

Contamination by nickel, copper and zinc during the handling of euro coins

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The introduction of the euro has revived interest in the risk of nickel allergy due to the handling of coins. In the present work, the transfer of metallic contamination during the manipulation of coins is examined by means of leaching experiments and manipulation tests. It is shown that pre-existing metallic species present on the surface of the coins are the major source of contamination during manipulation, and that friction inherent to everyday usage contributes predominantly to their transfer to the hands. The comparison of coins as to their relative risks of metal contamination should therefore rely on tests that simulate the friction inherent in everyday human handling. Carrying out such tests with the newly issued 1€ and 2€ pieces, we find, contrary to long-term leaching measurements, that the euros release less nickel than previously circulated pure-nickel coins, but that this decrease is less pronounced than might have been hoped for on the basis of their surface composition. When the coins are rubbed to a shiny polish before manipulation, contamination of the fingers is reduced by more than a factor of 10. A comparison of coins used in France indicates that the introduction of the common currency has led to a fourfold reduction in contamination by nickel, while causing a 45% increase in contamination by copper.

Key words: contact allergy; nickel; copper; zinc; coins; euro; leaching; pH; manipulation.

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The introduction of the euro currency has led to renewed interest in allergic risks related to the incorporation of nickel in coins. In a comprehensive paper recently published in this journal, Lidén & Carter (1) examined the soluble surface nickel content of used coinage from the UK, Sweden and France, showing that up to 5 µg of nickel is extracted from nickel-alloy coins on 2 min contact with water or artificial sweat. On this timescale, pure-nickel coins show release rates similar to pieces composed of copper-nickel alloys containing 25% nickel (British 10p, Swedish 1Kr), both in water and in artificial sweat. During week-long immersion tests using artificial sweat, however, the pure-nickel French 1F coin was found to release *less* nickel than the Cu75Ni25 10p and 1Kr pieces: 4 µg cm⁻² week⁻¹ as compared to about 30 µg cm⁻² week⁻¹. Analogous observations had been made by Pedersen et al. (2).

These differences in behaviour depending on the timescale considered raise the question of how to evaluate nickel release during the few seconds of contact relevant to the handling of

coins. Considering that the timescales and liquid volumes pertinent to the manipulation of coins represent limitations as to the amount of metal that can be dissolved, while friction during handling can be an efficient promoter of contamination transfer, we have carried out a series of complementary leaching experiments and manipulation tests to quantify the amounts of nickel, copper and zinc transferred to the hands during the manipulation of coins. These investigations substantiate the importance of friction in provoking metal contamination of the fingers. We therefore consider a test that simulates everyday handling to be more appropriate to compare the contamination risks of different type of coins than leaching tests, such as the standardized procedure (3) relevant to objects in prolonged contact with the skin. Manipulation tests were thus carried out to evaluate the relative contamination levels for a complete set of euro coins in comparison with a set of French francs.

A comparison between coins taken from circulation and pieces manually rubbed to a shiny

polish showed nearly complete removal of pre-existing species that account for contamination of the fingers. This allowed us to quantify the contamination potential of the coins.

Materials and Methods

Leaching experiments

The first part of the present investigation consisted of leaching experiments which compared pure-nickel coins (French 2F) with nickel-alloy 2€ coins over a broad range of pH values and on timescales ranging from a few min to 1 week. The characteristics of these coins and of the remaining franc and euro denominations are summarized in Table 1.

The 2F coins were little-used pieces from a mint collection. The 2€ coins were obtained from the demonstration kits made available at the end of 2001, and had not been circulated. Except where noted, the coins were individually rinsed for 15 min in 100 mL of demineralized water, using ultrasonic agitation, before being immersed in their respective leaching solutions by means of Teflon-coated tweezers.

