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Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Market survey on toxic metals contained in tattoo inks

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ARTICLE INFO

Article history:

Received 9 February 2009

Received in revised form 19 August 2009

Accepted 25 August 2009

Available online xxxxx

Keywords:

Metals

Tattoos

Inks

SF-ICP-MS

Skin allergies

ABSTRACT

Tattooing practice is adopted worldwide and represents an important socio-cultural phenomenon, but, the injection into the skin of coloring agents as metals might pose a risk for allergies and other skin inflammations as well as for systemic diseases. In this context, 56 inks for tattooing purchased from 4 different supply companies were analyzed for metal concentration. Aliquots of pigments were microwave digested by nitric acid, fluoridric acid and hydrogen-peroxide and Al, Ba, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Sb, Sr and V were quantified by sector field inductively coupled plasma mass spectrometry. Limits of quantification varied from 0.07 ng/ml (Cd) to 10 ng/ml (Al and Fe); recoveries ranged from 92% (Cd and Sb) to 109% (Sr); within- and between-day precisions were 3.2% and 4.67% on average.

The relative contribution of metals to the tattoo inks composition was highly variable between brands and colors, even in pigments with the same base color. Elements found as the main components of inks were as follows (in µg/g): Al, 1.59–5893; Ba, 0.058–1226; Cu, 0.076–31,310; Fe, 0.717–88,443; Sr, 0.174–36.4. Toxic metals as Cd, Mn, Pb, Sb and V were over the 1 µg/g in a few cases, while Hg was in traces. Among the allergenic metals, Cr was the highest (0.315–147 µg/g), followed by Ni (0.037–9.59 µg/g) and Co (0.0028–6.43 µg/g) then. On 56 tattoo inks, Cr, Ni and Co exceeded the safe allergological limit of 1 µg/g in 62.5%, 16.1% and 1.8% of cases, respectively.

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1. Introduction

The practice of skin tattoos has been adopted for several centuries worldwide assuming different significance passing from one country to another. Tattoos have been used to express not only a simple fashionable body ornament, but also the membership to a particular socio-cultural group.

Nowadays, epidemiological findings showed that the practice of depicting the body is even more adopted by people. Mayers et al. (2002) reported that the 25% of 302 subjects of a small Midwest private college had at least one tattoo, while Forbes (2001) highlighted that the prevalence for tattooing among 491 university students in New York State was of 23%. In 1995, on 1762 students the proportion of adolescents with a tattoo was 9% higher with respect to that in 1993, while the average age at first tattoo dropped from 16 years to 14.5 years (Armstrong and Murphy, 1997). In Italy this practice is largely adopted among 12–18 years old students; at national level, on 3800 students the 6.6% was tattooed (7.2% were males and 5.7% were females) (Eurispes, 2002), and in one Italian region the 4.8% of 496 interviewed students (3.0% males and 6.0% females) had at least one tattoo (Boncompagni et al., 2005).

In permanent tattoos and permanent make-up, the pigments are deposited in the dermis by means of a needle. This process ensures that the pigments cannot be removed and simultaneously the organism is exposed to the ingredients in the tattoo colors in a very direct way and for prolonged time. In this context, the main components of colors are metals. In fact, dichromate-, Co-, Cd- and Hg-salts were considered the base for green, blue, yellow and red colors, while iron oxide, titanium dioxide, C and Mn are prevalently in the brown, white, black and violet inks (Kaatze et al., 2008). In addition, organic pigments and metals (i.e., Al, Ca, Cd, etc.) were often combined to create different hues, brightness or lightness shade of colors (Duke et al., 1998). The intimate and continuative contact between skin and colors can create in many people metal-related skin inflammation such as allergic, eczematous, lichenoid, psudolymphomatous or granulomatous reactions due to a one or more metals contained in pigments (Blumental et al., 1982; Sowden et al., 1991; Morales-Callaghan et al., 2006; Eun and Kim, 1989; Rubianes and Sánchez, 1993; Bagnato et al., 1999).

