

Nickel release from coins

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Nickel allergy is the most frequent contact allergy and is also one of the major background factors for hand eczema. The clinical significance of nickel release from coins was discussed when the composition of euro coins was decided. Current European coinage is dominated by cupro-nickel coins (Cu 75; Ni 25); other nickel-containing and non-nickel alloys are also used. Nickel release from used coinage from the UK, Sweden and France was determined. It was shown that nickel ions are readily available on the surface of used coins. After 2 min in artificial sweat, approximately 2 µg of nickel per coin was extracted from cupro-nickel coins. Less nickel was extracted from non-nickel coins. Nickel on the surface was mainly present as chloride. After 1 week in artificial sweat approximately 30 µg/cm² was released from cupro-nickel coins; less nickel was released from coins made of other nickel alloys. Theoretically, several µg of nickel salts may be transferred daily onto hands by intense handling of high-nickel-releasing coins.

Key words: chemical analysis; coin alloys; contact allergy; cupro-nickel; euro coin; nickel; nickel release; bioavailability. © Munksgaard, 2001.

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Nickel allergy is the most frequent contact allergy in industrialized parts of the world, affecting 10–15% of women and a few % of men in the general population. Nickel allergy, as well as atopic dermatitis and wet work, are the most important background factors for hand eczema, which affects approximately 10% of the adult population. 30–40% of nickel-sensitive persons develop hand eczema (1–4). This is the most severe effect of nickel allergy due to the resulting suffering, sick leave, change of jobs and large costs for society. The EU Nickel Directive, aiming at primary and secondary prevention of nickel allergy, limits nickel in some types of products (5–7). The products covered are post assemblies used during epithelization of the wound caused by piercing, and personal items in direct and prolonged contact with the skin, such as jewellery, watches, buttons etc. Coins, tools, handles, keys and other types of objects that come into temporary but often repetitive contact with the skin are not covered by the Nickel Directive. They are, however, often made of materials with high nickel release (8, 9). Whilst, the Nickel Directive lists types of objects which are the overall the most common sensitizers, nickel release from other

objects may also elicit dermatitis in nickel-sensitive people and may induce sensitization in individuals.

Nickel allergy and nickel-containing alloys were discussed and evaluated when the composition of euro coins was decided (Table 1). Groups at different levels were involved, such as European Mint Officers, EU DG XXIV “Euro” working group, the DG XXIV Scientific Committee for Toxicity and Ecotoxicity of Chemical Compounds (CSTE) (the present Scientific Committee for Toxicity, Ecotoxicity and the Environment (CSTEE) and EU Joint Research Centre (JRC), the Danish Environmental Protection Agency (11), the nickel industry (12) and European dermatologists (13). Reasons for the discussion were that nickel allergy affects a large proportion of the population, and many coin alloys contain and release nickel.

Whilst ordinary consumers handle coins infrequently for short periods of time, many shop assistants and cashiers in shops, banks and post offices handle coins during large parts of the workday. However, knowledge of the health risk is limited as there are relatively few publications concerning coins and dermatitis (reviewed in 14, 15). It has been claimed that the duration of contact

Table 1. First series of euro coins including 8 denominations, their appearance and composition (10)

Denomination	Colour	Composition (%)
1, 2 and 5 cent	red	Cu-covered Fe
10, 20 and 50 cent	yellow	Cu 89; Al 5; Zn 5; Sn 1
1 euro	bi-colour: yellow (external ring) white (internal part)	external: Cu 75; Zn 20; Ni 5 internal (3 layers): Cu 75; Ni 25/Ni 100/Cu 75; Ni 25
2 euro	bi-colour: white (external ring) yellow (internal part)	external: Cu 75; Ni 25 internal (3 layers): Cu 75; Zn 20; Ni 5/Ni 100/ Cu 75; Zn 20; Ni 5

Table 2. Swedish, British and French coins selected for the study. Denominations, composition and total surface area of the coins

