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Silvia Bezzone graduated in chemical engineering from Turin Polytechnic. After a short period in the field of design and chemical and textile processes, in 2000 she moved to the jewellery industry. Her current field of responsibility is to produce semifinished items made from precision and continuous casting, with relevant wax production departments and test labs to check the metals.
She has taken part in numerous national and international conventions, including as speaker. Since 2012 she has been teaching further education courses for the precious metal working industry, dealing in the casting of precious metals at the For.al institute, Valenza.

Hervé Cantono graduated in industrial design from the Faculty of Architecture at Milan Polytechnic. He has been working in jewellery manufacturing since 2000, gaining experience in creation and design, as well as cost control and management. Since 2007, his specialisation has been quality specification management, starting with the design stages and through to aesthetic and functional controls of the finished jewellery. He has also been part of the business committee for the development of lean manufacturing since 2011 and was awarded six sigma green belt certification in 2012."

In 2011 the new European standard for nickel release was issued and all European states have been aligned with this new standard since 31 March 2013.
The information provided by alloy producers are nickel release values "as cast" from items and also from deformed and annealed products. Jewellery production processes are more complex than this and the release values can differ significantly according to the production and assembly processes used. It is therefore of interest to be able to assess the release of nickel, analysing the different work cycles.
This paper presents the results obtained by mapping the working cycles (casting, torch welding, laser, oven, moulding, shearing, stamping and cleaning) with the relevant amount of nickel release for different alloys in 18 carat gold, simil-gold and steel used in jewellery manufacture.

Assessment of nickel release from production items

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Introduction

Nickel has been used in the jewellery manufacture for over 50 years. Some of the reasons for its use are due to its colour characteristics, mechanical properties and low cost.
In the early 1990s, some researchers began naming nickel as a metal responsible for allergies, and studies were commenced into the effects of this metal on the skin. For this reason, since the mid 1990s, European countries began working on nickel release standards to limit its presence in items that are in prolonged contact with the skin.
In 1998 the first standard regulating the presence of nickel in jewellery and eyewear frames was issued.
More recent studies have shown how one woman in four and one man in ten can be affected by contact allergy (ACD) to nickel, as shown in various works published at JTF and SFS conferences.
In 2006, nickel was also included in the REACH lists as being among toxic metals. This further indication required an initial revision of the standard, which was issued in 2008.
In the meantime, an EU study commission was set up (CEN TC 347 WG 1) for the purpose of testing the components and methods for the nickel release test and subsequent revision of same. The 1998 and 2008 standards gave a correction factor of 0.1 for nickel release, due to the instability of the artificial sweat solution used in the test stage. The initial aim of the work group was to find an artificial sweat solution that could remain stable throughout the duration of testing in order to eliminate the correction factor.
The new standard was issued in 2011, as a result of the study group and this was implemented in European nations in 2013.
The regulations of the EN 1811:2011 standard state that semifinished items in prolonged contact with skin must have a reference release value of 0.5 µg/cm^2/week and that a semifinished item is compliant with the standard if the release value is under 0.28 µg/cm^2/week. A semifinished item is not compliant with the standard if the release limit is over 0.88 µg/cm^2/week; a semifinished product is in an undecided area if the nickel release value is between 0.28 µg/cm^2/week and 0.88 µg/cm^2/week.
The regulations of the EN 1811:2011 standard state that for semifinished items inserted in pierced areas of the human body, the reference release value is 0.2 µg/cm^2/week and that a semifinished item is compliant with the standard if the release rate is less than 0.11 µg/cm^2/week. A semifinished item is not compliant with the standard if the release limit is above 0.35 µg/cm^2/week; a semifinished product is in an undecided area if the nickel release value is between 0.11 µg/cm^2/week and 0.35 µg/cm^2/week.
With reference to these new limits and analysing the results of previous studies presented at international conventions and in trade publications, Bulgari decided to commence a study into nickel release for different production processes, in view of the experience and technological availability present in the production process, in conjunction with the alloy producer, Progold and the director of Eurolab, a laboratory accredited for the performance of these tests.
The purpose of this work was to analyse nickel release for four precious alloys containing 18 carat gold, two simil-gold alloys and two steel alloys in different production processes. The results of the study and the interpretation of same are presented on the following pages.

Analysis of the results: gold

As far as gold alloys are concerned, the release test behaviour of 4 alloys containing nickel was analysed. In particular, the choice fell on these metals, as they are commonly used to make jewellery. The nickel content can vary between 5 and 12%. The alloys are characterised by the presence or not of grain refinement agents and deoxidants and they are usable only for precision casting, or they can be used both in precision or continuous casting and then subsequently subjected to plastic deformation.

The chemical characteristics of the alloys studied are shown in Table 1.

Alloy	Au	Ni	Zn	In	Ag	Cu	Ga	Si	Refiner	limit value [µg/cm2/week]	Microfusion [µg/cm2/week]	Solubilised [µg/cm2/week]	Hardened [µg/cm2/week]	Annealed [µg/cm2/week]
8	75,1%	5%	3%	1%	1%	16%		x	x	0,280	0,428	0,359	0,615	0,416
22	75,1%	8%	4%			13%	1%	x	x	0,280	**3,069**	**1,819**	**1,385**	**1,913**
23	75,1%	8%	4%			14%		x	x	0,280	0,584	0,569	0,771	**1,202**
34	75,1%	12%	5%			8%				0,280	0,722	0,788	**1,179**	0,684

Table 1: Composition of alloys and nickel release for each production process

The above table also contains the release values provided by manufacturers of master alloys for four processes: precision casting, solubilisation, hardening and annealing.

Analysing the results, it is possible to hypothesis that the alloy 22 is the most critical metal alloy, in that it does not conform to the test in any of the four processes. The results from the other alloys are in the indeterminate field.

These four production processes, however, do not cover a wide variety of the assembly processes for a precious item. Rarely is a piece of jewellery just cast and hallmarked. It is usually a question of assembly with laser, flame or tunnel welding in the amount required to create a finished item. The same consideration applies for jewellery made using lost-wax casting processes. For example, for making chains and clasps on bracelets, there are parts made using sheets or strands from continuous casting.

As mentioned in the introduction, the release of nickel is directly linked to the type of production process and therefore to the finishes and heat treatments used on the metal.

For this reason, the analysis began by looking at the production processes in use in Bulgari and representative samples with assembly welds of different types were chosen, as were some of the alloys selected for experimental testing. Each finished item was subjected to a nickel release test. To obtain reliable test results, it was decided to use a minimum number of samples for each type of process/alloy and in no case, less than 3, as prescribed in the standard.

The result of these preliminary tests led to the compilation of Table 2, shown below.

Process	Process description	Semifinished item	Alloy	Description of semifinished item	Number of samples
1	Precision casting; Hallmarking; Laser marking	Ring	23	Plain ring	3
		Ring	22	Complex design ring	3
2	Process 1; 2 flame welds; 1 laser weld	Bracelet	23	Bracelet with high number of parts, springs and pins	1
		Pendant	22	Plain pendant	3
		Earring	23	Complex design earrings	3
3	Process 1; 1 flame weld; 1 laser weld	Ring	23	Ring with high number of parts, springs and pins	3
		Ring	23	Complex design ring	3
		Necklace	23	Complex design pendant and plain necklace	3
4	Process 1; 1 oven weld; 1 flame weld	Necklace	23	Plain ring	3
5	Process 1; 2 flame welds;	Charm	23	Plain pendant	3
6	Process 1; 2 laser welds 2 flame welds; 2 anneals; 1 mould	Bracelet	8	Complex design bracelet with high number of parts	1
		Bracelet	23	Complex design bracelet with high number of parts	1
7	Process 1; 1 laser weld	Necklace	8	Complex design necklace with high number of parts	1
		Pendant	23	Plain bracelet with high number of parts	3
8	Process 1; 1 flame weld	Earring	8	Complex design earrings	4

9	Process 1; 1 oven weld	Necklace	22	Complex design pendant and plain necklace	3
10	Process 1; 2 oven welds; 1 flame weld; 2 laser welds	Necklace	23	Plain charm and complex design necklace	3
		Pendant	8		

Table 2: production process analysis and selection of test alloys

The results of the release test, summed up visually, obtained for ten processes and for the three precision cast alloys, are shown in table 3.

