

Nickel Release from Euro and Polish Coins: a Health Risk?

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Abstract

The role of contact with nickel-containing coins has been controversial. The aim of our study was to compare the release of nickel from Euro (1 and 2) coins and from Polish coins (2 PLN and 5 PLN) at 4°C and 32°C in an immersion test using artificial sweat according to the EU reference method. Nickel extract was analyzed at 8 time points starting from 1 h up to 168 h. After 7 days of test duration at 32°C, nickel ion concentration was $96.27 \pm 4.01 \mu\text{g}/\text{cm}^2$, $79.31 \pm 1.95 \mu\text{g}/\text{cm}^2$, $38.34 \pm 1.19 \mu\text{g}/\text{cm}^2$, and $32.17 \pm 2.36 \mu\text{g}/\text{cm}^2$ for 2 Euro, 1 Euro, 5 PLN, and 2 PLN, respectively. The amount of nickel ion released at 4°C was reduced by about 70% and 40% for Euro and Polish coins, respectively. These values exceed the limit acceptable for prolonged contact with human skin as defined by the EU Nickel Directive, which indicates that nickel may be capable of eliciting allergic reactions in subjects handling nickel-containing coins daily.

Keywords: nickel, Euro coins, Polish coins, allergic contact dermatitis

Introduction

Nickel is a common allergen in Western countries that affects 10% of women and 1-2% of men [1]. It has been suggested as a possible cause of hand dermatitis and eczema, especially following direct and prolonged contact with products containing it [2]. Sensitization to this metal can be seen in a number of occupations, including pottery workers, construction workers, tailors, hairdressers, and painters [3]. High industrial exposure to nickel includes ore refining and nickel plating [4]. Furthermore, chemical processes utilizing nickel as catalysts may contribute to sensitization in nickel-sensitive subjects [5]. Nickel allergy in women can frequently be caused by wearing nickel-releasing jewellery [6]. Nickel may be released from some stainless steel products [7]. Its release is facilitated by corrosion of the metal enhanced by aggressive sweating, leading to rust formation [8].

Although persistent contact of nickel-containing items with the skin is generally believed to cause sensitization in nickel-allergic subjects, the role of brief and repeated contact with nickel containing materials, such as coins, is a matter of debate. Therefore, there are still unanswered questions as to whether nickel-releasing coins may be a risk factor for allergic contact dermatitis on hands [9]. Cashiers and shop assistant in money-handling occupations are regularly exposed to trace levels of nickel extracted by sweat on their fingers from coins containing appreciable amounts of the metal (5-10% Ni) [10]. The introduction of Euro currency in most EU countries in 2002 has led to new interest in the allergic risks related to the incorporation of nickel in Euro coins [11]. Some studies have claimed that Euro coins release more nickel and pose a greater risk to human health than the previous old coinage [12]. Others suggest that Euro coins do not pose a greater risk to human health than the previous national currencies because of too brief contact with sweat [13].

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Table 1. Characteristics of the coins selected for study. Coin surface areas were calculated, including the outer rim area.

Denomination	Appearance	Composition	Surface (cm ²)
2 Euro	white external ring	copper-nickel Cu ₇₅ , Ni ₂₅	12.2
	yellow center	nickel brass Cu ₇₅ , Zn ₂₀ , Ni ₅ nickel core (three layers Cu ₇₅ , Zn ₂₀ , Ni ₅ /Ni ₁₀₀ /Cu ₇₅ , Zn ₂₀ , Ni ₅)	
1 Euro	yellow external ring	nickel-brass Cu ₇₅ , Zn ₂₀ , Ni ₅ copper-nickel	10.2
	white center	nickel brass Cu ₇₅ , Ni ₂₅ nickel core (three layers Cu ₇₅ , Ni ₂₅ /Ni ₁₀₀ /Cu ₇₅ , Ni ₂₅)	
5 PLN	external ring	copper-nickel Cu ₇₅ Ni ₂₅	11.4
	yellow center	Cu ₉₂ , Al ₆ , Ni ₂	
2 PLN	yellow external ring	Cu ₉₂ , Al ₆ , Ni ₂	9.4
	white center	copper-nickel Cu ₇₅ , Ni ₂₅	

The aim of the present study was to compare the release of nickel from Euro coins (1 Euro and 2 Euro) and from Polish coins (2 PLN and 5 PLN) using the EU reference test method.