The 100 mL leaching solutions were prepared in 250 mL glass flasks using demineralized water and analysis-grade HCl or NaOH (Merck Euro-lab, 45250 Briare le canal, France). Their pH was measured using an Acumet 50 instrument (Denver Instrument Co., Arvana, CO, USA), with an accuracy of ± 0.03 units. The flasks were hermetically capped to limit absorption of CO₂ from the air, as such absorption can influence leaching phenomena through the formation of carbonate precipitates (4). They were placed in a closed laboratory hood, regulated at a room temperature of 25°C, while manipulation tests would have been at skin temperature, which is higher.

The metals released were determined qualitatively and quantitatively by inductively coupled plasma optical emission spectroscopy (ICP-OES), employing a Jobin-Yvon JY 24 spectrometer (Horiba, 91163 Longjumeau, France). It takes 3 min for measuring Ni, Cu, and Zn in triplicate and about 5 mL are withdrawn from the leaching solution during that interval. The instrument provides concentration readings which were calibrated by means of SPEX Plasma Shot standards, certified by the manufacturer (Spex industries, Edison, NJ, USA) to be accurate within $\pm 3\%$. Where appropriate, the standards were diluted to ensure a less than 10-fold difference between the calibration sample and the leaching solution. At the concentrations of interest, the ICP-OES technique has excellent linearity, allowing quantification at concentrations 100 times higher or lower than that of the calibration standard. The reproducibility of the concentration measurements, repeated in triplicate for each sample analysed, is better than $\pm 2\%$. Taking into account the uncertainty of the volume and concentration measurements, the amounts of metal released are measured with an accuracy of $\pm 5\%$. The methodology used derives from leaching studies relevant to environmental investigations (5).

Manipulation tests

The daily manipulation of coins was simulated by a number of volunteers counting representative sets of coins while transferring these from one polypropylene recipient to another. Depending on the individual, the manipulation time per coin ranged from 2 to 3 s, with an average of 2.6 s. The overall manipulation time by any participating individual did not exceed 3 min, which is a time short enough to avoid allergic reactions even by sensitized persons (6).

Table 1. Main characteristics of the coins investigated in the present study. The surface areas are obtained from the geometric dimensions and do not take the relief of the pieces into account. They are listed both including and excluding the area of the outer rim, as leaching experiments concern the full surface of coin, whereas manipulation essentially involves the 2 faces.

Denomination	Appearance	Composition	Surface, rim incl. (cm ²)	Surface, rim excl. (cm ²)
Francs				
10 F "Génie"	yellow outer ring white centre	aluminium bronze Cu92Al6Ni2	5.63	4.19
0.50 F; 1 F; 2 F; 5 F	white	pure nickel	4.12	4.12
5 cts; 10 cts; 20 cts	yellow	pure nickel	7.2; 10.4; 12.5; 15.1	6.0; 9.0; 11.0; 13.2
Euros				
1 €	yellow outer ring White centre	nickel-brass Cu75Zn20Ni5	5.92	4.22
2 €	white outer ring	copper-nickel Cu75Ni25 nickel core	4.28	4.28
	yellow centre	copper-nickel Cu75Ni25	7.11	5.33
		nickel brass Cu75Zn20Ni5 nickel core	5.09	5.09
10 ct; 20 ct; 50 ct	yellow	nordic gold Cu89Al5Zn5Sn1	7.33; 9.27; 11.1	6.13; 7.78; 9.24
1 ct; 2 ct; 5 ct	red	copper-covered steel	5.00; 6.51; 8.21	4.15; 5.52; 7.09

While in our earlier investigation (7, 8) unused 1€ and 2€ coins were employed, the present work was carried out with approximately 180 2€ coins that had been in circulation for between 2 and 5 months, divided into 3 sets. A 1st set of 58 pieces was counted as collected. A 2nd set was subjected to preliminary rinsing by immersing the 58 coins in groups of 5 or 6 in flasks containing 100 mL of demineralized water, placed for 10 min in an ultrasonic bath. After removal from the flasks, the coins were dabbed with paper towels and left to dry in the air. The first 2 volunteers counted these 'washed' coins after about 20 min drying, and the next 2 volunteers did so 24 h later. A third set of 58 coins was counted after both faces of each piece were brought to a shiny polish using the same wipes as used to sample the fingers (see below). The coins were held laterally in a Teflon clamp designed for that purpose and thoroughly rubbed about 10 times on each side, each time using a different portion of the wipe. Three sets of 58 used 2F coins were examined in an identical manner for comparison. They were taken from circulation at the beginning of 2002, and had been in use for several years.

