may reliably screen for jewellery-related contact dermatitis with nickel, cobalt, and chromium. However, for silversmiths, goldsmiths, metal platers, jewellery manufacturing/polishing workers, or consumers with dermatitis suspicious for jewellery without nickel, cobalt or chromium patch test positivity, patch testing with additional metals (copper, gold, manganese, molybdenum, palladium, platinum, rhodium, or titanium) may be undertaken.

We conclude that many different metals, including common skin sensitizers and toxic lead, are used to produce inexpensive jewellery including common metal sensitizers. Patch testers should be aware of the possible need to patch test patients with jewellery-related dermatitis with metals beyond the baseline series. Much remains to be done by regulators, authorities, jewellery manufacturers, importers and retailers globally to protect the health of consumers and workers.

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