Process 1	Process 7	Process 8	Process 9	Process 3	Process 5	Process 4	Process 2	Process 10	Process 6
Fusion; hallmarking; laser engraving	Process 1; 1 laser weld	Process1; n°1 saldata fiamma	Process 1; 1 oven weld	Process 1; 1 flame weld; 1 laser weld	Process 1; 2 laser welds	Process 1; n°1 saldata forno; n°1 saldata fiamma	Process 1; 2 flame welds; 1 laser weld	Process 1; 2 oven welds; 1 flame weld; 2 laser welds	Process 1; 2 flame welds; 2 flame welds 2 anneals; 1 plastic deform.
√	√			√	√	√	√	√	√
not determinate	not determinate	not determinate							not determinate
√			not determinate				not acceptable		

Table 3: nickel release results

Analysing the data obtained, it is possible to state that alloy 23 conforms to the release test for all processes examined. Experiments and analysis of the results, which will be shown below, allow us to assume that the alloy would also pass the tests after assembly with processes 8 and 9, although these processes were not studied for this paper.

For process 3 and 4 on alloy 23, the spring component was analysed separately as it was made with alloy 34 using continuous mould process, lamination and annealing.

Alloys 8 and 22 gave uncertain results. Alloy 22 conforms to simple processing tests, but for more complex processing, it no longer conforms. Alloy 8 is always in an undecided field; its results are different from those obtained with the four simple processes in table 1. Tests for alloy 8 were also carried out on parts from fusion with continuous casting, processing with CNC machinery, plastic deformation and annealing. For all of these types of process, the alloy was found to conform to the release test.

As a further comparison to alloy 8 and as described above, the release of nickel from parts made with alloy 34 was tested, which as shown in table 1, has high nickel content. This alloy, given its mechanical and colour characteristics, is normally used to manufacture springs.

The following section looks at the results of the test for each type of alloy and production process. This analysis was made to further understanding of the extent that each production process is able to influence test results.

Table 4 shows the results for alloy 8, obtained for 4 types of assembly process. We must reiterate that this alloy has a nickel content of 5% (table 1).

Alloy 8 process	Nickel release [µg/cm2/week]	Lower limit [µg/cm2/week]	Assessment
Precision casting	0.428	0.28	Indeterminate
1 laser weld	0.374	0.28	Indeterminate
1 flame weld	0.562	0.28	Indeterminate
6 laser welds +flame	0.825	0.28	Indeterminate

Table 4: Alloy 8- precision casting component assembly

As shown in Figure 1, nickel release tends to increase as the number of welds increases.
With this composition we remind you that the type of welding process also influences the release of nickel. The release values obtained for flame welds are double compared to laser welds.

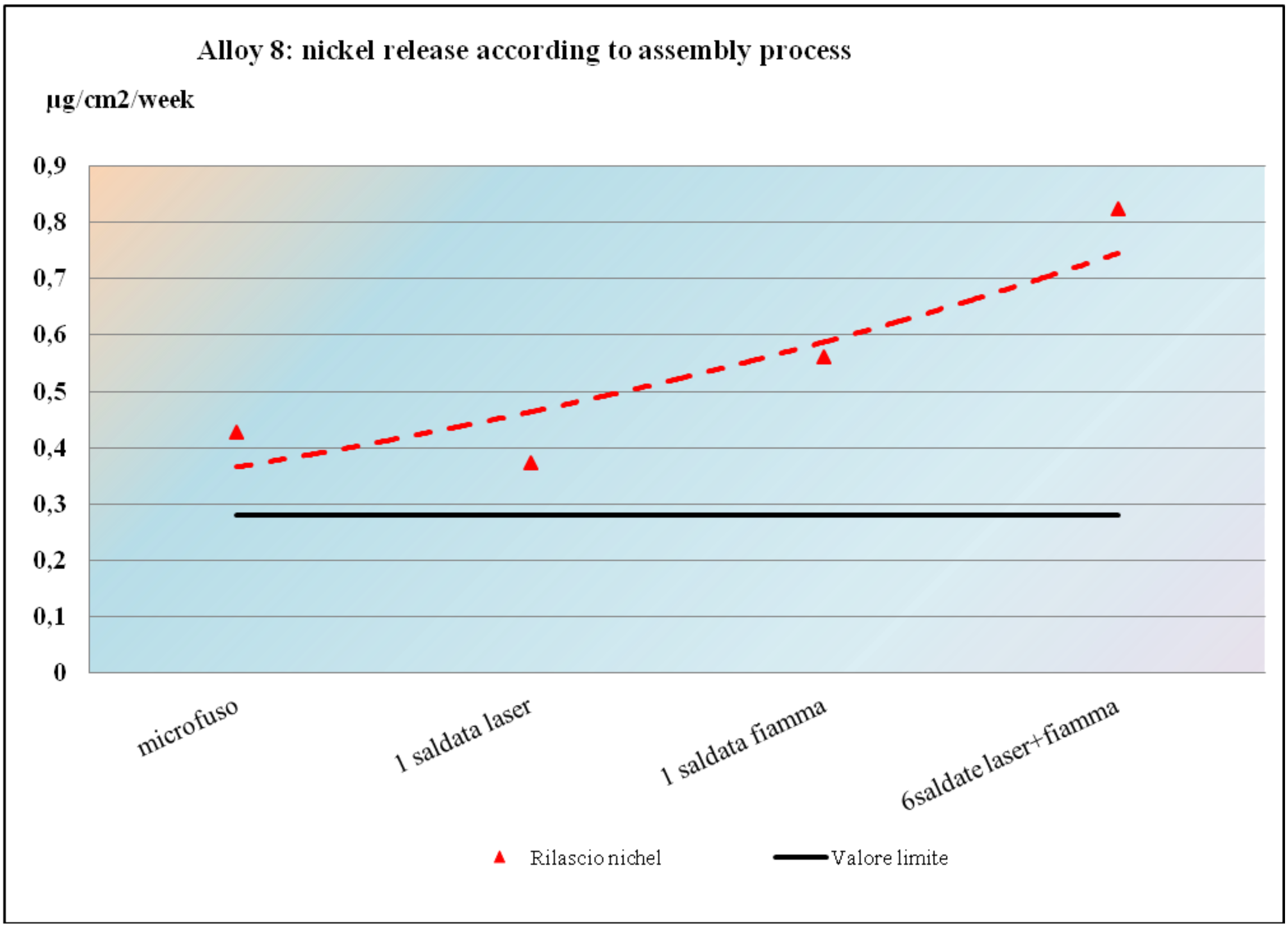

Figure 1: Alloy 8, results

Table 5 shows the release results for alloy 22 for three different assembly processes

Alloy 22 process	Nickel release [µg/cm2/week]	Lower limit [µg/cm2/week]	Assessment
Precision casting	0.224	0.28	ok
1 oven weld	0.412	0.28	Indeterminate
3 laser welds +flame	1.134	0.28	Does not conform

Table 5: Alloy 22- precision casting component assembly

It is noticeable that this alloy conforms for tests with fusion only. The results show that when the assembly process is complicated, for example, by introducing a welding process, the release value doubles. As seen in Figure 2, as the number of welds increases, the nickel release is also significantly increased.

