

Coin exposure may cause allergic nickel dermatitis: a review

Jacob P. Thyssen¹, David J. Gawkrödger², Ian R. White³, Anneli Julander⁴, Torkil Menné¹ and Carola Lidén⁴

¹Department of Dermato-Allergology, National Allergy Research Centre, Copenhagen University Hospital Gentofte, DK-2900 Hellerup, Denmark,

²Department of Dermatology, Royal Hallamshire Hospital, Sheffield S10 2JF, UK, ³Department of Cutaneous Allergy, St John's Institute of Dermatology, London SE1 7EH, UK, and ⁴Institute of Environmental Medicine, Karolinska Institutet, SE-171 77 Stockholm, Sweden

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Summary

Nickel is used in coins because the metal has beneficial properties, including price, colour, weight, and corrosion resistance, and also because it is easy to stamp. It has often been claimed that the duration of skin contact with coins is too short to cause nickel release and dermatitis. However, it is well known by dermatologists specialized in occupational skin diseases, and by their nickel-allergic patients, that hand eczema in cashiers and other professionals who handle coins may be caused or aggravated by nickel release from coins. In this review, we present evidence from past studies showing that nickel-containing coins can indeed pose a risk for those who handle them. For protection of the health of consumers, cashiers, and other workers who handle coins, it is suggested that coins without nickel release should be used as a substitute for the high nickel-releasing coins currently in widespread use. The key risk factor in this situation is the ability of metal alloys in coins to release nickel and contaminate the skin after repeated contact from coin handling.

Key words: coins; hand eczema; nickel allergy; nickel release; public health; risk assessment; skin exposure.

Nickel allergy is prevalent, affecting 10–30% of women and 1–3% of men (1, 2). It is mainly caused by repeated or prolonged exposure to nickel-releasing items such as jewellery, buttons, and belts (3–10). However, skin contact with any item that releases nickel in sufficient amounts may cause contact allergy and dermatitis, as shown recently by the increasing use of metallic mobile phones and laptop computers (11). When sensitized individuals develop allergic nickel dermatitis, the eruption is typically located at the site of nickel exposure, such as the hands or face, or under jewellery and buttons. The reaction can also be systemic if a high amount of nickel is deposited on the skin (12), or if the individual is

exposed orally (13, 14). Genetic predisposition to nickel allergy does exist (15–18), but nickel allergy is mainly an environmental disorder caused by nickel release from manufactured items in contact with the skin, as shown by the lower prevalence of nickel allergy in men. Allergic nickel dermatitis remains an occupational problem, as work tools and materials may release nickel in high enough amounts (19, 20). This may result in hand eczema, a chronic condition that can result in poor quality of life, reduced ability to work, and large costs to individuals and society (21–23).

A coin can be defined as a piece of hard material that is standardized in weight and is produced in large quantities to facilitate trade. Nickel is used in coins because the metal, according to industry, has excellent properties, including low cost, a shiny surface, sufficient weight, and corrosion resistance, and also because many nickel-containing materials are easy to stamp and can be recycled (24). It has often been claimed that the duration of skin contact with coins is too short to cause release

Correspondence: Jacob P. Thyssen, Department of Dermatolo-Allergology, National Allergy Research Centre, Gentofte Hospital, University of Copenhagen, 2900 Hellerup, Denmark. Tel: +45 3977 3977; Fax: +45 3977 7118. E-mail: jacob.p.thyssen@regionh.dk

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of nickel and dermatitis (25, 26). However, it is well known by dermatologists specialized in occupational skin diseases, and by their nickel-allergic patients, that hand eczema in cashiers and other professionals who handle coins may be caused or aggravated by coins. In this review, we present evidence from past studies showing that nickel-containing coins can indeed pose a risk for those who handle them, and argue that central banks and mint manufacturers should carefully consider the future use of nickel in coins.

Materials and Methods

An online literature search using Pubmed-Medline was performed during January and February 2012, with the following search terms: nickel, metal, hand eczema, hand dermatitis, allergic contact dermatitis, coins, and coinage. The search terms were applied to the database in different combinations, to identify relevant articles. No limits in terms of time periods or types of article were chosen in the Pubmed-Medline search, meaning that articles from the early 20th century until 2012 were included, as well as case reports, clinical trials, original research, and review articles. However, only articles written in English were included. Additionally, databases were searched by the use of the 'related articles' function. References were localized by the use of reference lists in selected articles and reports. J. P. Thyssen performed the online literature search, and the remaining authors provided reports on coin exposure.

Aspects of Risk Assessment of Nickel Allergy and Dermatitis

When attempts are made to assess the risk of nickel exposure from coins, and the resulting allergy and dermatitis, it is relevant to distinguish between prolonged and intermittent skin contact.