Considering the wide diffusion of the tattooing practice and the serious problems for the human health, a strict legislation for colors used for tattooing should be mandatory. In fact, there are no coded rules that reported which raw materials are allowed and how to test the final product. In addition, in most cases is very difficult to retrieve the relevant ink ingredients because only relatively few manufacturers release the documentation. In this context, each National Health Service should collect ink samples at both suppliers and

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Table 2
Level in ng/g of metals in tattoo inks form “Millennium Colorworks Inc.”.

	Color									
	Commercial name									
	Black	Blue	Brown	Green	Grey	Orange	Red	Violet	Yellow	White
	Onyx	Ice	Doo doo	Mean	Hound	Agent	Monthly	Violent	Hello	Power
Al ^a	189 ± 13	2963 ± 137	150 ± 10	1960 ± 115	5893 ± 200	304 ± 18	2.41 ± 0.15	5110 ± 108	1120 ± 88	5868 ± 249
Ba ^a	2.74 ± 0.11	0.960 ± 0.073	3.96 ± 0.18	0.748 ± 0.052	2.84 ± 0.13	1.01 ± 0.06	9.74 ± 0.38	1.17 ± 0.06	0.709 ± 0.055	0.549 ± 0.011
Cd	1.35 ± 0.11	278 ± 16	34.6 ± 2.0	88.8 ± 3.7	516 ± 33	23.5 ± 1.8	26.3 ± 1.4	280 ± 25	144 ± 5	465 ± 41
Co	13.0 ± 0.8	56.9 ± 3.3	17.3 ± 1.3	25.1 ± 2.4	44.0 ± 2.9	16.0 ± 1.0	10.7 ± 0.6	39.3 ± 2.0	21.3 ± 1.5	35.0 ± 1.7
Cr	1106 ± 91	3340 ± 199	1502 ± 126	1087 ± 83	1007 ± 77	648 ± 37	1131 ± 74	1708 ± 118	1118 ± 49	841 ± 39
Cu ^a	0.789 ± 0.043	3683 ± 211	0.679 ± 0.051	4540 ± 188	29.6 ± 1.5	3.22 ± 0.16	0.790 ± 0.039	21.9 ± 1.6	3.50 ± 0.31	10.0 ± 1.0
Fe ^a	69.3 ± 3.0	92.1 ± 5.9	46.9 ± 2.8	54.5 ± 1.7	92.9 ± 7.6	24.9 ± 1.1	0.717 ± 0.057	85.4 ± 6.6	52.5 ± 3.3	77.8 ± 4.0
Hg	<LoQ	<LoQ	<LoQ	11.2 ± 0.7	112 ± 10	20.7 ± 1.4	<LoQ	22.6 ± 1.8	<LoQ	<LoQ
Mn	408 ± 22	1450 ± 106	827 ± 28	918 ± 48	1525 ± 125	293 ± 11	619 ± 39	1265 ± 84	1151 ± 79	1287 ± 68
Ni	86.8 ± 3.4	644 ± 52	118 ± 8	154 ± 11	1067 ± 82	62.5 ± 2.7	44.8 ± 3.7	263 ± 19	114 ± 10	200 ± 15
Pb	87.2 ± 5.5	72.7 ± 4.0	113 ± 7	87.9 ± 2.9	71.9 ± 3.1	99.7 ± 7.4	422 ± 30	116 ± 7	103 ± 6	70.7 ± 4.7
Sb	114 ± 10	62.4 ± 3.3	19.3 ± 1.7	39.3 ± 3.0	575 ± 44	3.84 ± 0.11	9.03 ± 0.64	141 ± 12	48.9 ± 3.5	101 ± 8
Sr ^a	0.275 ± 0.018	1.07 ± 0.04	0.370 ± 0.025	0.745 ± 0.036	1.09 ± 0.08	3.42 ± 0.22	0.320 ± 0.028	0.648 ± 0.049	0.979 ± 0.059	0.488 ± 0.033
V	153 ± 11	1522 ± 94	84.8 ± 4.1	735 ± 22	1490 ± 101	79.6 ± 2.5	27.0 ± 1.1	2521 ± 194	272 ± 16	1588 ± 124

^a Values in µg/g.

Table 3
Level in ng/g of metals in tattoo inks form “Intenze Prod.”.