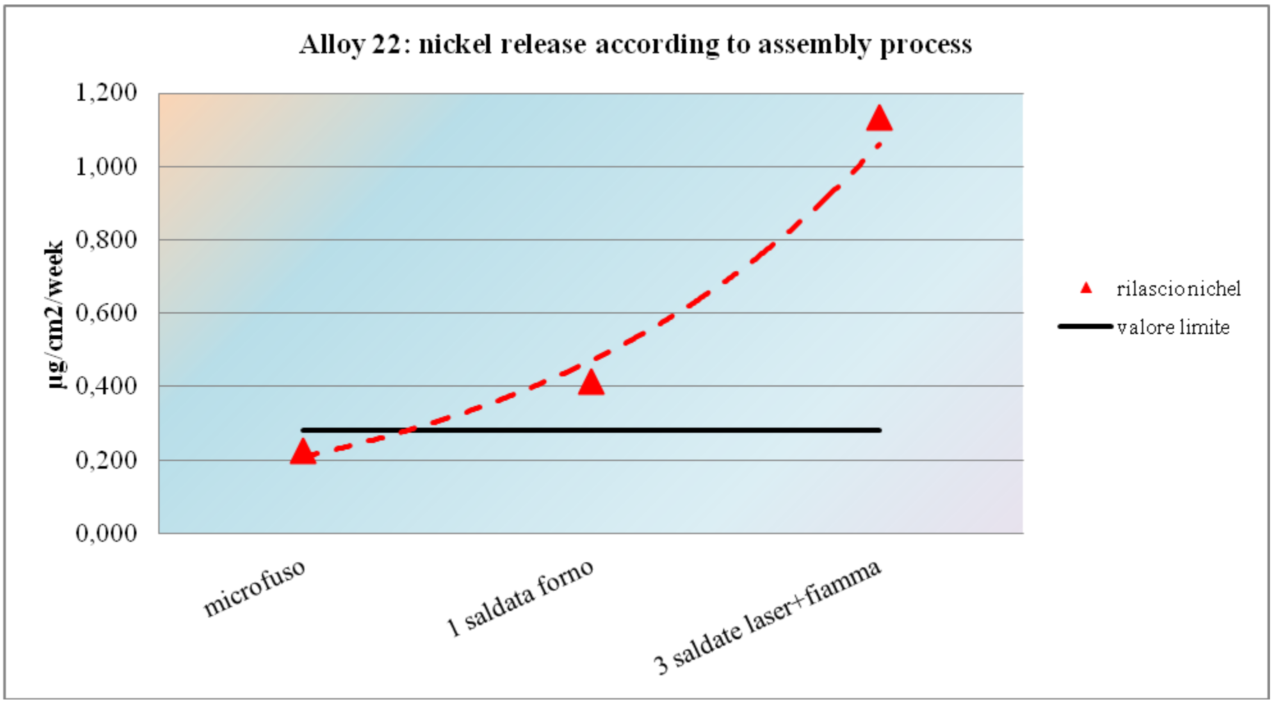

Figure 2: Alloy 22, results

If the behaviour of alloy 8 is compared to that of alloy 22, the latter shows a strong tendency to release nickel as the number of part assembly processes is increased. In fact, for alloy 22, we start with a release value of 0.22 [µg/cm2/week] for precision casting pieces and with three welding processes, the nickel release is six times higher. In the case of alloy 8, nickel release increases by 100% after 6 welding processes.

The following shows the results for alloy 23, used to manufacture and then assemble precision casting items. The nickel content in alloy is 7.5% (table 1).

Table 6 shows the results for the 6 different assembly processes. Looking at this data, it is possible to state that alloy 23 conforms in the majority of assembly processes. Further surveys are being carried out concerning the way in which laser welding and then oven welding are able to influence release values. This sixth process was introduced at a later moment to check the behaviour of this alloy when the jewellery processing stages include oven welds and not just laser or flame.

Alloy 23 process	Nickel release [µg/cm2/week]	Lower limit [µg/cm2/week]	Assessment
Precision casting	0.233	0.28	Ok
1 laser weld	0.189	0.28	Ok
2 laser welds + oven	0.485	0.28	Indeterminate
2 laser welds+flame	0.138	0.28	Ok
3 laser welds+flame	0.147	0.28	Ok
6 welds	0.189	0.28	Ok

Table 6: Alloy 23-precision casting component assembly

The data in table 6 were used to plot the graph in Figure 3. Analysing the curve shows a constant trend in nickel release as a function of the assembly process type. As far as the number and type of welds are concerned, an initial analysis does not show that they influence the test result.
The behaviour of this alloy is completely different compared to that observed in the other two alloys (alloy 8 and alloy 22), where there was an obvious tendency to release more nickel according to the number of heat treatments to which the sample was subjected.