For sampling the metal contamination resulting from manipulation, the inside surface of the 3 fingers used in counting (thumb, index and middle finger) were rubbed with a cellulose-fibre wipe measuring $14 \times 20 \text{ cm}^2$, which was subsequently immersed for 24 h in 100 mL of a pH 2 HCl solution at room temperature. The latter was then analysed by ICP-OES as outlined above, allowing quantification of the metals removed from the fingers.

The wipes used are commercialized in department stores for the cleansing of babies' skins. Seven different brands were tested to select the one (Leader Price, Israel) having the lowest inherent nickel content. The wipes were slightly impregnated with lanolin, and contain unquantified amounts of ethylenediamine tetraacetic acid, a metal-complexing agent, citric acid, propylene glycol, disodium methylchloroisothiazolinone, and methylisothiazolinone. For the present purposes, the characteristics that needed to be verified, as summarized below, are the possible contribution of metals contained in the wipes themselves, their efficiency in collecting metals from the fingers, and the extent to which the sampled metals were extracted into the solution analysed by ICP-OES.

Before each counting test, the 3 fingers were wiped to remove metallic contamination resulting from daily activities. The wipe was immediately immersed in the extraction solution at pH 2, contained in a 200-mL polypropylene flask closed by

a screw cap. Analysis was carried out 24 h later. The results thus obtained were denoted as 'ambient'. Subsequently, the volunteer proceeded to the counting of the predetermined number of coins, after which the inner surface of his/her 3 fingers were wiped again, and the wipe collected and analysed as just mentioned.

To reduce variations in sampling efficiency, the wiping of all of the volunteers' fingers was carried out by one of the same 2 people, who each time thoroughly cleaned their hands beforehand using several fresh wipes. Blank measurements were carried out to evaluate the metal content of the wipes. They typically contained $0.1 \mu\text{g}$ of nickel, $2 \mu\text{g}$ of copper, and $3 \mu\text{g}$ of zinc (8). These numbers can be compared with the amounts extracted after counting 58 euro coins, which in reference (8) were found to be 20, 93, and $15 \mu\text{g}$, respectively. All measurements were corrected for this 'blank' contribution, which represent a minor adjustment, in particular for nickel. It was also shown (8) that lengthening the wipes' extraction time from 24 to 84 h had no significant effect on the measured metal concentrations, justifying the adoption of 24 h duration. The efficiency with which the wiping removes metals from the fingers was determined by repeatedly cleansing the fingers with fresh wipes and analysing each of the corresponding extracts. It was found (8) that a single wiping removed approximately 90% of the metals deposited on the fingers by the counting of coins, and this efficiency figure has been used throughout in reporting the contamination of the fingers.

We noted that, even after several wipings of the 3 fingers, one detected metal traces slightly higher than the 'blank' contribution from the wipe. This small persistent contribution typically amounted to $0.3 \mu\text{g}$ of Ni, $2 \mu\text{g}$ of Cu, and $2 \mu\text{g}$ of Zn per wipe and has been subtracted from the data. Similar numbers were obtained by wiping a comparable area of skin on the back of the shoulders, indicating that it is not related to the handling of coins. We have not identified its origin: sweat is reported to contain $0.057 \mu\text{g mL}^{-1}$ of nickel and $1.5 \mu\text{g mL}^{-1}$ of copper (9), and the amount of sweat picked up by the wipe is certainly much less than the 1–3 mL required to account for the persistent levels observed. On the basis of the data of Denkhaus & Salnikow (10), abrasion of skin also makes much too small a contribution to be significant.