Country	Denomination	Composition of alloy (%) ^{a)}	Area of coin surface (cm ²)
Sweden	50 öre ^{b)}	Cu 74; Zn 25; Sn 0.5	6.65
	1 krona	Cu 75; Ni 25	11.8
	5 krona	3 layers: Cu 75; Ni 25/Ni 100/ Cu 75; Ni 25	14.8
	10 krona	Cu 89; Al 5; Zn 5; Sn 1	8.56
UK	2 pence	Cu-plated Fe	12.9
	10 pence	Cu 75; Ni 25	11.1
	20 pence	Cu 84; Ni 16	8.76
	1 pound	Cu 70; Ni 5.5; Zn 24.5	10.4
France	10 centime	Cu 92; Al 6; Ni 2	7.78
	20 centime	Cu 92; Al 6; Ni 2	9.98
	1/2 franc	Ni 100	7.35
	1 franc	Ni 100	10.3

^{a)} According to official information obtained from the Swedish Royal Mint.

^{b)} The old 50-öre coin based on Cu 75; Ni 25 was not used for the study.

with coins is too short for nickel to contaminate the hands, based on the fact that ionization of metallic nickel has to occur(8). Yet dermatitis patients and occupational dermatologists have experience of hand eczema related to coin exposure (14). The following issues have been discussed in relation to nickel release from coins: can coins induce nickel allergy; elicit dermatitis in the already-sensitized; or worsen ongoing hand eczema in nickel-sensitive consumers or in cashiers?

The aims of the present study were to determine the soluble surface nickel content of used coinage from the UK, Sweden and France; to investigate the nature of the surface nickel; and to determine nickel release from cleaned surfaces of coinage, representing the alloys used in their manufacture. The study was conducted on behalf of the Royal Swedish Bank (16).

Materials and Methods

Selection of coins

Coins in general circulation in Sweden, the UK and France were selected for the study. Swedish coins (50 of each denomination) were obtained from the

Swedish Post Office; British coins (a total of 50 coins) and French coins (a total of 30 coins) were taken from circulation. The denomination and composition of the coins are shown in Table 2.

Metal release

Solutions and reagents

Demineralized water and artificial sweat were used for the release procedures. The artificial sweat consisted of deionized and aerated water containing sodium chloride 0.5%, lactic acid 0.1% and urea 0.1%. pH was adjusted to 6.5 with ammonia. The solution was used within 3 h of preparation.

Release procedures

Washing coins with water for surface nickel. 5 coins were washed with 10–20 ml (depending on the size of the coins) of demineralized water at room temperature (20±2°C) by swirling the coins in a flask for 1 min. The flask was left to stand for a further 1 min. The water extract was transferred to a clean screw-capped container and analysed for nickel (see below). The procedure was carried out in triplicate for each denomination tested (Table 3).

Table 3. Nickel extracted from coins by washing them in water or in artificial sweat, or storing them 1 week in artificial sweat; analysis by ICP-MS

Denomination	Nickel release from coins		
	Washed with artificial sweat ($\mu\text{g}/\text{coin}$) ^{a)}	Washed with water ($\mu\text{g}/\text{coin}$) ^{a)}	Immersed in artificial sweat for 1 week ($\mu\text{g}/\text{cm}^2/\text{week}$) ^{b)}
50 öre	0.07, 0.08, 0.11	0.07, 0.08, 0.09	<0.01, <0.01
1 krona	0.57, 0.71, 1.02, 1.60 ^{c)}	NT	31.5, 45.2
5 krona	0.89, 1.36, 5.22	0.49, 0.62, 0.75	NT
10 krona	NT	0.04, 0.04, 0.04	0.07, 0.10
2 pence	0.10, 0.22, 0.26	0.03, 0.05, 0.06	<0.01, <0.01
10 pence	1.03, 1.24, 1.32	0.65, 0.81, 1.04	16.3, 39.8
20 pence	1.13, 1.55, 1.91	0.29, 0.37, 0.38	12.9, 15.9
1 pound	3.30, 3.31, 3.56	0.56, 0.59, 0.69	13.4, 14.2, 16.3
10 centime	0.11, 0.15, 0.16	0.06, 0.06, 0.06	0.65, 3.77
20 centime	0.10, 0.14, 0.24	0.06, 0.12, 0.12	NT
1/2 franc	0.79, 1.49, 3.51	0.65, 0.96, 1.69	NT
1 franc	2.19, 2.83, 3.27	NT	2.26, 6.24
detection limit	0.05	0.0005	0.01

NT=not tested.