Prolonged skin contact

In terms of nickel allergy and dermatitis, nickel can be used safely in alloys as long as the nickel is tightly bound and not released in high concentrations upon contact with the skin. It seems to be impossible to define a safe threshold level that will protect all individuals from nickel allergy and dermatitis, as sensitization and elicitation thresholds differ at least 250-fold (27, 28), and some nickel-allergic individuals may react to even very low amounts of nickel (29). It is important to understand the basis for the risk assessment underlying the 1994 EU Nickel Directive (since 2009, part of REACH), a regulation that aims to

prevent nickel allergy and dermatitis by limiting nickel exposure from items intended to be in prolonged skin contact, for example jewellery, buttons, belts, and hair clasps (30). The regulation states that items that will have direct and prolonged contact with the skin should not release more than 0.5 μg nickel/ cm^2 /week, and items for pierced holes not more than 0.2 μg / cm^2 /week. The reference test method for showing compliance with the regulation (EN 1811) specifies that items should be immersed in artificial sweat for 1 week (31); the nickel concentration in the solution is then analysed, and the nickel release calculated. The concept 'prolonged contact with the skin' is not defined in the regulation, but is currently being discussed in the European Commission, and may in the future cover the situation of repeated contact occurring over a period of hours. The limit value of 0.5 μg / cm^2 /week in the regulation and the reference test method EN 1811 was based on large patch test studies in which nickel-allergic subjects were patch tested with metallic discs of known composition, and the nickel release rates were determined as part of the studies (4, 32). Discs that caused allergic nickel dermatitis typically released more than 0.5 μg / cm^2 /week; hence the basis for the regulation. The regulation has proven to be successful, as the rates of nickel allergy and dermatitis have decreased in parts of Europe (33–35).

Intermittent skin contact

Some believe that intermittent skin contact with nickel-releasing items (e.g. coins and keys) is insufficient to cause nickel allergy and dermatitis. We propose that this is incorrect, and suggest that, when attempts are made to address this issue, there is a need for integration of knowledge derived from several studies. It is clear that skin contact with coins is mostly intermittent, and rarely prolonged. Although consumers typically handle coins for short periods of time, cashiers and shop assistants may have contact with coins over long periods of their work day, and hence be heavily exposed to nickel on their hands. For these individuals, coin exposure can indeed be considered to be prolonged. Dose–response elicitation studies have shown that the dose of contact allergen per application that elicits a reaction in the repeated open application test is substantially lower than the dose required to elicit a reaction in the single-dose closed patch test in a period of 2 days (36). Moreover, a recent experimental study showed that three exposures to 10 μg / cm^2 2,4-dinitrochlorobenzene (DNCB, an experimental strong skin sensitizer), that is, 30 μg / cm^2 cumulatively, led to the same degree of sensitization as one exposure to 60 μg / cm^2 DNCB (37).

Thus, repeated exposure to even low amounts of nickel, as occurs when coins are handled, may in fact considerably increase the risk of sensitization and elicitation of dermatitis. It can therefore be compared with prolonged exposure.

Nickel Use in Coins

Different metals and alloys are used to produce coins. The first coins were made of precious metals such as gold and silver, but as states and governments could not supply enough precious metals for the coins, the use of base metals such as nickel, copper, manganese, zinc and aluminium was introduced. Such changes led to reductions in the intrinsic value of coins, but were necessary for the authorities to produce more coins. An overview of coin alloys, platings and the terminology used in this review is provided in Table 1. The use of nickel in coins increased during the mid-19th century as pure nickel coins came into circulation (24). The US coinage system is unusual, because the composition of US coins has been only slightly modified since the middle of the 19th century. A review article detailed the use of nickel in US coinage, and can be consulted by interested readers (38). In Table 2, we provide an overview of the composition of coins currently in use in the EU euro zone, the United Kingdom, Denmark, Sweden, and the United States. As it can be seen, nickel is widely used in coins, typically as copper–nickel (i.e. Cu 75; Ni 25) and other alloys and plating, causing putative nickel exposure of almost 1 billion people in these countries alone.

Nickel Release from Coins

Several studies have, under different test conditions, investigated nickel release from coins. The results are summarized in Table 3 (39–44). The composition and size of coins, and solvents, duration and temperature for immersion have varied widely, and the nickel release has been expressed as $\mu\text{g}/\text{cm}^2$ or $\mu\text{g}/\text{coin}$ and time unit. Thus, great care is required when results from different studies are compared. The main conclusions resulting from an assessment of the nickel allergy risk caused by coins, based on these studies, are the following.

Experimental conditions

Artificial sweat versus water. Nickel release is substantially higher in artificial sweat than in water. This has been shown in parallel experiments with coins of copper–nickel, nickel–brass, pure nickel, and other

composition, the difference varying between coin materials, and increasing with duration of immersion (Table 3) (39, 41, 43, 44).

Temperature. Nickel release increases with temperature. When the temperature was increased from 20°C to 35°C, nickel release increased by one-third, in a study where copper–nickel coins were immersed for 24 hr in artificial sweat (Table 3) (41). According to EN 1811, the immersion temperature should be 30°C.

Duration of immersion. The amount of released nickel increases with duration of immersion (Table 3). Generally, nickel release studies have immersed coins in artificial sweat for 24 hr or 1 week. Few studies have investigated shorter durations, such as 2 min or 1 hr, and considerable amounts of nickel were released within 2 min from coins of copper–nickel, nickel–brass, and pure nickel (approximately 1–3 $\mu\text{g}/\text{coin}$ and 0.1–0.3 $\mu\text{g}/\text{cm}^2$) (40, 44, 45). According to EN 1811, the duration of immersion should be 1 week.