Results

Leaching experiments

Figure 1 shows the nickel concentrations measured by ICP-OES after immersing previously

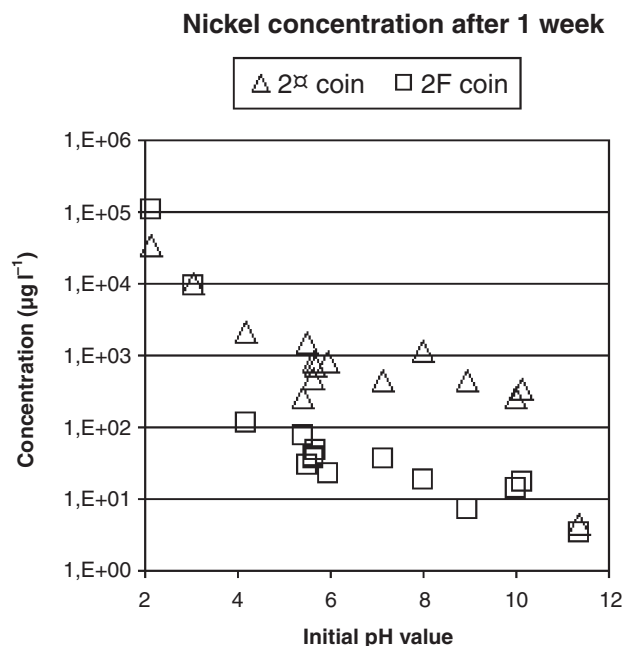


Fig. 1. Nickel concentrations, in μg per litre, measured after 1 week immersion of a 2€ or a 2F coin in 100 mL of an aqueous solution, as a function of the initial pH, adjusted using either HCl or NaOH.

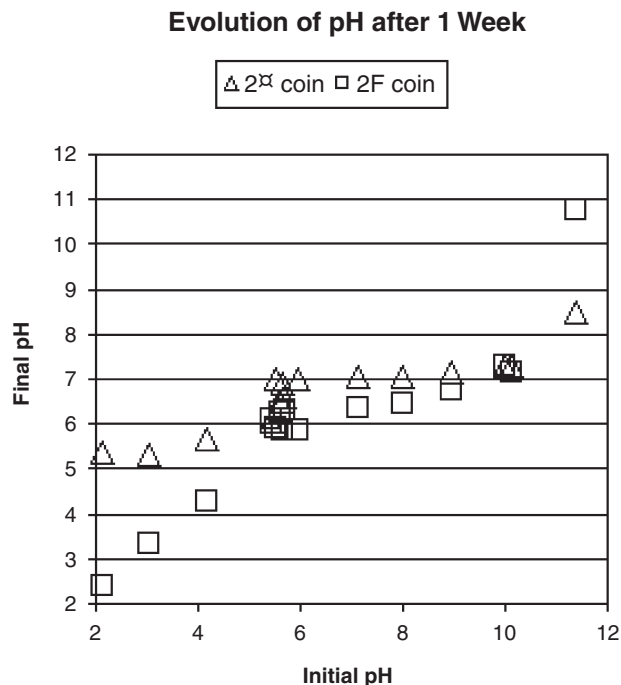


Fig. 2. Final pH reached after 1 immersion of a 2€ or a 2F coin in 100 mL of an aqueous solution, as a function of the initial pH, adjusted using either HCl or NaOH.

rinsed single 2F and 2€ coins for 1 week in a series of 100 mL solutions made up of demineralized water and HCl (initial pH < 5.6) or NaOH (initial pH > 5.6). The data are plotted as a function of the initial pH, but it should be pointed out that the pH varies with time, in particular for the more reactive 2€ coin, where even highly acidic or basic solutions tend to approach buffered conditions, as shown in Fig. 2.