^{a)} Each value is an average based on 5 coins per extraction.

^{b)} Each value based on 1 coin per extraction.

^{c)} Each value is an average based on 3 coins per extraction.

Washing coins with artificial sweat for surface nickel. 5 coins were washed with 10–20 ml (depending on the size of the coins) of artificial sweat at room temperature by swirling the coins in a flask for 1 min. The flask was left to stand for a further 1 min. The artificial sweat extract was transferred to a clean screw-capped container and analysed for nickel (see below). The procedure was carried out in triplicate for each denomination tested (Table 3).

Washing coins with water for surface anion and cation analysis. 10 coins were washed with 10 ml of demineralized water at room temperature by swirling them in a flask for 1 min. The flask was left to stand for a further 1 min. The water extract was transferred to a clean screw-capped container and analysed for anions and cations, respectively (see below). The procedure was carried out for the Swedish 10-krona, 1-krona and 50-öre coins, respectively.

Immersing coins in artificial sweat for nickel release. The proposed reference test method for nickel release, prEN 1811, developed by CEN/TC 283/WG 4 was used. (The published standard EN 1811 (17) is only slightly revised.) Each coin was cleaned with detergent in an ultrasonic bath before the release procedure was carried out. A single coin was totally immersed and extracted with either 10 or 15 ml (depending on size of coin) of artificial sweat at 30°C for 1 week. The procedure was carried out in duplicate on a selection of coin types representative of the coinage alloys (Table 3).

Chemical analysis

Inductively-coupled plasma-mass spectrometry (ICP-MS) was used for analysis of nickel in both

the water and artificial sweat extracts. The results were expressed in $\mu\text{g}/\text{coin}$ or $\mu\text{g}/\text{cm}^2/\text{week}$ (unadjusted values), as appropriate.

Inductively-coupled plasma-optical emission spectroscopy (ICP-OES) was used for analysis of cations (aluminium, nickel, copper, tin, iron and zinc), and *ion chromatography* was used for analysis of anions (chloride, nitrate and sulfate) in water extracts. The results were expressed in $\mu\text{g}/\text{coin}$.

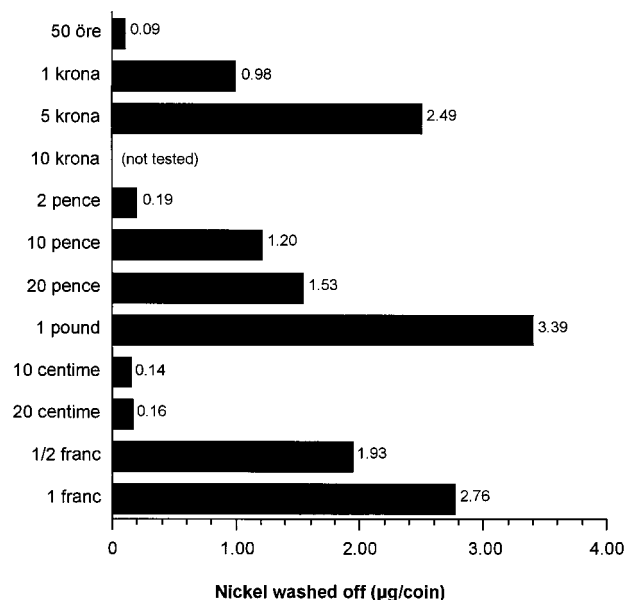


Fig. 1. Nickel washed off from coins in 2 min by artificial sweat at room temperature ($20 \pm 2^\circ\text{C}$). Mean value based on 3 separate extractions each of 5 coins (for composition of coins, see Table 2).