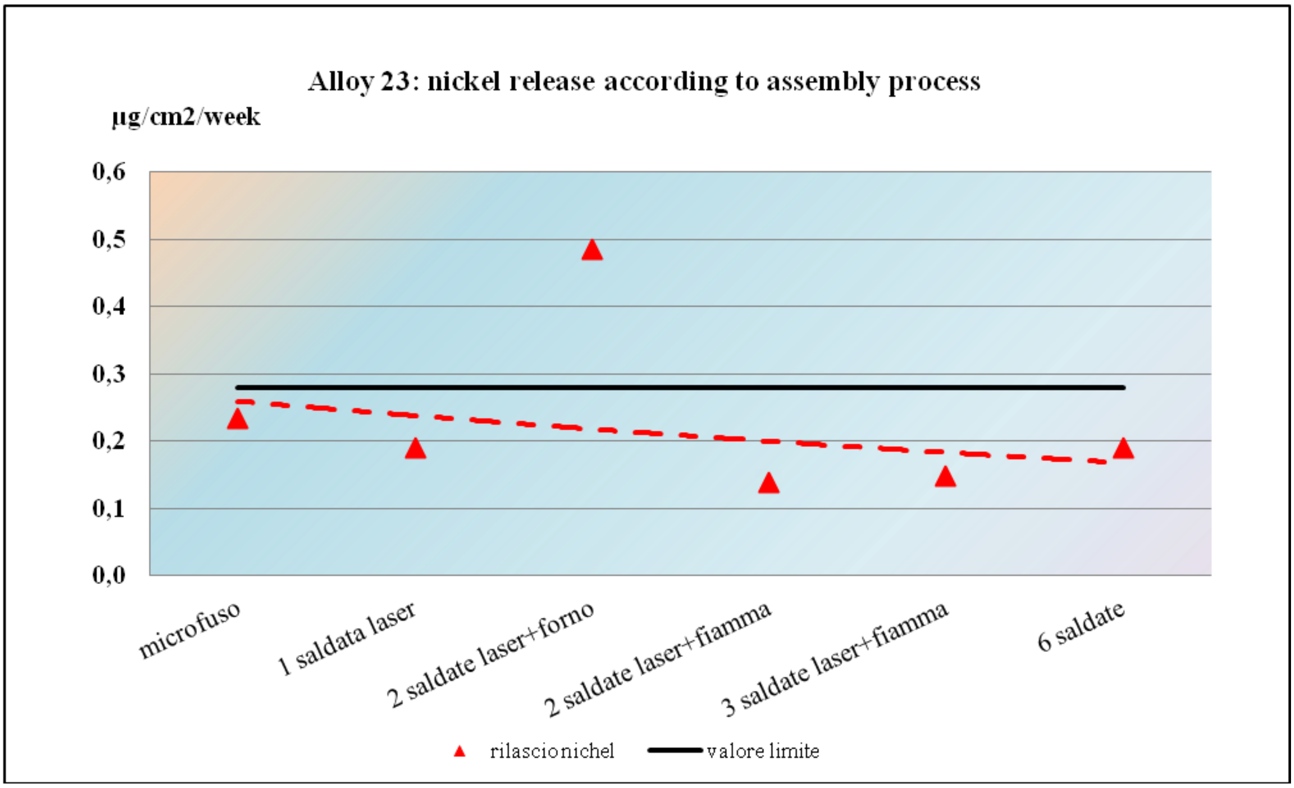

Figure 3: Alloy 23, results

The following shows analysis of the results obtained from release tests on the alloys used for fusion with continuous casting and successive plastic deformation. The alloys in this battery of tests are alloy 8 with 5% nickel content and alloy 34 with 12% nickel content (Table 1).
Table 7 contains the results for alloy 8, subjected to plastic deformation and successively to heat treatment (annealing). Plastic deformation for the samples analysed consisted of lamination processing. During this production process, the reduction in section was 50-70%. Processing parameter values such as times and temperatures for heat treatment are given in table 7.
The results shown for alloy 8 subjected to plastic deformation, are different to those shown for the same alloy used in precision casting.

1 deformation and annealing cycle	650 °C - 25 min	0,419	indeterminate
2 deformation and annealing cycles	650 °C - 25 min	0,245	ok
3 deformation and annealing cycles	650 °C - 15 min	0,100	ok
4 deformation and annealing cycles	650 °C - 20 min	0,102	ok
5 deformation and annealing cycles + shearing	650 °C - 15 min	0,072	ok

Table 7: Alloy 8-assembly of components from plastic deformation

Figure 4 shows the curves obtained from values from the battery of tests previously listed in table 7. The trend of these curves shows that after two deformation cycles and annealing, the nickel release is constant and no longer influenced by heat and deformation cycles.

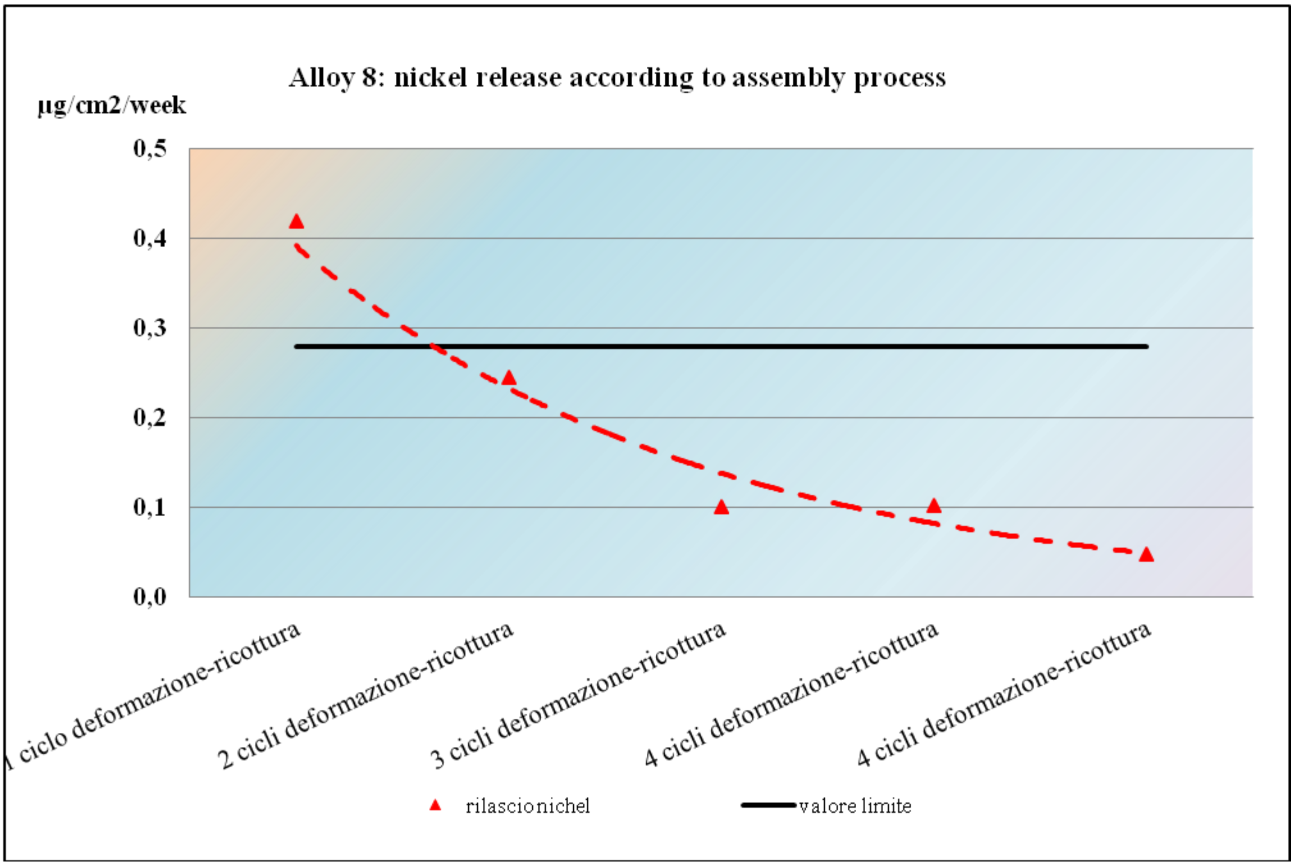

Figure 4: Alloy 8, results

Table 8 shows the results obtained from the tests using alloy 34. This metal has a high nickel content, 12% and this type of alloy is normally used to make springs and components needing high mechanical characteristics. The nickel release test was carried out on laminated and annealed pieces which have undergone four processing cycles and successive deformation to be adapted for insertion into rings.
Although it has high nickel content and was "stressed" for five lamination and annealing cycles, the alloy was conforming to the nickel release test, as can be seen in the results in table 8.

Alloy 34	Process	Heat treatment	Nickel release [µg/cm2/week]	Assessment
sheet for springs	4 def cycles +annealing		0,063	ok
Xlarge	ring ϕ17.5 mm	5 min - 650 °C	0,131	ok
Medium	ring ϕ15.5 mm	7 min - 650 °C	0,182	ok
Small	ring ϕ14.5 mm	8 min - 650 °C	0,249	ok

Table 8: Alloy 34- assembly of parts from plastic deformation

To understand how much a surface coverage can influence nickel release, we looked at the influence of galvanic coverage. Specifically, for plating in Rhodium, we have sought to establish a relationship between the thickness of the metal layer and the release of nickel. We also decided to repeat the measurements to establish the degree of test repeatability.

Analysing the influence of rhodium on the result of the release test, the data in figure 5, show that the rhodium plating, even if high thickness, is not a sufficient barrier to prevent the nickel ion transfer in artificial sweat. One of the reasons for this behaviour is that the rhodium layer is porous, meaning it cannot have a "barrier effect" as hoped for. The only galvanic plating that gives results in this sense are platinum, palladium and silver, with a further finishing layer of rhodium. However, using this type of galvanic plating is a decidedly complicated process with no sufficient guarantees.

As seen in figure 5, galvanic depositing has no influence on alloys that pass the release test in their rhodium free form.

The test used for the rhodium plated samples is EN12472 (involving a cycle to remove the rhodium plating layer), followed by the EN1811:2011 test.