Alloys. Tables 3 and 4 show that the ability to release nickel is not directly linked to the nickel concentration, a fact that is well known among metallurgists and corrosion experts (25). The background is that metals in alloys have different properties from pure metals, partly governed by the galvanic properties of metals. Ideally, comparison of nickel release from different coin materials should be based on data from the same experiment, as variation between experiments and conditions may be considerable, particularly for materials with high nickel release and immersion of long duration (Table 3). It should be recalled that EN 1811 is fine-tuned for assessing nickel release around the limit value of the EU nickel regulation (0.5 $\mu\text{g}/\text{cm}^2/\text{week}$). The relative order of magnitude of nickel release from coins differed when coins were immersed in artificial sweat for 2 min and 1 week (Table 3) (39). The highest 2 min release value was from nickel–brass (0.34 $\mu\text{g}/\text{coin}$), whereas the highest 1 week value was from copper–nickel (38 $\mu\text{g}/\text{cm}^2$). It is interesting that pure nickel gave a relatively high 2 min release value (0.27 $\mu\text{g}/\text{coin}$) and a relatively low 1 week value (4.3 $\mu\text{g}/\text{cm}^2$). When the euro coins were introduced, it was debated whether they posed larger allergy risks than the former national coins. It was shown that 1 euro and 2 euro coins (combination of copper–nickel and nickel–brass) released much nickel (Table 3). It was suggested that they released more nickel than copper–nickel coins, owing to a galvanic effect resulting from the combination of the two alloys (42). However, no significant difference between nickel release

Table 1. Coin alloys, platings and terminology in this review

Name of coin alloy and composition of coins ^a	Composition of alloys and platings – metals and concentration (%)	Examples (see also Table 2)
<i>Acmonital</i> , Italian monetary steel, stainless steel	Fe 81.5; Cr 18.5	50, 100, 500 lire (steel part) (ITL) ^b
<i>Aluminium–bronze</i>	Cu 92; Al 6; Ni 2	20 krone (DKK), 500 lire (yellow part) (ITL) ^b 10 centime (FRF) ^b
<i>Bronze</i>	Cu 97; Zn 2.5; Sn 0.5	50 øre (DKK)
<i>Copper–nickel</i> , cupronickel, CuNi	Cu 75; Ni 25	1, 2 euro (silver-coloured part) (EUR). Many other coins worldwide (including GBP, DKK, SEK, USD)
	Cu 84; Ni 16	20 pence (GBP)
<i>Manganese–brass</i>	Cu 88.5; Zn 6; Mn 3.5; Ni 2	1 dollar (USD)
<i>Nickel</i>	Ni 100	1, 2 franc (FRF) ^b
<i>Nickel–brass</i>	Cu 75; Zn 20; Ni 5	1, 2 euro (yellow part) (EUR), 1 pound (GBP)
<i>Nordic gold</i>	Cu 89; Al 5; Zn 5; Sn 1	10, 20, 50 cent (EUR), 10 krona (SEK)
<i>Silver in CuNiZn</i>	Ag 40 in Cu 50; Ni 5; Zn 5	1 krona (SEK) ^c
<i>Plated, covered</i>	CuNi-plated Cu	10, 25, 50 cent (USD)
	Cu-plated steel	1, 2, 5 cent (EUR) 1, 2 pence (GBP)
	Cu-plated Zn	1 cent (USD)
	Ni-plated steel	5, 10 pence (GBP) ^d
<i>Combination coins</i> , bi-colour, bi-metallic	Outer and inner parts of different alloy (two colours)	1, 2 euro (EUR) 2 pound (GBP)
<i>Three layers</i>	A core with a layer of other alloy or metal on each surface	5 krona (SEK), 1, 2 euro (inner part) (EUR)

^aItalics = expression used throughout this paper; normal font = other often used expression.

^bReplaced by the euro.

^cManufactured until 1968.

^dIntroduced in 2012.

from copper–nickel coins (1 krona $\approx$ 1 Swedish crown) and that from combined copper–nickel and nickel–brass coins (1 euro and 2 euro) was shown after 2 min or 1 week, when they were assessed in the same experiment (Table 3) (40, 44). It was shown, by 1 week of immersion in aqueous solution at different pH levels, that more nickel was released from combined copper–nickel and nickel–brass coins than from pure nickel coins, whereas more nickel was available on the surface of pure nickel coins than on those of the combined copper–nickel and nickel–brass coins when they were rubbed with a wipe (Table 4) (46). The effect of corrosion combined with friction was studied. It was shown that rubbing decreased nickel release from a 2 euro coin, emphasizing that corrosion is only one important factor in nickel release (Table 4) (47). We consider that short-term immersion in artificial sweat is more relevant and useful than immersion for 1 week in the assessment of nickel release

from coins and other items in short and repeated contact with the skin.