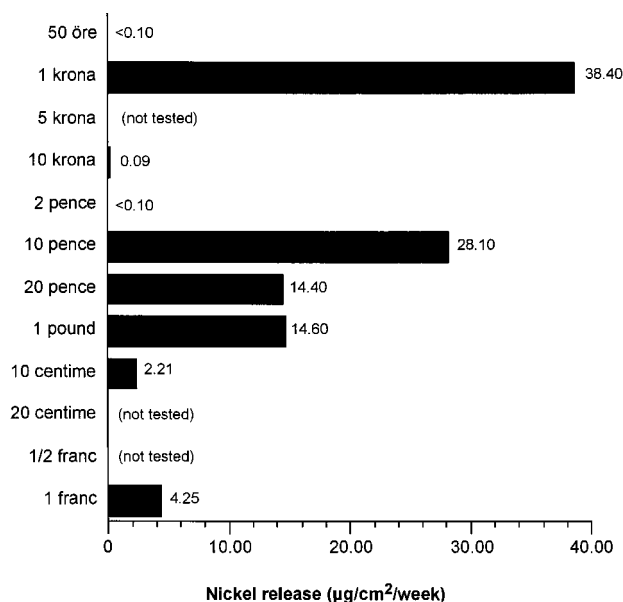


Fig. 2. Nickel release from coins immersed for 1 week in artificial sweat at 30°C. Mean value based on 2 separate extractions each of 1 coin (for composition of coins, see Table 2).

Results

The results of analysis of nickel extracted from the surface of coins by washing them for 2 min with artificial sweat (Fig. 1) and water, respectively, are shown in Table 3. Nickel was detected in all extracts from washing coins with artificial sweat or water. Generally, more nickel was extracted with artificial sweat than with water.

The highest levels of nickel released by washing with artificial sweat were obtained from 1-krona, 5-krona, 10-pence, 20-pence, 1-pound, 1/2-franc and 1-franc coins (range 0.57–5.22 µg/coin). Lower levels were obtained from 50-öre, 2-pence, 10-centime and 20-centime coins (range 0.07–0.26 µg/coin) (Table 3). 10-krona coins were not tested.

The results of analysis of anions and cations washed off by water from 50-öre, 1-krona and 10-krona coins are shown in Table 4. The major anion

in the extracts was chloride, approximately 2 µg/coin. The major cation was copper, approximately 3 µg/coin. Nickel was detected in the water-wash extracts from all coins, 0.85 µg/coin from the cupro-nickel, 1-krona coins and approximately 0.05 µg/coin from the non-nickel-containing coins.

The results of analysis of the amount of nickel released by immersion of coins in artificial sweat for 1 week are shown in Table 3 and Fig. 2. The highest level of nickel release was obtained from the 1-krona, 10-pence, 20-pence, 1-pound coins (range 12.9–45.2 µg/cm²/week); followed by 10-centime and 1-franc coins (range 0.65–6.24 µg/cm²/week). Low nickel release was detected from 10-krona coins (approximately 0.08 µg/cm²/week). No nickel release was detected from 50-öre and 2-pence coins. 5-krona, 20-centime and 1/2-franc coins were not tested.

Discussion

The present study shows that nickel ions are readily available on the surface of used coins. After 2 min in artificial sweat, an average of approximately 2 µg of nickel per coin was extracted from the surface of a number of different cupro-nickel coins and pure nickel coins. Some nickel (approximately 0.15 µg/coin) was extracted from the surface of coins made of non-nickel alloys (Table 3, Fig. 1). This has previously been shown also by Bang Pedersen et al. (18) when washing coins with ether.

It was shown that artificial sweat extracts more nickel salts from the surface of nickel-containing coins than does water (Table 3). This is due to the well-known corrosive effect of the sweat (8). Water extraction, however, had to be used for the analysis of anions on the surface of coins, as artificial sweat itself contains some of the anions analysed. The current study indicates that ionic nickel on the surface of used coins is mainly present as the chloride (Table 4).

The inherent ability of different coin alloys to release nickel ions when exposed to artificial sweat

Table 4. Anions and cations extracted by demineralized water from the surface of used Swedish coins; analysis of anions by ion chromatography and of cations by ICP-OES

Denomination	Anion (µg/coin) ^{b)}			Cation (µg/coin) ^{c)}			
	Chloride	Nitrate	Sulfate	Al	Ni	Cu	Zn
50 öre ^{a)}	2.4	0.15	0.2	ND	0.04	2.96	0.31
1 krona ^{a)}	2.64	0.28	0.39	ND	0.85	1.46	<0.05
10 krona ^{a)}	2.75	0.25	0.2	0.01	0.04	2.75	0.63
detection limit	0.1	0.1	0.1	0.005	0.002	0.004	0.05

ND=not detected.