Materials and Methods

Polish coins were selected from general circulation and the Euro coins were purchased from an exchange office. In total, eight pieces of each coin were used. The characteristics of the coins selected for the studies are shown in Table 1. The reference test method for nickel release, EN1811 (EU Nickel Directive), was used [14]. Prior to our experiment, the coins were cleaned with detergent and alcohol and rinsed with deionized water.

The artificial sweat used in the study was prepared from 0.1% urea, 0.1% lactic acid, and 0.5% sodium chloride dissolved in deionized water. The pH was adjusted to 6.5 by the addition of ammonium hydroxide. The solution was used within 3 hours of preparation. After the cleaning procedure, each coin was separately immersed in 10.4-12.5 ml of artificial sweat (depending on the size of the coin) in a plastic tube. The extraction test was performed at 32°C and at 4°C in a closed laboratory hood. After 1 h, 24 h, 48 h, 72 h, 96 h, 120 h, 144 h, and 168 h of extraction, each coin was removed from the solution using plastic forceps and the concentration of nickel released in the artificial sweat was determined by atomic absorption spectroscopy (model ASA vario 6) with acetylene flame at a wavelength of 232 nm. Nickel released into artificial sweat after each of 8 extraction times was measured five times. The amount of nickel extracted from an area of the coin was calculated and expressed in µg/cm². The surface of the areas of the tested coins were obtained from geometric dimensions including the area of the outer rim.

Statistical analysis was performed with the use of Statistica 8.0 computer program. The use of the Shapiro-Wilk test did not confirm the normal distribution of the ana-

lyzed data. To compare the differences between the tested coins, the non-parametric alternative of the analysis of variance ANOVA was applied (Kruskal-Wallis test). To compare the statistical significance between two tested coins, the non-parametric alternative of t-Student's test (U Mann-Whitney) was used. A p value of <0.05 was considered statistically significant. The concentration of nickel ions was expressed as median ± interquartile range.

Results

The results of nickel extraction from coins immersed in artificial sweat for 1 h, 24 h, 48 h, 72 h, 96 h, 120 h, 144 h, and 168 h are shown in Fig. 1. Nickel was detected in all extracts, but the amount increased significantly with the duration of extraction with artificial sweat. The largest amount of nickel ions released after 7 days (168 h) of immersion in the artificial sweat at 32°C was obtained from

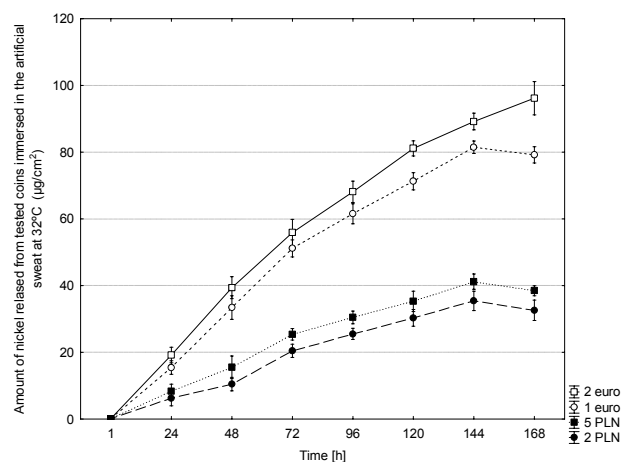


Fig. 1. The amount of nickel released from tested coins immersed in the artificial sweat 1 h, 24 h, 72 h, 48 h, 96 h, 120 h, 144 h, and 168 h at 32°C, as expressed in µg/cm². The figure shows the median ± interquartile range of Ni²⁺ concentration (p=0.0019).

Table 2. Statistical significance of differences in nickel released by tested coins in artificial sweat at 32°C based on U Mann-Whitney' test.

Tested coins	2 Euro	1 Euro	5 PLN	2 PLN
2 Euro	-	NS	0.0004	0.0001
1 Euro	NS	-	0.0033	0.0006
5 PLN	0.0004	0.0033	-	NS
2 PLN	0.0001	0.0006	NS	-

NS – no statistical significance ($p > 0.05$).

Table 3. Statistical significance of differences in nickel releasing by tested coins in artificial sweat at 4°C based on U Mann-Whitney' test.

Tested coins	2 Euro	1 Euro	5 PLN	2 PLN
2 Euro	-	NS	0.0005	0.0001
1 Euro	NS	-	0.0034	0.0003
5 PLN	0.0005	0.0034	-	NS
2 PLN	0.0001	0.0003	NS	-

NS – no statistical significance ($p > 0.05$).