Deposition of Nickel on the Skin

Important information has been obtained from nickel deposition studies using different sampling techniques, namely hand washing, wipe sampling, and finger immersion (Table 5). A pioneering Swedish study showed that nickel was found in various concentrations on the hands of volunteers who were counting washed or used 1 krona coins for 5 min (mean 32 and 37 μ g/person, respectively) and on the hands of shop assistants after 4 hr at work in which some coin handling was performed (mean 50 μ g/person) (Table 5) (43). Polishing of coins, but not rinsing, affected the contamination of the fingers in individuals who handled the coins repeatedly for $\sim$ 3 min (46). Hence, the authors suggested that metallic

Table 2. Metal composition (alloys and platings) of coins in circulation in 2012 in the EU countries that have adopted the euro (euro area), the United Kingdom, Denmark, Sweden, and the United States

Euro area Euro (EUR)	UK Pound sterling (GBP)	Denmark Danish krone (DKK)	Sweden Swedish krona (SEK)	USA US dollar (USD)
2 euro Outer silver-coloured part: Cu 75; Ni 25 Inner yellow part: Three layers: Cu 75; Zn 20; Ni 5 Ni 100 Cu 75; Zn 20; Ni 5	5 pound Cu 75; Ni 25	20 krone 10 krone Cu 92; Al 6; Ni 2	10 krona Cu 89; Al 5; Zn 5; Sn 1	1 dollar Cu 88.5; Zn 6; Mn 3.5; Ni 2
1 euro Outer yellow part: Cu 75; Zn 20; Ni 5 Inner silver-coloured part: Three layers: Cu 75; Ni 25 Ni 100 Cu 75; Ni 25	2 pound Outer yellow part: Cu 76; Zn 20; Ni 4 Inner silver-coloured part: Cu 75; Ni 25		5 krona Three layers: Cu 75; Ni 25 Ni 100 Cu 75; Ni 25	50 cent (half dollar) 25 cent (quarter) 10 cent (dime) CuNi-plated Cu
50 cent Cu 89; Al 5; Zn 5; Sn 1	1 pound Cu 70; Zn 24.5; Ni 5.5	5 krone Cu 75; Ni 25	2 krona Cu 75; Ni 25	
20 cent Cu 75; Ni 25	50 pence Cu 75; Ni 25	2 krone Cu 75; Ni 25	1 krona Cu 75; Ni 25	
10 cent Cu-plated steel	20 pence Cu 84; Ni 16	1 krone		5 cents (nickel) Cu 75; Ni 25
5 cent Cu-plated steel	10 pence Cu 75; Ni 25 and ^a	50 øre Cu 97; Zn 2.5; Sn 0.5		1 cent (cent) Cu-plated Zn
2 cent Ni-plated steel	5 pence Ni-plated steel			
1 cent Cu-plated steel	2 pence Cu-plated steel			
	1 penny			

Name of currency, ISO code, and coinage, by country. Information was collected from national currency web-pages and a numismatic web-page. When different compositions of a coin existed, the most recent is listed. Terminology is harmonized according to Table 1, to facilitate comparison.

Euro: <http://www.ecb.int/euro/coins/common/html/index.en.html>

Pound sterling: <http://www.royalmint.com/Corporate/facts/coins/OnePoundCoin.aspx>

Danish krone: http://www.nationalbanken.dk/DNUK/NotesAndCoins.nsf/site/Denmarks_coin_series/OpenDocument

Swedish krona: <http://www.riksbank.se/templates/Page.aspx?id=9120>

US dollar: http://www.usmint.gov/about_the_mint/?action=coin_specifications

Numista online catalog: <http://en.numista.com/catalogue/pays.php>

Specifications on Danish coins were partly obtained by personal correspondence with H. Denkov from the national bank in Denmark.

^aIntroduced in 2012.