Short-term metal release was examined by immersing a set of nine 2€ coins in 1 L of demineralized water, agitated in an ultrasonic bath. The coins were taken from circulation without any preliminary cleaning. Metal concentrations were measured after 2 and 20 min. The solution was then replaced by a fresh 1 L water volume, and concentration measurements repeated after 2 and 20 min, and so on, for a total of 4 successive washings. The large and renewed rinsing volumes were chosen to avoid saturation effects. The results are shown in Fig. 3, expressed as μg of Ni, Cu and Zn released per coin as a function of cumulative rinsing time.

Manipulation tests

Table 2 summarizes data obtained by counting 2F pieces that had been used for several years and 2€ coins that had been in circulation for 2–5 months. The data are reported as amounts of contamination resulting from the manipulation of a single

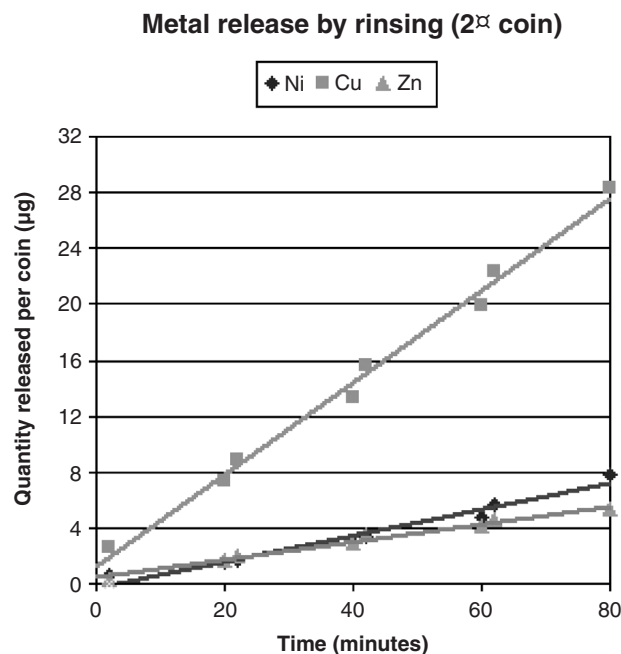


Fig. 3. Quantities of nickel, copper and zinc, expressed as μg per coin, released by 2€ coins upon rinsing by 4 successive 1 L volumes of de-mineralized water. The nickel concentrations in each of these are measured after 2 and after 20 min to determine the amounts, summed over the successive washings, indicated on the y-axis. The cumulative rinsing time, indicated on the x-axis, is the sum of the successive measurement intervals, neglecting the few 10s of seconds required to replace the rinsing volumes.

Table 2. Comparison of the contamination by nickel, copper and zinc resulting from the manipulation of “unwashed” coins taken from circulation, with that of pieces that were first “washed” by 10 min immersion in demineralized water or rubbed to a shiny polish. The data result from the manipulation of 2 sets of 58 coins, and are reported as averages, expressed in μg , of metal transferred to 3 fingers by one manipulation of a single coin. Uncertainty limits correspond to 90% confidence limits and result mainly from differences in handling by the participating volunteers.

	F			€		
	unwashed	washed	polished	unwashed	washed	polished
Ni	0.38 ± 0.10	0.46 ± 0.16	0.009 ± 0.004	0.23 ± 0.06	0.26 ± 0.07	0.012 ± 0.006
Cu	0.44 ± 0.10	0.24 ± 0.07	0.013 ± 0.004	1.4 ± 0.2	1.3 ± 0.2	0.10 ± 0.01
Zn	0.14 ± 0.03	0.12 ± 0.04	0.012 ± 0.003	0.26 ± 0.03	0.28 ± 0.05	0.07 ± 0.03

coin. They were obtained by determining the contamination resulting from the manipulation of 58 coins, corrected as outlined in the Materials and Methods section and averaged over the participating volunteers, the results being divided by 58 to yield the average for the handling of 1 coin. The data uncertainties indicated here and in all our tables are 90% confidence limits, obtained using standard spread-sheet treatment, which takes into account the spread of the data and the number of participants. They are representative of individual differences in the handling of currency. Both for the francs and for the euros, data are shown for ‘unwashed’ coins (8 volunteers), for pieces ‘washed’ or ‘polished’ as outlined earlier (4 volunteers in both cases). There was no significant difference between ‘washed’ coins counted after 20 min drying and those counted 24 h later, indicating that there is no measurable impact from air corrosion on a 24-h timescale.