	Color											
	Commercial name											
	Black	Blue	Brown	Green	Grey	Orange	Pink	Red	Violet	Yellow	White	
	True	Baby	Dark chocolate	Grasshopper	Platinum	Peach	Rose	Cherry bomb	True magenta	Grape	Lavender	Snow opaque
Al ^a	9.36 ± 0.34	2180 ± 158	105 ± 10	2012 ± 100	2903 ± 135	1828 ± 146	1727 ± 115	670 ± 49	7.13 ± 0.52	2702 ± 95	1625 ± 110	2987 ± 197
Ba ^a	0.170 ± 0.011	24.0 ± 1.8	19.3 ± 1.6	102 ± 8	0.135 ± 0.010	0.518 ± 0.035	0.529 ± 0.037	161 ± 12	36.7 ± 2.8	20.9 ± 1.3	0.069 ± 0.004	0.129 ± 0.009
Cd	12.6 ± 1.1	776 ± 60	347 ± 30	296 ± 16	69.3 ± 4.6	2986 ± 220	372 ± 28	36.0 ± 3.0	12.5 ± 0.9	520 ± 44	918 ± 73	556 ± 40
Co	10.5 ± 0.8	184 ± 13	6439 ± 348	24.2 ± 1.4	16.6 ± 1.2	26.2 ± 1.9	11.1 ± 1.0	8.88 ± 0.66	30.5 ± 2.5	42.2 ± 1.8	14.3 ± 1.1	10.0 ± 1.0
Cr	1549 ± 140	637 ± 50	147229 ± 9918	2529 ± 186	737 ± 61	889 ± 49	484 ± 24	4144 ± 391	4672 ± 319	1462 ± 103	495 ± 33	335 ± 29
Cu ^a	5.02 ± 0.29	558 ± 38	260 ± 18	1606 ± 128	41.4 ± 2.6	32.4 ± 1.1	65.2 ± 4.0	1.47 ± 0.09	1.27 ± 0.11	146 ± 9	11.0 ± 0.9	44.9 ± 3.1
Fe ^a	6.42 ± 0.38	9.27 ± 0.41	88443 ± 274	19.6 ± 1.2	5.93 ± 0.42	13.0 ± 1.0	6.24 ± 0.53	38.5 ± 1.8	34.6 ± 2.9	10.0 ± 0.6	6.81 ± 0.40	3.97 ± 0.22
Hg	10.9 ± 0.1	<LoQ	146 ± 10	9.35 ± 0.09	<LoQ	<LoQ	<LoQ	34.1 ± 1.8	6.77 ± 0.49	<LoQ	35.3 ± 2.4	<LoQ
Mn	79.2 ± 6.4	580 ± 41	98790 ± 5574	582 ± 43	299 ± 17	479 ± 31	359 ± 30	274 ± 16	360 ± 27	159 ± 13	445 ± 29	118 ± 10
Ni	70.4 ± 4.9	274 ± 15	9592 ± 651	259 ± 20	233 ± 15	140 ± 13	141 ± 10	66.8 ± 2.2	641 ± 55	271 ± 14	260 ± 22	196 ± 17
Pb	56.9 ± 3.8	33.2 ± 1.8	8128 ± 422	204 ± 14	106 ± 10	14798 ± 1182	86.7 ± 6.8	389 ± 26	106 ± 11	64.3 ± 3.7	45.3 ± 3.8	56.1 ± 4.2
Sb	69.6 ± 1.7	196 ± 12	4116 ± 381	156 ± 10	97.8 ± 8.0	290 ± 20	181 ± 13	44.7 ± 1.8	61.4 ± 2.9	138 ± 11	241 ± 18	134 ± 8
Sr ^a	0.174 ± 0.016	0.347 ± 0.025	0.382 ± 0.029	14.3 ± 0.9	0.391 ± 0.027	0.323 ± 0.029	2.64 ± 0.18	8.21 ± 0.40	0.970 ± 0.067	0.424 ± 0.036	0.291 ± 0.024	0.384 ± 0.017
V	98.3 ± 8.0	593 ± 44	11049 ± 681	1404 ± 116	2600 ± 194	1505 ± 131	1510 ± 100	168 ± 11	27.2 ± 1.3	1170 ± 85	677 ± 48	1423 ± 129

^a Values in µg/g.