Table 3. Nickel release from coins

Alloy and plating	Coin	Test conditions for immersion: solvent/temperature/duration	Released amount of Ni (mean)/surface area/time	References
Copper–nickel	1 krona	Distilled water/24 hr	15 µg/coin/24 hr	(43)
Silver in CuNiZn	1 krona		49 µg/coin/24 hr	
Copper–nickel	1 krona	Artificial sweat/24 hr	137 µg/coin/24 hr	(41)
Silver in CuNiZn	1 krona		96 µg/coin/24 hr	
Copper–nickel	1 krone	Distilled water/20°C/24 hr	20 µg/coin/24 hr	(44)
		Artificial sweat/20°C/24 hr	409 µg/coin/24 hr	
		Artificial sweat/35°C/24 hr	691 µg/coin/24 hr	
Copper–nickel and nickel–brass	2 euro	Artificial sweat/2 min	0.23–0.84 µg/cm ² /2 min (four laboratories)	(44)
		Artificial sweat/1 week	23–65 µg/cm ² /week (four laboratories)	
Copper–nickel	1 krona	Artificial sweat/20°C/2 min	0.98 µg/coin/2 min	(39)
Cu-plated steel	2 pence		0.19 µg/coin/2 min	
Copper–nickel	10 pence		1.2 µg/coin/2 min	
	20 pence		1.5 µg/coin/2 min	
Nickel–brass	1 pound		3.4 µg/coin/2 min	
Aluminium–bronze	10 centime		0.14 µg/coin/2 min	
Nickel	1 franc		2.8 µg/coin/2 min	
Copper–nickel	1 krona	Artificial sweat/30°C/1 week	38 µg/cm ² /week	
Nordic gold	10 krona		0.09 cm ² /week	(42)
Cu-plated steel	2 pence		Not detected	
Copper–nickel	10 pence		28 µg/cm ² /week	
	20 pence		14 µg/cm ² /week	
Nickel–brass	1 pound		15 µg/cm ² /week	
Aluminium–bronze	10 centime		2.2 µg/cm ² /week	
Nickel	1 franc		4.3 µg/cm ² /week	
Cu-plated steel	50 cent	EN 1811 (conditions not specified)	Not detected	
Copper–nickel and nickel–brass	1 euro		Approximately 120 µg/cm ² /week	(40)
	2 euro		Approximately 160 µg/cm ² /week	
Copper–nickel	1 krona	Artificial sweat/20°C/2 min	0.11 µg/cm ² /2 min	(40)
Copper–nickel and nickel–brass	1 euro		0.25 µg/cm ² /2 min	
	2 euro		0.22 µg/cm ² /2 min	
Copper–nickel	1 krona	Artificial sweat/30°C/1 hr; 24 hr; 1 week	4.3, 52, 121 µg/cm ² /hr, 24 hr, week	(40)
Copper–nickel and nickel–brass	1 euro	Artificial sweat/30°C/1 week	86 µg/cm ² /week	
	2 euro		99 µg/cm ² /week	

Different methods for immersion in artificial sweat or water. Krona (SEK); krone (DKK); pence, pound (GBP); centime, franc (FRF).

contamination of the fingers and hands resulted from pre-existing metallic ions on the surface of the coins.

Two sampling methods have recently been developed to measure the amounts of nickel and other metals deposited on the skin: finger immersion and acid wipe sampling (48, 50). The finger immersion method measures nickel on the skin by immersion of the fingers in tubes containing ultrapure water and chemical analysis of the nickel content (48). It was shown that nickel contamination of the fingers was in direct proportion to the exposure time of rubbing coins, although the slope varied between the participants. This was based on results from two volunteers who each rubbed different pre-cleaned 20 pence coins between their thumbs and

index fingers for 10 seconds to 10 min. The total nickel concentrations on the fingers of individuals from different occupations were also assessed, and ranged from 6.3 to 65 ng/cm² (0.0063–0.065 µg/cm²) in six cashiers. Nickel levels were, as expected, much higher in nickel refinery workers and platers. In recent work, the finger immersion method was slightly refined by taking into account that the method averages the amount of nickel over the whole finger, and therefore does not consider that most nickel is deposited on the volar aspect of the fingertip (49). A correction factor was introduced, and the corrected nickel levels reached a mean value of 0.15 µg/cm² in cashiers after at least 1 hr of work, as compared with 0.058 µg/cm² in office staff.

Table 4. Nickel release from coins, assessed by other methods than immersion of whole coins in artificial sweat or water

Alloy	Coin	Method/solvent/temperature/ duration	Released amount of Ni (mean)/surface area/time	References
Copper–nickel and nickel–brass	2 euro	Aqueous solution, initial pH range between 2 and 11/25°C/1 week	2 euro released more nickel than 2 franc/week at pH between 3 and 10	(46)
Nickel	2 franc			
Copper–nickel and nickel–brass	2 euro	Rubbing coins with commercial skin wipes to assess amount of nickel available on surface	5 µg/coin	
Nickel	2 franc		12 µg/coin	
Nickel–brass	2 euro (innerpart)	Corrosion with artificial sweat/1 hr Corrosion combined with friction (tribocorrosion)/1 hr	211 µg/cm ² /hr 37 µg/cm ² /hr	(47)

Table 5. Nickel deposited onto skin by coin handling: exposures, sampling methods, and skin dose