Table 3 shows the data obtained by analysing the 58 wipes used to polish the coins, again dividing the measured amounts of metal by 58 to yield the contamination corresponding to a single coin. These results are labelled ‘accessible’. The 3rd data column shows the ‘ambient’ contamination of 3 fingers which results from everyday activities, obtained from a total of 49 individual measurements carried out during the present study and in our earlier investigation (8).

To compare the contamination levels resulting from the full set of euro coins with those of the

francs, we have carried out counting tests on ‘baskets’ of 80 coins comprising 10 pieces of each of the respective denominations: 1, 2, 5, 10, 20 and 50 cents and 1 and 2€ in the one case, and 5, 10 and 20 centimes, 0.50, 1, 2, 5 and 10F in the other. The main characteristics of the coins are summarized in Table 1. Four people participated in the tests, using coins taken from circulation without further precautions. The individual contamination data are presented in Table 4 as ratios between euros and francs for each of nickel, copper, and zinc as well as for the total of these metals. The last column gives the average of the individual ratios. The same person will handle different coins in an analogous manner, so that differences between individuals are less pronounced when comparing such ratios rather than absolute numbers.

Discussion

Leaching experiments

The data of Fig. 1 show that the 2€ coin, made up of 2 different nickel alloys (see Table 1) releases more nickel than the pure-nickel 2F piece in the pH range between 3 and 10, in agreement with Pedersen et al. (2) and Lidén & Carter (1), who made analogous observations using solutions of artificial sweat at a pH initially fixed at 6.5. At such a pH, the 2€ is seen to release about 10 times more nickel than the 2F, while its

Table 3. ‘Accessible’ metal content on the surface of 2F and 2€ coins, expressed as μg of metal for one single coin, as obtained by measuring the metal contamination accumulated on the wipes used to polish the pieces. The last column gives the average metal contamination of 3 fingers resulting from everyday activities, expressed in μg .

	F accessible	€ accessible	ambient
Ni	12 ± 1	5.0 ± 0.7	3.0 ± 0.5
Cu	13 ± 8	38 ± 5	11 ± 2
Zn	2 ± 2	8 ± 2	18 ± 3

Table 4. Comparison between “baskets” of euro coins and of French francs, each comprising 10 coins of each of the 8 denominations listed in Table 1. The data obtained in counting tests involving 4 volunteers are listed as the ratios of euros to francs for nickel, copper and zinc and for the total of these 3 metals. The last column gives the averages of these individual ratios.

Participant	A	B	C	D	Average
Ni	0.24	0.21	0.26	0.24	0.24 ± 0.02
Cu	1.42	1.34	1.54	1.50	1.45 ± 0.07
Zn	1.00	1.16	1.36	1.44	1.24 ± 0.17
Ni + Cu + Zn	1.06	1.05	1.25	1.15	1.13 ± 0.08

surface-averaged Ni content is about 6 times lower, 16.7% Ni as compared to 100%, and its surface area similar (see Table 1).

The pH range representative of human sweat extends between 2.1 and 6.9 and averages 5.3 (11, 12). The data of Fig. 1 suggest that strongly acidic sweat may give rise to greatly enhanced nickel contamination on prolonged exposure to nickel objects, since even in as simple a reactive medium as diluted HCl, the pure-nickel coin is seen to release 100 times more nickel in the pH range between 2 and 3 than at neutral pH values. It may therefore be of interest to verify possible correlations between nickel allergy and sweat acidity.