2 Euro ($96.27 \pm 4.01 \mu\text{g}/\text{cm}^2$) and 1 Euro coins ($79.31 \pm 1.95 \mu\text{g}/\text{cm}^2$), whereas the nickel ion concentrations derived from 2 PLN and 5 PLN was much lower ($38.34 \pm 1.19 \mu\text{g}/\text{cm}^2$ and $32.17 \pm 2.36 \mu\text{g}/\text{cm}^2$, respectively). A comparison of nickel amounts extracted from all analyzed coins revealed statistically significant differences (ANOVA, $p = 0.0019$). However, there was no statistically significant difference in nickel concentrations between 2 and 1 Euro coins and between 5 and 2 PLN after 7 days of immersion in the artificial sweat. For the all remaining pairs of tested coins to be compared, the differences were statistically significant ($p < 0.05$, Table 2). The ocular visible increase in nickel ion extraction leading to blue-greenish colour of the extraction solution was observed after 72 h.

The amounts of nickel released from tested coins after immersion in the artificial sweat at 4°C were statistically lower than those released at 32°C temperature (Fig. 2). The analysis showed similar differences in the quantity of nickel released by the analyzed coins as that performed at 32°C. The lowest amount of nickel ions released after 7 days of immersion in artificial sweat at 4°C was found for 2 PLN ($12.42 \pm 1.04 \mu\text{g}/\text{cm}^2$) and 5 PLN coins ($16.73 \pm 1.9 \mu\text{g}/\text{cm}^2$), whereas the nickel ion concentration obtained from 1 Euro and 2 Euro was much higher ($54.21 \pm 1.4 \mu\text{g}/\text{cm}^2$ and $65.31 \pm 3.98 \mu\text{g}/\text{cm}^2$, respectively). The differences in nickel concentration extracted from all tested coins at 4°C were statistically significant (ANOVA, $p = 0.0021$), but also, there was no statistical significance between nickel amounts extracted from 2 and 1 Euro coins and from 5 and 2 PLN after 7 days of immersion in the artificial sweat. For the all remain-

ing pairs of tested coins to be compared, the differences were statistically significant (Table 3). After 7 days of immersion in artificial sweat, the surface of tested coins showed the effects of corrosion.

Discussion

It is well known that when nickel-containing alloys are in direct contact with the skin, nickel is readily released due to the influence of human sweat [15]. The free nickel ions denote a risk of primary sensitization or elicitation of dermatitis in nickel-sensitized subjects. This observation was the cause of the legislative regulation and the introduction of the Nickel Directive in EU countries (94/27/EEC) [16]. It has been established that nickel-containing jewelry, which is in constant and direct contact with human skin and sweat, may contribute to nickel sensitization [17].

Nickel released from coins remains controversial. The absence of wet and irritant work, interrupted contact, and partial protection by the horny layer of the palm may be why it is too difficult to prove that coin handling is the eliciting allergy factor in the general public. Some researchers have found no significant increase in the prevalence of hand eczema in the individuals occupationally exposed to coins [18], but others have claimed that a large percent of cashiers have a history of nickel dermatitis [10, 19]. Further investigations have shown that only highly sensitive subjects were likely to be susceptible to clinical hand eczema [20].

In the present study, Euro coins released two times more nickel ions than Polish coins after 7 days of immersion in artificial sweat. This dissimilarity may explain the composition of tested coins. Alloys cannot be considered as mixtures of metals, so that the rates of release of a particular constituent do not necessarily scale with its percentage in the alloy [21]. Pure nickel coins (French 1 F) were found to release less nickel than $\text{Cu}_{75}\text{Ni}_{25}$ coins (Swedish 1 Kr, British 10 p) ($4 \mu\text{g cm}^{-2} \text{ week}^{-1}$ vs. $30 \mu\text{g cm}^{-2} \text{ week}^{-1}$) [22, 23]. The 1 and 2 Euro coins are bimetallic and, moreover, they contain three layers in which nickel is in different concentrations.