Occupation or type of exposure/duration; subjects (no.)	Sampling method	Nickel on skin (mean) and area/time	References
Manipulating coins (ether-washed) in laboratory/1 krona/5 min; volunteers (n = 13)	Washing hands with distilled water and nickel-free soap	32 µg/person/5 min	(43)
Manipulating used coins in laboratory/1 krona/5 min; volunteers (n = 30)		37 µg/person/5 min	
Shop assistants in Sweden/4 hr (n = 5)		50 µg/person/4 hr	
Manipulating coins (unwashed, washed or polished) in laboratory/2 franc or 2 euro/3 min each in separate experiments; volunteers (n = 8; n = 4; n = 4)	Wipe sampling by rubbing three fingers (volar thumb, index finger, and middle finger) with commercial skin wipes	1 franc: 0.38, 0.46 and 0.009 µg 2 euro: 0.23, 0.26 and 0.012 µg on three fingers/3 min Unwashed, washed and polished coins respectively	(46)
Cashiers in Sweden/10–185 min (n = 7) Secretaries/1 hr (n = 4); and other professionals (hands were cleaned before exposure)	Acid wipe sampling from defined areas on both hands (palm, tip of thumb, index finger, and middle finger) with cellulose wipes and 1% nitric acid	Cashiers: 0.20 µg/cm ² on hands/hr Secretaries: 0.018 µg/cm ² on hands/hr	(39)
Manipulating coins in laboratory/1 krona or 2 euro/1 hr in separate experiments; volunteers (n = 3) (coins were washed and hands were cleaned before exposure)	Acid wipe sampling from defined areas on both hands (tip of thumb, index finger, and middle finger) with cellulose wipes and 1% nitric acid	1 krona: 1.7 µg/cm ² on fingers/hr 2 euro: 1.4 µg/cm ² on fingers/hr	(40)
Cashiers in the UK (n = 6); and other professionals	Immersion of fingers (thumb and index finger) in ultrapure water	Cashiers: 0.029 µg/cm ² on fingers/after work	(48)
Cashiers in the UK (n = 7) Office staff (n = 5); and other professionals	Immersion of fingers (thumb and index finger) in ultrapure water; measured value and value corrected for uneven distribution on fingers	Cashiers: 0.017 (corrected 0.15) µg/cm ² /at least 1 hr of work Office staff: 0.007 (corrected 0.058) µg/cm ² /at least 1 hr of work	(49)

Acid wipe sampling, a method that samples >90% of metals from the skin, has so far been used successfully to measure the amount of nickel deposited onto the hands in cashiers and other workers performing their normal work (45), in an experiment comparing handling of different coins (40), in metal workers (51), and in patients with nickel allergy and hand eczema (52). In

the first occupational study, the mean deposition of nickel on the hands of seven cashiers was 0.20 µg/cm²/hr, as compared with 0.018 µg/cm²/hr for secretaries, 0.077 µg/cm²/hr for carpenters, and 0.36 µg/cm²/hr for locksmiths (40). In the study comparing coins, 3 volunteers were instructed to simulate a cashier's work by handling, respectively, 25 copper–nickel coins (1 krona)

for 1 hr on 1 day, and 25 copper–nickel and nickel–brass combination coins (2 euro) 4 days later (40). Nickel was deposited on the hands in significant amounts after only 1 hr of coin handling ($0.09\text{--}4.1\text{ }\mu\text{g}/\text{cm}^2$), with the largest amounts on the fingers. Similar amounts were deposited from 1 krona and 2 euro coins (40). The recent studies clearly show that the amounts of nickel deposited onto the skin in individuals handling coins during a work day can be significant.

Case Evidence of Nickel Allergy and Dermatitis from Coin Handling

Numerous case reports have been published. A few illustrative examples are presented here. German case reports from the 1930s have previously been reviewed elsewhere (53). In 1930, an obstinate case of dermatitis affecting the hands, forearms, shoulders and neck was reported (54). The patient worked at counting coins all day for the Budapest City Tramway Company, and was diagnosed with nickel allergy on the basis of 24 hr of testing with nickel coins. The patient was advised to ask his directors for different work procedures, and this request was granted. Four weeks later, all eruptions had cleared. In 1977, 5 patients with palmar hand eczema caused by prolonged contact with British coins were described (55). They were all engaged in money counting, and their eruptions disappeared once they disengaged from this activity. Dermatitis was located on the palms, and in particular on the fingers in several patients. It is of note that primary sensitization was suspected in 1 patient. A woman who occasionally worked as a cashier developed hand eczema each year when she was engaged in money handling (56). Among 7 female cashiers who were nickel-allergic, only 1 had definite hand eczema worsened by coin handling (57). A nickel-allergic bank clerk who counted coins for half of the work day developed dermatitis on the fingers, and later the hands (58). Vacations and changed work tasks resulted in complete healing. The investigators believed that the patient had been sensitized by coin handling, as she had never reacted to jewellery or other metallic items. Two nickel-allergic patients were reported: one developed dermatitis on the nose and the finger from rubbing a coin against the nose when it itched; the other one developed dermatitis on the finger, because he often carried a coin in the finger portion of the glove (26).

A nickel-allergic cashier with hand eczema experienced improvement of dermatitis when not at work (53). When a nickel-containing coin was applied to her palms for 20 min, and she was asked to refrain from washing her hands for 4 hr, 24 hr inspection showed erythema. A case report described 2 nickel-allergic Indians with

hand eczema whose job was to change paper money into coins (59). It is likely that dermatitis caused by coins is common outside of Europe, for example in the developing countries, although cases are not reported. The accumulation of case reports indicates that excessive cutaneous exposure to coins, as seen in cashiers and other occupational groups handling money, may result in nickel sensitization and dermatitis.