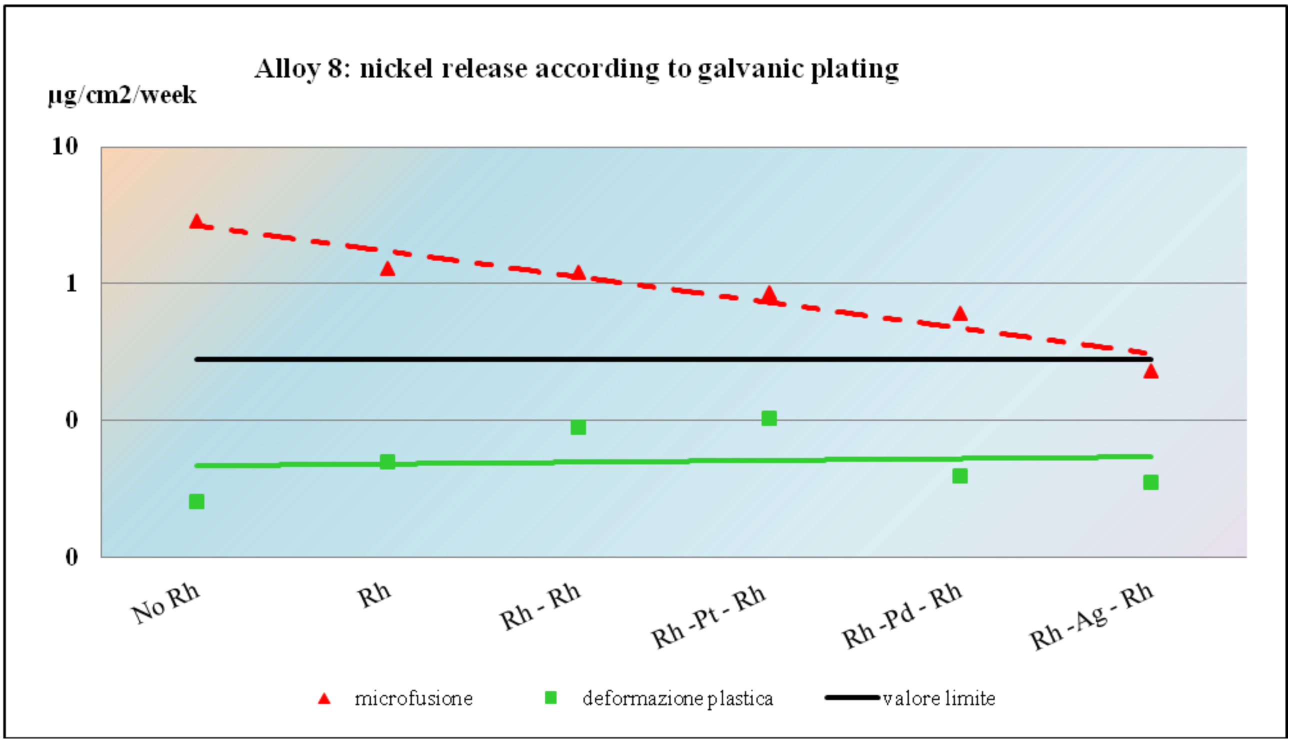

Figure 5: nickel release for galvanic plating processes

Further analysis has shown that the results are not exactly reliable. Three identical samples from the same assembly cycle were sent to five different laboratories providing them with the size of the surface. The result of this last test is shown in figure 7, which shows that three laboratories provide results in the indeterminate area and two come back with unacceptable as a result. During our analysis we have defined that the result of the indeterminate test was to be considered the same as non conforming alloy.

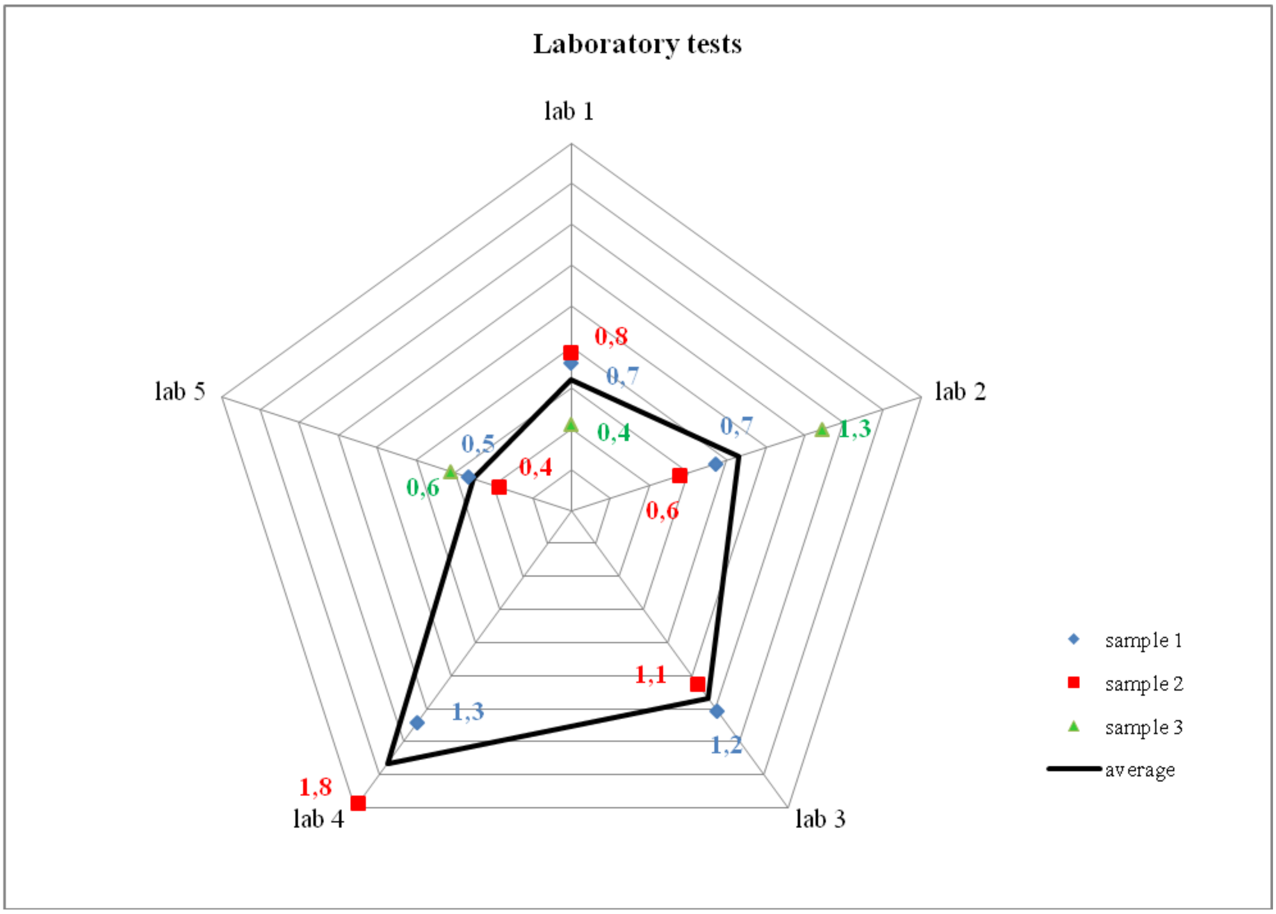

Figure6: laboratory comparisons

The last point of attention is the repeatability of the test. Figure 7 contains the results of the different tests. For pieces subject to mechanical processes, the test results were constant for the twelve tests carried out, while the pieces made with precision casting have shown variable test results. One of the reasons for this different behaviour is that the transformation and successive assembly of pieces processed mechanically are standardised and repeatable. The precision casting assembly processes are subject to variation depending on the ability of the goldsmith and the results of fusion that are anything but standardised from the point of view of microstructure and surfaces.