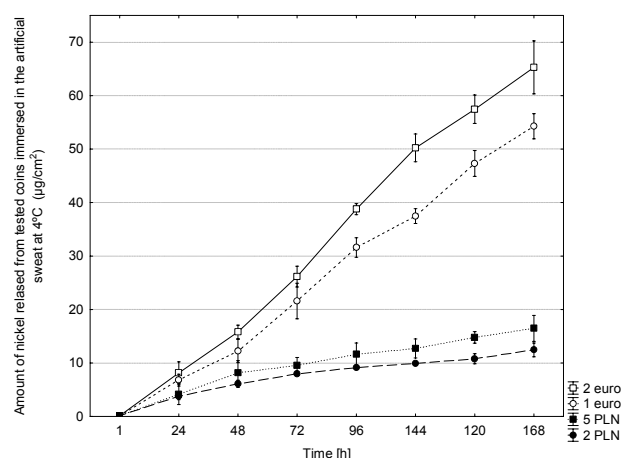


Fig. 2. The amount of nickel released from tested coins immersed in artificial sweat 1 h, 24 h, 72 h, 48 h, 96 h, 120 h, 144 h, and 168 h at 4°C, as expressed in $\mu\text{g}/\text{cm}^2$. The figure shows median \pm interquartile range of Ni^{2+} concentration ($p = 0.0021$).

In the 1 Euro the yellow outer ring contains nickel-brass ($\text{Cu}_{75}\text{Zn}_{20}\text{Ni}_5$) by weight, and the white center contains a copper-nickel core ($\text{Cu}_{75}\text{Ni}_{25}$). In the 2 Euro coin the yellow centre contains nickel-brass, the white outer ring is cupro-nickel. Nickel release is enhanced by metal electrochemical corrosion because of the presence of high galvanic potential of 30-40 mV between the two metallic parts in human sweat [24, 25]. An alternative explanation can be sought in the nature of passivating corrosion layers formed upon exposure to the artificial sweat. Copper-rich Cu/Ni alloys (such as those composing of 1 and 2 Euros) build up a layer consisting of cuprous oxide, while nickel-rich alloys build up a layer of nickel oxide and hydroxide. This implies that during the growth of the corrosion layer, copper-rich alloys may release nickel into solution while retaining copper, whereas nickel-rich alloys (pure nickel coins) retain nickel in a thin, resistant layer [26].

The lower amount of the nickel ions released during the immersion test of Polish coins may explain the presence of aluminum in their composition. Aluminum in the yellow center of 5 PLN and in yellow external ring of 2 PLN inhibit nickel electrochemical corrosion because of its location in the galvanic series. Nickel is more noble than aluminum, thus aluminum has corroded working as an anode during contact with human sweat.

The release of nickel from 1 and 2 Euro coins and Polish coins (2 PLN and 5 PLN) at 32°C exceeded the limit acceptable for prolonged contact with human skin (as defined by EU Nickel Directive 0.5 mg/cm²/week) by a factor of 160-190 for Euro coins and 68-78 for Polish coins. Similar observations concerning Euro coins were made by Liden and Carter and Liden et al. [22, 27].

The increase of temperature enhances the nickel ions release from different coins [28]. In the present study, the increase of temperature from 4°C to 32°C accelerated nickel releasing from all tested coins. The amount of nickel ions after 7 days of immersion in artificial sweat augmented by about 70% and 40% for Euro and Polish coins, respectively, so the most important in the protection of nickel sensitized subject is low room temperature. Low temperature also inhibits aggressive sweating of hands, which protects metallic items from rust formation.

The test method with artificial sweat has some limitations. Although artificial sweat of pH 6.5 is used, it should be pointed out that pH value varies with time, where even a highly acidic solution tends to approach buffered conditions. Enhanced nickel release does not necessarily imply enhanced risk of nickel contamination during everyday manipulation of coins, particularly when the relevant time scale is on the order of seconds rather than hours or days, and where the available solution volumes are very much smaller than in the experimental condition [29]. On the other hand, the contact test during the experiment does not reproduce the mechanical function that accompanies the handling of currency.

After the introduction of the new currency, Euro coins are handled most frequently in most European countries. Thus, some professional categories, such as cashiers, taxi

drivers, shop assistants, and other individuals handling coins for large parts of their working days, are currently far more exposed than before Euro introduction. Several micrograms of nickel chloride may be transferred daily onto the hands by intense contact with high nickel releasing coins and apart from possibly causing hand dermatitis in predisposed persons, nickel may be carried to other skin sites, where an impaired barrier may favour its penetration. The nickel content in 1 and 2 Euro coins may represent a possible health hazard and the introduction of Euro missed the chance to put an end to the risk run by occupationally exposed and nickel-allergic individuals.

Conclusions

Nickel is released from 2 Euro and 1 Euro coins at similar amounts that exceed the limit acceptable for prolonged contact with human skin, as defined by the EU Nickel Directive.

In comparison with Euro coins, nickel released from Polish coins (2 PLN and 5 PLN) is significantly lower because of the influence of aluminum in their composition.

The increase of temperature from 4°C to 32°C significantly enhances nickel ion release.

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