Epidemiological Studies

Few epidemiological and observational studies have investigated the association between occupational exposure to coins and nickel dermatitis. We consider these studies to be of limited value, as many factors may predispose to hand eczema, including genetic predisposition, atopic dermatitis, other contact allergies, and wet work (60). Also, a healthy worker effect may affect the outcome. The prevalence of hand eczema was much higher in nickel-allergic cashiers (72%) than in nickel-allergic patients from 'less exposed populations' (25%) (61). Moreover, only 7 of 30 cashiers had nickel allergy (62). The prevalences of hand eczema among nickel-allergic cashiers, hairdressers and office workers were 50%, 14%, and 14%, respectively (44). The 1-year prevalence of hand eczema was similar among occupational groups exposed to coins and other agents, for example foods, oils, solvents, and paints (22). The annual rate of nickel contact dermatitis was 2.2/100 000 among cashiers and counter clerks but 23.9/100 000 among hairdressers when occupational data for the period 1993–1999 were analysed (63). However, no adjustment for age or sex was performed, which should be taken into account when interpreting these data. A large-scale German study showed that the nickel allergy prevalence ratio for cashiers was similar to those of other occupational groups, for example household workers, cooks, and cleaners, but lower than the prevalence ratio for metal workers (64).

Patch Test Reactivity to Coins

Several old reports, not mentioned in this review, showed positive patch test reactions to coins in nickel-allergic individuals (26, 65). Studies concerning the euro coins are presented. Positive dimethylglyoxime test reactivity and positive patch test reactions to 1 euro and 2 euro coins was shown (66), and it was argued that these coins were not safe for consumers (67). Moreover, reactivity to 1 euro coins applied for 48 hr to, respectively, the volar aspect of the forearms, and the thenar and the palmar sides of the thumbs, was investigated (68). Positive reactions were observed on the forearms of all 10 nickel-allergic

individuals, but not in the 5 controls, whereas reactivity on the thenars and thumbs was observed in only one very nickel-allergic patient. The authors suggested that the protection provided by the thick epidermis on the hands could explain their findings. Nickel-allergic patients showed stronger patch test reactions when patch tested with 1 euro and 2 euro coins than when tested with 500 lire coins (combination coin with aluminium–bronze and stainless steel; see Table 1) (69). Finally, one study showed that patients with the strongest patch test reactivity to 1 euro and 2 euro coins reacted to the lowest nickel concentrations (70).

Hand Eczema Resulting from Nickel Exposure

It is beyond the scope of this article to review the association between hand eczema and nickel allergy. Despite conflicting results in epidemiological studies (2, 71–73), nickel exposure in sufficient concentrations on the hands of nickel-allergic individuals will elicit dermatitis in most individuals, although skin ‘hardening’ (suggested loss of reactivity as a result of constant or intermittent exposure) may prevent nickel dermatitis in some individuals (65). A few experimental studies on coin exposure have been performed. No exacerbation of hand eczema of the pompholyx type was observed when 11 nickel-allergic patients stirred their hands in a jar containing 1 kg of nickel-releasing items, mainly copper–nickel coins, for 6 min (74). However, it is important to note that pompholyx (now referred to as ‘acute and recurrent vesicular hand eczema’) is a subtype of hand eczema, and that it might not be representative of all types of hand eczema. Furthermore, 6 min of nickel exposure is a short period of time as compared with the duration of professional coin handling, which can last for hours or a full day, 5 days/week. When 3 nickel-allergic cashiers, who worked in a cafeteria and had work-related deterioration of their hand eczema, were asked to count cupronickel coins for 15 min/day without washing their hands until the next morning (75), 2 of them developed vesicular dermatitis on their fingers and palms after 2–3 days, whereas the third did not develop any symptoms after 5 days. A blinded controlled cross-over exposure study of 18 subjects (10 nickel-allergic and 8 non-nickel-allergic) was conducted with Canadian 5 cent coins (Cu 75; Ni 25) and 1 cent coins (Cu 98; Zn 2; or copper-plated zinc) taken from circulation (76). The participants were instructed to handle 10 coins (either nickel-containing or non-nickel-containing) for 5 min, followed by 5 min of rest, for 8 hr/day over a 12-day period. No differences were found between the two groups regarding erythema, transepidermal water loss, or blood flow volume, and no signs of dermatitis were

observed in nickel-allergic subjects. The Royal Swedish Mint requested a study to assess the risk of dermatitis caused by nickel in coins (77). A reference group of nine European dermatologists was formed to plan and conduct a provocation study, preceded by a limited pilot study. Investigations were performed in Denmark, Italy, The Netherlands, Spain, Switzerland, and Sweden. The main study included 40 nickel-allergic volunteers with ongoing hand eczema who were asked to count and stack either 50 1 krona (Cu 75; Ni 25) or 10-krona (Cu 89; Al 5; Zn 5; Sn 1) coins for 4 hr, imitating tasks performed by cashiers. Their hands were inspected in a blinded manner by dermatologists just before the provocations, and 4, 24 and 48 hr after: 14 of 21 participants in the 1 krona group and 9 of 19 in the 10 krona group had worsening of their hand eczema after 48 hr. Lesions on the fingers and hands were more aggravated and spread in the 1 krona group. Thirteen of 21 participants from the 1 krona group reported worsening of their symptoms, in comparison with 8 of 19 from the 10 krona group.