Figure 2 shows that pH changes occur during long-term exposure to an acidic medium, and this in a different manner for the pure nickel pieces and for the alloyed coins. The standardized evaluation test EN1811 might thus benefit from being made more specific with regard to the initial and final pH when evaluating long-term nickel release.

As stressed by Flint (12), 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. It is nevertheless surprising that, in long-term corrosion tests, coins containing less nickel in their surface layers release 10 times more nickel into solution. In Fournier et al. (8) we suggested that the juxtaposition of 2 different alloys in the 1€ and 2€ coins may give rise to enhanced electrochemical corrosion. In an article published shortly thereafter, Nestle et al. (13) independently reported experiments that might substantiate that hypothesis. An alternative explanation can be sought in the nature of the passivating corrosion layers formed upon exposure to artificial sweat. Colin et al. (14) have shown that copper-rich Cu/Ni alloys build up a layer consisting of cuprous oxide, Cu_2O , 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 release nickel into solution while retaining copper, whereas nickel-rich alloys (and *a fortiori* pure nickel) retain the nickel in a thin resistant layer. Thus, copper-rich alloys, such as those composing the 1- and 2€ coins, may indeed release more nickel into solution than pure nickel.

Such enhanced nickel release does not necessarily imply an enhanced risk of nickel contamination during the everyday manipulation of coins, where the relevant timescale is of the order of seconds, rather than hours or days, and where the available dissolution volumes are very much smaller than in leaching experiments. On the other hand, leaching experiments or contact

tests do not reproduce the mechanical friction that accompanies the handling of currency. These considerations led us to investigate metal leaching on as short a timescale as the sensitivity of our ICP-OES measurements allowed, and, subsequently, to measure metal contamination transferred to the hands by manipulation.

Figure 3 shows that, on a 1-h timescale, the amounts of metal released by rinsing a 2€ coin in large volumes of water vary linearly with time, at rates that are substantially higher than those obtained from week-long immersion tests. For nickel, for instance, Fig. 3 yields a release rate of $0.07\text{ }\mu\text{g}$ per min and per coin, while 1-week immersion at near-neutral conditions yields an average value of $0.01\text{ }\mu\text{g}$ per min, as can be evaluated from Fig. 1. In addition to possible saturation effects in the week-long test, this difference suggests that at least part of the metals observed at shorter times result from the removal of readily soluble compounds and possibly loosely bound metallic particulates resulting from friction between coins, as well as from corrosion during rinsing. However, even these enhanced initial rates are much too low to account for the $0.2\text{--}0.3\text{ }\mu\text{g}$ of nickel found (see Table 2) to be transferred to the hands during the manipulation of 2€ coins, which typically lasts less than 3 s. As, in addition, the volumes available to dissolve into are very much reduced when considering the manipulation of a coin, transfer by dissolution analogous to rinsing cannot be very efficient, and friction must play a major role in the contamination process. By the same token, the 1-week standardized leaching test of reference (3) cannot, in our opinion, be considered appropriate to quantify metal contamination resulting from the manipulation of coins.

Manipulation tests

Table 2 demonstrates that the contamination of the fingers resulting from coin handling does not differ significantly if the coins are rinsed before manipulation or not, even though the metal content of the rinsing water was found to be significant ($69\text{ }\mu\text{g}$ of Ni, $258\text{ }\mu\text{g}$ of Cu and $163\text{ }\mu\text{g}$ of Zn for the 58 pieces, figures which are in good agreement with the results of Lidén & Carter (1)). This indicates that relatively large amounts of pre-existing metallic species were present on the surface, and that sufficient material is left after rinsing to contaminate the fingers as much as with unwashed pieces. This is corroborated by the results in Table 3, where the accessible metal content on the surface is measured by 'polishing' the coins (see below). The data of Table 2 are in good agreement with our

earlier measurements, obtained with unused euros (7, 8), indicating the absence of significant ageing effects on a timescale of several months.