^{a)} 10 coins in each extraction.

^{b)} Oxide was not determined.

^{c)} Sn and Fe were not detected. Detection limits (µg/coin): Sn 0.006, Fe 0.05.

was studied using the proposed reference test method for nickel release (17). Used coins from circulation were tested after cleaning. The highest nickel release (about $30 \mu\text{g}/\text{cm}^2/\text{week}$) was obtained from the cupro-nickel coins containing 25% nickel (viz. the 1 krona and 10 pence) (Tables 2, 3, Fig. 2). Relatively high nickel release (approximately $14 \mu\text{g}/\text{cm}^2/\text{week}$) was also obtained from the other British nickel-containing coins tested (20 pence, 1 pound). Lower nickel release was obtained from the pure nickel, 1-franc coins (approximately $4 \mu\text{g}/\text{cm}^2/\text{week}$) and from the 10-centime coins containing 2% nickel (approximately $2 \mu\text{g}/\text{cm}^2/\text{week}$). Low or no nickel release was detected from the non-nickel alloy coins (50 öre, 10 krona, 2 pence). The origin of the small amount of nickel release from the 10-krona coins, which are declared nickel-free, remains unexplained.

In a study of pre-fabricated, unused 2-euro coins, on behalf of the European Commission DG XXIV (11), the nickel released when coins were immersed for 1 week in artificial sweat (range of mean values from 4 laboratories $23.2\text{--}65.1 \mu\text{g}/\text{cm}^2/\text{week}$) was of the same magnitude as in the present study with 1-krona and 10-pence coins (copper 75%, nickel 25%) (Table 3, Fig. 2). It was also shown that the unused 2-euro coins released nickel when washed with water (range of mean values $0.03\text{--}0.13 \mu\text{g}/\text{cm}^2$), and $7\times$ more when washed with artificial sweat (range of mean values $0.23\text{--}0.84 \mu\text{g}/\text{cm}^2$). These values correlate well with the results from the present study when values are corrected for the area of the coins (Tables 2, 3).

Coins in circulation are known to be "dirty". The exact composition of this contamination has not been determined. But sweat and metal salts contribute, and when coins and bank notes come into contact with one another they may contaminate each other. This is the most probable explanation for the presence of nickel on the surface of non-nickel coins (Table 3) and on bank-notes (18).

A provocation study frequently quoted showed no aggravation in 11 patients with nickel allergy and hand eczema of the pompholyx type (19). Hands were exposed for 6 min to cupro-nickel coins and some other nickel-releasing items. The study is, however, not relevant for the intense handling of coins by cashiers, etc.

Repeated open-skin exposure to 10 and 100 ppm nickel, in nickel-sensitive persons with low-grade hand eczema, caused aggravation of the dermatitis (20). The concentration threshold for reactivity to a single exposure in open testing was established as $1.5 \mu\text{g}/\text{cm}^2$ (21). Theoretically, several micrograms of nickel salts may be transferred daily onto hands by intense handling of high-nickel-releasing coins. Contamination of hands with nickel was

shown to occur by handling cupro-nickel coins for 5 min (18). However, it is not known how much nickel is deposited on hands by occupational coin handling, and such information would be of great interest. Methods for determination of the nickel concentration in skin and in nails may be useful for this (22, 23).

Current European coinage is dominated by cupro-nickel alloys that have a nickel release up to $100\times$ greater than the $0.5\text{-}\mu\text{g}/\text{cm}^2/\text{week}$ limit for objects in direct and prolonged contact with the skin according to the EU Nickel Directive. Only 2 out of 8 euro coins, however, will be made of alloys with such high nickel release, and 6 will be made of non-nickel alloys (Table 1). In the future, when the composition of the next generation of euro coins and of national coins is decided, further information concerning skin dose and effects of nickel release from different coin alloys would be of interest. Such information can be obtained from well-designed experimental, clinical and epidemiological studies.

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