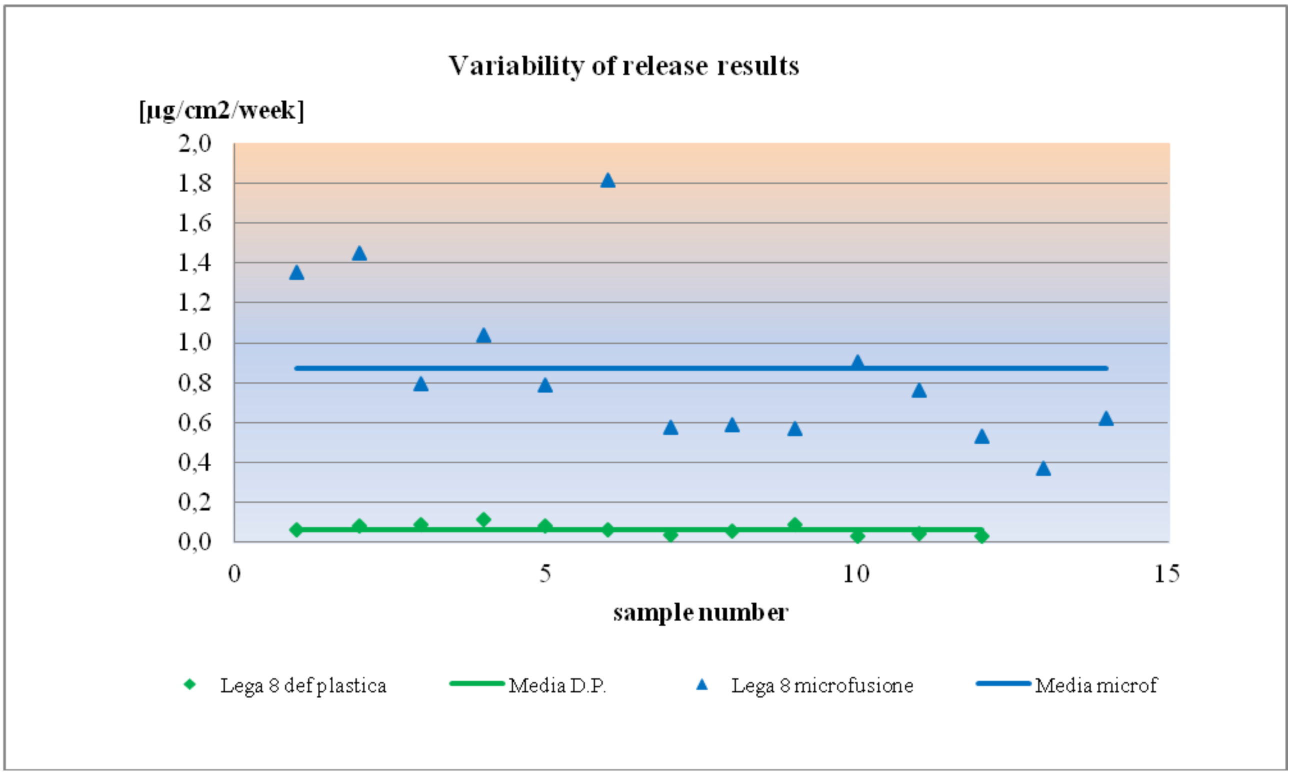

Figure7: Alloy 8 – variability of release results

Analysis of results for non-precious metals

We looked at some types of non-precious metals used to make jewellery. We considered two alloys used to make models or jewellery in simil-gold, of which one containing nickel alloy and the other without nickel alloy. We also tested two iron alloys normally used for making jewellery, and watch cases and components.

For all types of non-precious alloy, we analysed the amount of nickel released according to the different production and assembly processes, following the same survey methods used for gold alloys.

Analysis of results for non-precious metals: alpacca and brass

As shown previously, two alloys not containing precious metals were tested, one identified with the letter A (alpacca) and one with the letter O (brass). Table 9 shows the composition of the alloys.

Alloy A has a high nickel content (10%); alloy O is without nickel.

Alloy	Ni	Cu	Zn	Sn	Si	Grain refiner
A	10%	50%	40%			
O		93%		7%	Y	Y

Table 9: Composition of non-precious alloys

The following table, table 10, shows the processes analysed and the characteristics of the pieces tested for nickel release. For these alloys, only the process for creating the semi-finished item in precision casting and subsequent assembly with flame or laser welding is given.

Process	Process description	Semifinished	Alloy	Description of semifinished item	Number of samples
1	Fusion; Marking; laser marking	Semifinished	A	Complex semifinished piece	3
		Semifinished	O	Plain semifinished piece	3
2	Grinding process; polishing	Semifinished	A	Complex semifinished piece	3
		Semifinished	O	Plain semifinished piece	3
3	Grinding process; 1 flame weld; polishing	Ring	A	Complex design ring	3
		Semifinished	O	Plain semifinished piece	3
4	Process 1; grinding; 1 torch weld; 1 laser welding; polishing	Semifinished	A	Complex semifinished piece	3

Table 10: Analysis of production processes and attribution of non-precious alloys for tests

Table 11 shows the results of nickel release for semi-finished items made using alloy A.

Alloy A process	Nickel release [µg/cm2/week]	Lower limit [µg/cm2/week]	Assessment
as cast rough	24.72	0.28	Not acceptable
as cast polished	13.25	0.28	Not acceptable
1 welded polished	17.03	0.28	Not acceptable
2 welded polished	21.22	0.28	Not acceptable

Table 11: Alloy A- precision casting part assembly

In no cases does alloy A have nickel release conforming to standard. In all of the processes examined, the release was 50-100 times above that prescribed by the regulations.
The same data are provided in the graph below, figure 8. It can be seen that the release trend is influenced by the type of process and finish. The same piece, if left rough, releases twice the amount of nickel as a polished piece. This behaviour is certainly caused by an increase in the surface area of a piece left rough cast compared to a polished piece, but it is also due to the closure of the micropores on account of the malleability of the metal during polishing.
Moreover, as seen for gold alloys, the heat treatments and welds used influence nickel release on this type of alloy; the release increases in line with the number of welding processes.