Contrary to rinsing, 'polishing' the coins strongly diminishes the contamination resulting from their manipulation, as evidenced by the more than tenfold reduction shown in Table 2. It is clear that the polishing process removed essentially all of the pre-existing species that contribute to metallic contamination during the manipulation of coins.

An analysis of the wipes used to polish the coins therefore allows us to evaluate the metal content of the pre-existing species that constitute the reservoir accessible to contaminate the fingers. The results are listed under the headings 'accessible' in Table 3. The 'accessible' nickel present on the surface of the euro coins is lower than that of the francs by only a factor of 2, comparable to the 1.6 and 1.7 franc/euro contamination ratios that can be calculated from Table 2. One notes the high proportion of zinc and especially of copper available at the surface of the pure-nickel 2F piece: 7% and 50% of the total, whereas the bulk nickel material contains less than 0.5% of zinc and 0.05% of copper. While some surface enrichment is possible (15), we attribute this presence to friction with the other franc denominations which contain copper and zinc (Table 1).

The last column of Table 3 lists the 'ambient' contamination values that reflect everyday activities. For nickel and copper they correspond to about 10 times the contamination transferred by a single manipulation of a 1€ or 2€ coin. It is therefore possible that the handling of coins contributes significantly, if not predominantly, to the 'ambient' contamination of the fingers by these 2 metals. In the case of zinc, other sources of contamination must be more important.

We note that the contamination due to the compulsive manipulation of coins will be limited by the finite extent of the 'accessible' reservoir, which is a few times larger than the average 'ambient' contamination of 3 fingers.

Insofar as a 'basket' of coins composed of equal numbers of each denomination is representative of their repartition in daily usage, the data of Table 4 allow us to conclude that the total contamination by nickel, copper and zinc differs little whether one considers francs or euros, but that there are significant differences in the respective contributions of these metals, particularly those of nickel and copper. The nickel contamination by the euros is 4 times lower than that by the francs, a lowering which results to a comparable extent from the performance of the 1€ and 2€ coins and from the higher proportion of nickel-free denominations. It is difficult to

imagine that a fourfold decrease in nickel contamination could by itself result in an increased risk of nickel allergy, unless the simultaneous 45% increase of copper were responsible for unexpected synergistic effects (16).

We should also emphasize that the above comparison relates to 'weathered' franc coins on the one hand, and relatively recent euro coins on the other. The ageing of the latter pieces may modify this picture in the future. The manipulation tests employed in our investigation and the measurement of the pre-existing contaminants removed by 'polishing' the coins offer a quantitative means to monitor such a development.

Conclusions

Metallic contamination of the hands by the manipulation of coins results from the transfer of pre-existing metallic species present on the surface of the currency. Friction inherent to manipulation is the main contributor to this transfer, rather than simple dissolution into the moisture on the hands. Neither short- nor long-term leaching measurements are appropriate to quantify such contamination. Manipulation tests that simulate everyday handling, as described in this paper, do provide a means to evaluate this contamination reliably.

Polishing renders the coins essentially contamination-free and makes it possible, through analysis of the wipes used for polishing, to determine their original contamination potential. Such measurements could be developed into a standardized test to evaluate the contamination risk of currencies.

The introduction of the euro, in a country such as France where pure-nickel coins were common, has led to a decrease in nickel contamination due to the handling of coins. It is therefore unlikely that the common currency could be the cause of an enhanced risk of nickel allergy, unless the simultaneous increase in contamination by copper were responsible for synergistic sensitization.

When compared to pure-nickel coins, the level of nickel release by the new 1€ and 2€ pieces is somewhat encouraging: while their surface-averaged nickel content is 6 times lower, contamination during handling is only reduced by a factor of 2. Manipulation tests and polishing evaluations, such as employed in this investigation, offer a means of evaluating the ageing of euro coins over time, and to study alternative compositions for future issues of the common currency in a quantitative manner.

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