Table 4
Level in ng/g of metals in tattoo inks form “Diabolo by Deep Colours”.

	Color									
	Commercial name									
	Black		Blue		Brown	Green		Grey		Orange
	Magic	Blue	Turquoise	Ultramarine	Noisette	Basic	Willow	Grey	Sumi	Dark
Al ^a	1.92 ± 0.16	32.0 ± 2.9	55.4 ± 3.7	39.6 ± 1.7	42.9 ± 3.5	254 ± 17	137 ± 11	118 ± 9	6.47 ± 0.41	1.59 ± 0.13
Ba ^a	68.3 ± 4.9	1030 ± 79	682 ± 21	111 ± 8	3.63 ± 0.27	25.1 ± 1.9	12.1 ± 1.0	8.21 ± 0.64	0.451 ± 0.039	1.90 ± 0.08
Cd	138 ± 10	60.8 ± 4.8	41.0 ± 3.1	52.1 ± 4.0	64.4 ± 4.6	41.4 ± 1.8	31.6 ± 1.8	97.0 ± 6.4	11.3 ± 0.8	35.7 ± 1.8
Co	72.2 ± 3.4	20.4 ± 1.4	15.2 ± 1.0	17.5 ± 1.3	30.6 ± 2.0	110 ± 9	17.5 ± 1.1	15.5 ± 1.2	29.2 ± 1.9	26.0 ± 1.8
Cr	872 ± 53	1399 ± 110	1236 ± 81	1114 ± 69	1364 ± 110	2008 ± 156	1683 ± 100	2053 ± 149	366 ± 32	428 ± 35
Cu ^a	10.4 ± 0.6	8329 ± 359	5933 ± 303	14759 ± 907	23.9 ± 1.8	5887 ± 408	1494 ± 86	125 ± 10	0.076 ± 0.005	0.580 ± 0.049
Fe ^a	5.47 ± 0.32	8.09 ± 0.29	9.63 ± 0.33	6.69 ± 0.41	23.2 ± 1.9	44.9 ± 3.1	16.4 ± 1.1	15.8 ± 1.3	2.95 ± 0.13	6.52 ± 0.49
Hg	190 ± 15	137 ± 11	98.1 ± 7.9	124 ± 10	126 ± 11	120 ± 10	186 ± 15	92.0 ± 7.4	130 ± 11	146 ± 9
Mn	1037 ± 57	234 ± 17	258 ± 17	168 ± 15	275 ± 20	1701 ± 125	468 ± 35	229 ± 15	582 ± 43	83.5 ± 4.8
Ni	73.3 ± 5.9	871 ± 49	855 ± 70	1616 ± 120	518 ± 36	5049 ± 345	1168 ± 81	470 ± 32	221 ± 18	143 ± 10
Pb	1448 ± 130	872 ± 55	763 ± 58	277 ± 20	746 ± 43	120 ± 7	540 ± 41	502 ± 46	60.5 ± 3.7	187 ± 18
Sb	166 ± 10	1098 ± 85	1115 ± 80	2259 ± 183	189 ± 16	671 ± 48	231 ± 13	35.2 ± 2.4	18.3 ± 1.4	97.3 ± 6.8
Sr ^a	4.11 ± 0.31	24.4 ± 1.8	17.0 ± 1.3	36.4 ± 2.0	4.88 ± 0.29	5.59 ± 0.34	6.10 ± 0.42	4.39 ± 0.35	1.19 ± 0.08	2.19 ± 0.16
V	5.98 ± 0.48	1984 ± 152	1917 ± 167	1797 ± 152	801 ± 64	580 ± 37	453 ± 34	766 ± 66	7.93 ± 0.80	58.3 ± 3.7

^a Values in µg/g.