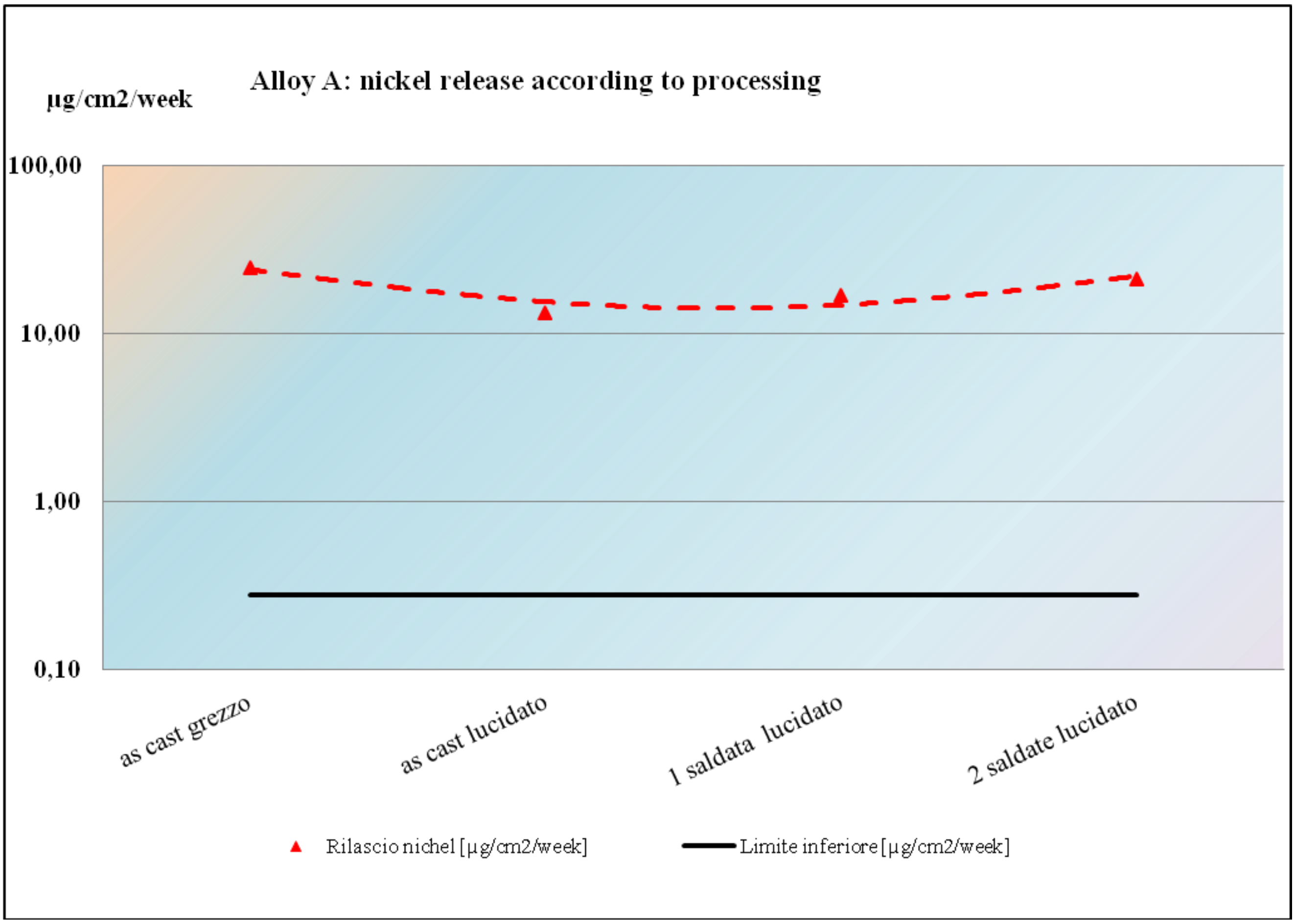

Figure 8: Alloy A, results

Table 12 shows the results obtained from a nickel release test for semi-finished items made with alloy O.

Alloy O process	Nickel release [µg/cm2/week]	Lower limit [µg/cm2/week]	Assessment
as cast rough	0.057	0.28	ok
as cast polished	0.158	0.28	ok
1 weld polished	0.109	0.28	ok

Table 2: Alloy O- precision casting part assembly

Alloy O contains no nickel, as stated by the supplier and found with testing; however, there was one result with release above zero. It is probable that the nickel found during the testing stages was inside the melting pot at the time of casting. Casting was in fact carried out with the same melting pot used for the casts with alloy A and as is common practice, the melting pot and shutter were cleaned of residues visible to the naked eye. This datum shows how the components of alloys, even if invisible, remain on the surface of melting pots and are transferred to successive castings and therefore, if casting alloys with or without nickel in sequence and without changing materials, the allots will contain even minimum amounts which can be picked up during testing.
Figure 9 shows the test results.

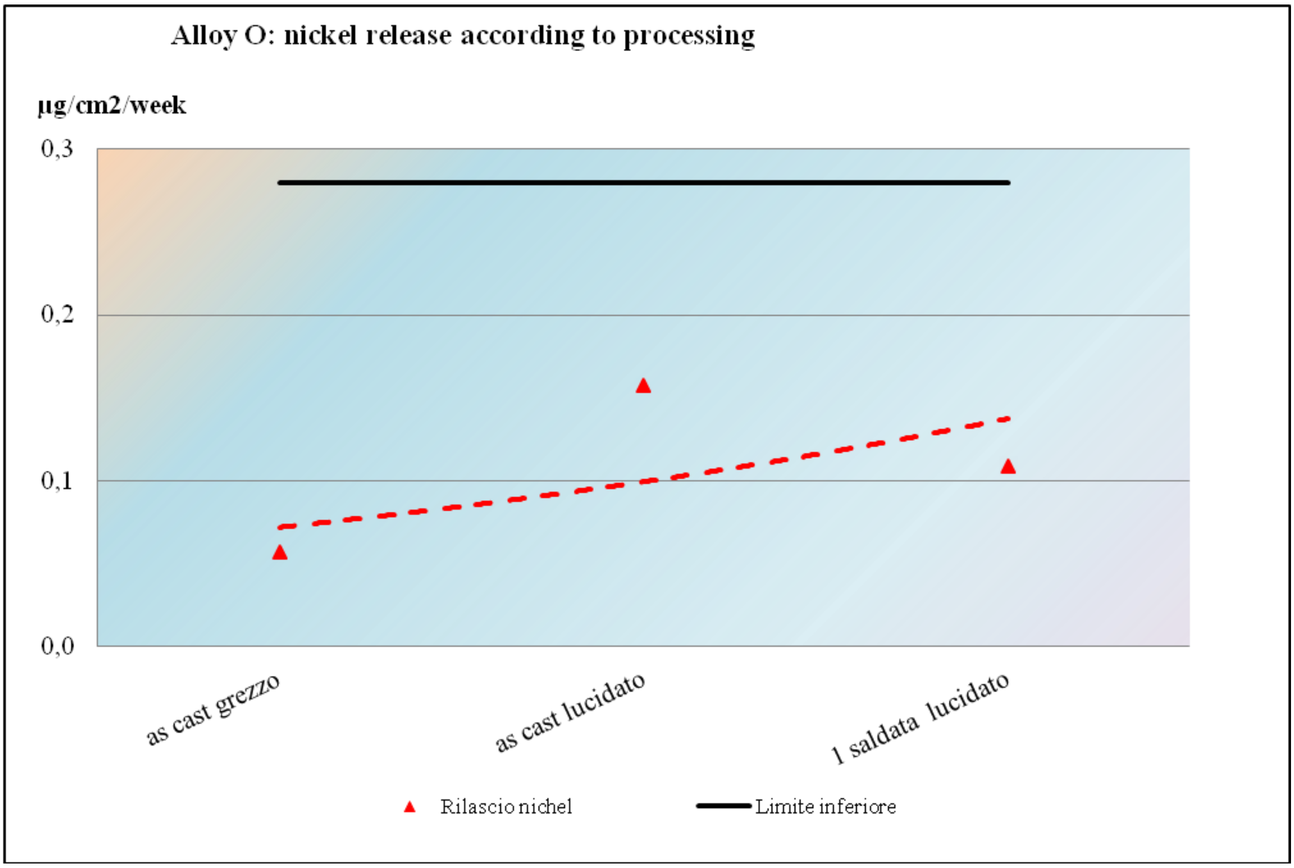

Figure 9: Alloy O, results

Analysis of results for non-precious metals: steel
We analysed two iron alloys generally used in jewellery and watch making. The following table, table 13, shows the nominal composition of the alloys identified with the names M1 and M2.

Alloy	Fe	Ni	Cr	Mo	Mn	Cu	C	Si	Other elements
M1	62.2%	13.5%	18%	3%	2%	0.1%	0.03	1%	P+S
M2	46.1%	25%	20%	4.5%	2%	1.6%	0.02	0.7%	P+S

Table 13: Chemical composition of the steel alloys used for testing

Table 14 contains the processes for which nickel release was analysed.
The production processes tested contain both precision cast semifinished pieces and semifinished pieces prepared for processing on CNC machinery, and also semifinished pieces from metallurgical dust.