It is the experience of dermatologists and their patients that nickel exposure from coin handling may result in allergic nickel dermatitis. A double-blind placebo-controlled exposure study convincingly showed a statistically significant aggravation of hand eczema when patients with nickel allergy and mild to moderate hand eczema were exposed to 10–100 ppm nickel for 10 min/day over a 2-week period (78). The acid wipe sampling study performed by the Swedish group showed that 1 hr of coin handling resulted in nickel deposition in the range of 0.09–4.1 $\mu\text{g}/\text{cm}^2$ (40), a concentration within the range of that found in Danish nickel-allergic patients with occupational nickel exposure and related hand eczema (52). A recent British study established the threshold level of nickel dermatitis in nickel-allergic patients exposed to nickel in an open manner on the forearms (single application) (49). They showed that 28% of 21 patients reacted to 5.0 μg nickel/ cm^2 . Another Danish study showed that nickel patch test doses of 0.78 and 10 μg nickel/ cm^2 will elicit reactions in 10% and 50% of nickel-allergic individuals, respectively, and that, at 1 week, 22% of nickel-allergic patients reacted to 0.035 μg nickel/ cm^2 applied twice daily as open exposure (36). On the basis of the presented results on nickel deposition following coin handling and the dose response, nickel release from coins is indeed expected to result in allergic nickel dermatitis on the hands in some of those excessively exposed. It is possible, and even likely, that filaggrin mutation carriers have an increased risk of developing nickel dermatitis on the hands. Risk assessment should take this into account, and, ideally,

new coin handling studies should be performed to consider this genetic predisposition.

Situation in EU Member States

It is worth reflecting on the different political use and interpretation of data in EU member states. As part of the discussion process during the choice of metals for the euro coins, the European Commission was asked the following questions in 1997 (<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:1998:102:0066:0067:EN:PDF>):

- (1) What evidence is there to link nickel in coinage
 - (a) to the onset of hand eczema or
 - (b) to the persistence of hand eczema?
- (2) If there is any evidence, how many Europeans
 - (a) have developed hand eczema as a result of nickel in coinage or
 - (b) have a persistent hand eczema condition because of nickel in coinage?

The European Commission's Scientific Advisory Committee on the Toxicity and Ecotoxicity of Chemical Compounds expressed an opinion on nickel in euro coins (http://ec.europa.eu/food/fs/sc/oldcomm5/out01_en.print.html). The committee pointed out that very few data on existing coinage as the cause of allergic dermatitis existed; no formal epidemiological studies were available. However, the limited information available suggested that very few cases of dermatitis may have been caused by nickel release from the then current coins, and that workers professionally handling coins appeared to have a low risk. In the European Commission's formal response to the questions, there was a reiteration of the above opinion, but it was also stated that 'Further studies appear necessary to obtain statistically significant evidence concerning the eventual role of nickel release from coins in relation to aggravation of hand eczema'. In 2011, the United Kingdom's competent authority, HM Treasury, published an impact assessment on the proposed conversion of 5 pence and 10 pence copper–nickel coins to nickel-plated steel coins (http://www.hm-treasury.gov.uk/d/impact_assessment_of_5_and_10p_nickel_plated_steel_coins.pdf). In the assessment of

impacts on health and well-being, it was stated that the nickel-plated coins would have no impact. When challenged on this, HM Treasury said that it had undertaken no formal risk assessment in relation to health, but had accepted what the Royal Mint, which is to manufacture the coins, had told it (Sarah Gannaway, personal communication, December 2011). The Royal Mint stated that it had not undertaken any risk assessment on the coins, as they were not governed by legislation, and that 'Contact with all coins is usually fleeting' (P. Hawkins, The Royal Mint, letter dated 22 December 2011). They had no information on nickel release from their nickel-plated coins (79). Also in 2011, the Sveriges Riksbank decided that new banknotes and coins will be issued in 2014–2015, and that the coins will be made of copper-plated steel (1 krona and 2 krona) and Nordic gold (5 krona and 10 krona) (http://www.riksbank.se/Upload/Dokument_riksbank/Kat_publicerat/Pressmeddelanden/2011/nr07_e.pdf). The decision was based on risk assessment in a report (http://www.riksbank.se/upload/Dokument_riksbank/Kat_sedlar/2011/SedeloMynt_Format,%20materialochfärger_ENG.pdf). The report stated 'Nickel should not be used in the new coins because of the allergy risk'. The contrary views of two competent authorities in the EU concerning the safety of nickel in coins are of concern. The additional studies recommended by the European Commission in 1997 have not been undertaken by them. Perhaps it is time for the European Commission to perform a re-evaluation?

Conclusion

Coins that release nickel constitute a risk factor for ill-health resulting from nickel allergy. According to the data presented in this review, those who handle coins professionally and consumers with nickel allergy are at particular risk. Risk assessments of coin materials should consider nickel allergy. For the protection of the health of consumers, cashiers, and other workers who handle coins, it is suggested that coins with no or minimal nickel release should be used to replace the currently widely used coins that release high amounts of nickel. The key risk factor in this situation is the ability of materials to release nickel and contaminate skin by repeated contact, as in coin handling.

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