Process	Process description	Semifinished piece	Alloy	Description of semifinished piece	Number of samples
0	As cast alloy	Sheet	M1	Sheet	3
1	Process 0; Precision casting; sandblasting grinding; polishing	Semifinished	M1	Plain semifinished piece	3
		Semifinished	M2	Plain semifinished piece	3
2	Process 0; processing with CNC machinery Polishing	Semifinished	M1	Plain semifinished piece	3
3	Process 0; processing with CNC machinery Oven welding Polishing	Pendant	M1	Complex pendant	3
		Pendant	M2	Plain pendant	3
5	Process 0; processing with CNC machinery Laser marking	Semifinished	M1	Complex semifinished piece	3
5	MIM; polishing	Semifinished	M1	Plain semifinished piece	3

Table 14: analysis of production processes and attribution of non-precious metals for testing

Table 15 below shows the nickel release results for the processes concerning alloy M1

Alloy M1 process	Nickel release [μg/cm2/week]	Lower limit [μg/cm2/week]	Assessment
sheets	0.00	0.28	Ok
as cast	6.63	0.28	Not acceptable
CNC	0.03	0.28	Ok
CNC+welding	0.05	0.28	Ok
CNC+laser	1.22	0.28	Not acceptable
MIM	2.02	0.28	Not acceptable

Table 15: Alloy M1- precision casting part assembly

Table 16 below shows the nickel release results for the processes concerning alloy M2

Alloy M1 process	Nickel release [μg/cm2/week]	Lower limit [μg/cm2/week]	Assessment
as cast	1.439	0.28	Not acceptable
CNC+laser	0.883	0.28	Uncertain

Table 16: Alloy M2- precision casting part assembly

Figure 10 shows the results for both steel alloys.

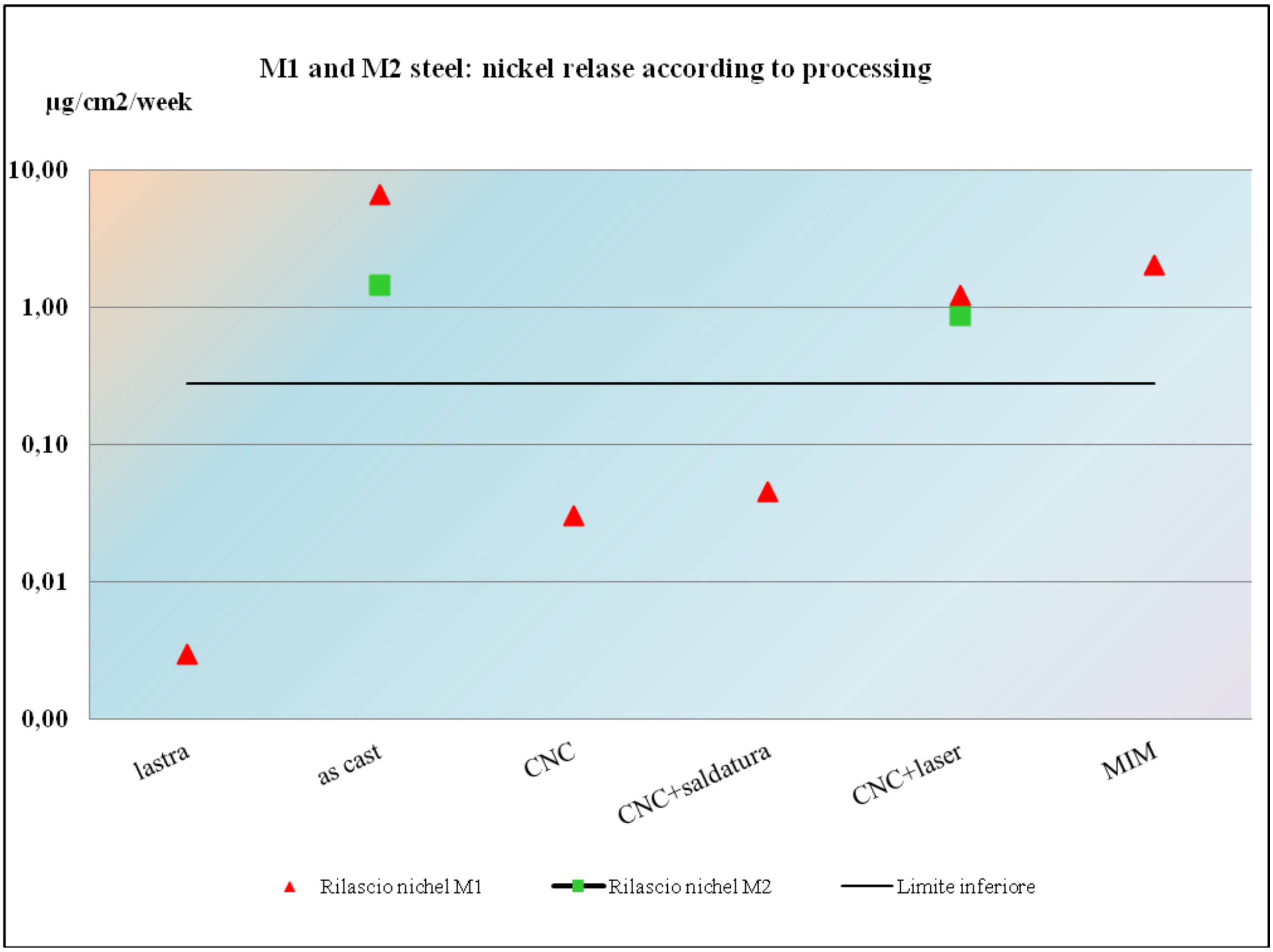

Figure 10: Alloy M1 and M2, results

The M1 alloy release is sensitive to the type of processing and localised heat treatments, such as welding or laser engraving, because the checked assembly processes locally modify the microstructure of the metal, increasing nickel release into artificial sweat solution.

For semi-finished pieces made with M1 alloy and processed on CNC machinery, with plastic deformation processes and subsequent heat treatments, nickel release conforms to the standard. Even items welded with belt oven processes conform to the standard.

Semi-finished pieces made with M2 alloy do not conform or are in the undecided zone. M2 alloy has a greater nickel content than M1, but its release is lower than that for semifinished parts made with M1. In this case, too, the nickel release is not proportionate to the amount of this metal in alloy form, but it is linked to the structure that forms during processing and heat treatment.

Conclusions

In conclusion, as analysed, nickel release does not just depend on the nickel content of an alloy but rather it is directly linked to chemical composition (all elements contained in the alloy), to the casting method used, assembly method and number and type of heat treatments.

The nickel release value provided by the alloy manufacturers is for information purposes only since no supplier is able to provide release data by reproducing all of the different casting and assembly processes used when making jewellery. Each process is typical to the item being made and a function of the equipment available. For each change in the process, as analysed in the tables 2, 10 and 14, may cause different release values, which makes it necessary to map the processes and measure the release for each of them.

In conclusion, nickel release is not directly proportionate to the metal content in an alloy; it is closely tied to the production process, which influences the microstructure of a material. One such example is alloy 8 which when used in the precision casting process, is not conforming, but if used in the continuous casting process and plastic deformation, it is.

Galvanic plating of jewellery using rhodium does not make an alloy already criticised in the past compliant with release levels.

The casting process for nickel alloys and non-nickel alloys using the same melting pot during production means that even if only in tiny amounts, nickel was found to be present during the test process, which goes to show how sensitive the test is to the chemical composition of the alloy as well as its structure.

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