The LoDs ranged from 0.02 ng/ml (Cd) to 3 ng/ml (Al and Fe), while the LoQs varied from 0.07 ng/ml (Cd) to 10 ng/ml (Al and Fe) demonstrating the high method's sensitivity and that there were wide margins for quantifying elements at the concentration levels in real samples. The recovery values were between 92% (Cd and Sb) and 109% (Sr) testifying the good method's accuracy. The data obtained for all the elements gave similar good results for both within- and between-day precision, which emphasized the robustness of the method. The between-day precision was in the range 1.58% (Co)–5.33% (Cu), while the within-day precision varied between 2.67% (Co) and 7.05% (Cu).

3.2. Metal content of tattoo pigments

The results of the chemical analysis of 56 tattoo colors by 4 different tattoo ink suppliers are given in Tables 1–4. All the measured metals were present in all the colors; only Hg was under the quantification limit in 16 of them. The inks varied in metallic composition from manufacturer to manufacturer and from color to color and even among like-colored pigments, but, as a general trend, Al, Ba, Cu, Fe and Sr were the main components (from few µg/g to tens of mg/g) in all the 56 colors. The concentrations of Cr, Mn, Ni, Pb and V varied in the range ng/g–µg/g. Cadmium, Co, Hg and Sb were the elements less concentrated, i.e. from units of ng/g to hundreds of ng/g.

With reference to metals which are mostly looked as those allergologically relevant, Cr showed the highest concentration followed by Ni and then by Co. The following concentration ranges were observed (in ng/g): Cr, 315–147,229; Ni, 37.5–9592; Co, 2.78–6439. The Co, Cr and Ni values obtained can be compared with the published maximum levels defined as allergologically safe for consumers exposed to products containing the metals. In this context, Basketter et al. (2003) has shown that in the presence of irritants and/or following repeated exposures to Co, Cr and Ni such individuals rarely react to levels below 10 ppm. For this reason the same Authors recommended that consumer products should not contain more than 5 ppm of Co, Cr and Ni or for a better health protection the levels should not exceed the 1 ppm. Fig. 1 shows the levels of Cr and Ni contained in colors produced by the 4 companies compared to the safe limit of 1 ppm. It is worth noting that a high percentage (62.5%) of inks had the Cr level out of the limit: the 69.2% of dyes outlying the limit belonged to the “Starbrite” series, the 80.0% to the “Millennium”, the 46.1% to the “Intenze” and the 60.0% to the “Diabolo”. Regarding Ni, samples exceeding the safe limit were the 16.1% of the total. In this case, the samples higher than the safe value were shared as follows:

the 15.3% in the “Starbrite” series, the 10.0% in the “Millennium”, the 7.7% in the “Intenze” and the 25.0% in the “Diabolo”. With reference to Co, only one color exceeded the limit (i.e., the 1.8% of all cases). These results indicated that the contact of the skin with such quantities of Cr and Ni contained in inks might pose a serious risk for the development of dermatological pathologies in tattooed patients.

As regards toxic metals, Mn (79.2–98,790 ng/g), Pb (15.9–14,798 ng/g) and V (5.98–11,050 ng/g) were those at the highest concentration followed by Cd (1.35–2986 ng/g) and Sb (3.84–4116 ng/g). Mercury was at traces or even undetectable (i.e., <LoQ–253 ng/g).

Most tattoo inks are metal salt-based pigments that are not made specifically to be used under the skin. Currently, regulatory bodies such as the US Food and Drug Administration have not approved any coloured inks to be injected into the skin. The common idea is that these pigments are inert and cause no problems for human health. Actually, in literature adverse reactions due to inorganic metal salts in tattooed people have been well documented.

As regard the origin of colors, the natural black ink is obtained from magnetite and wustite (iron oxides) or amorphous carbon from combustion. Other sources normally used are represented by the India ink (containing carbon particles) and logwood which is extracted from the plant *Haematoxylum campechisnum* (containing Cr). The presence of Fe and C as the main components of the black color has been confirmed by Timko et al. (2001) and Kim et al. (2006). Cases of skin sensitisation due to black pigments are in a very low number. In one case, iron oxide present in the ink used to create a permanent pigmentation of the eyebrow was responsible for the development of granulomatous dermatitis (Rubianes and Sánchez, 1993). Morales-Callaghan et al. (2006) reported of a patient with sarcoid granulomas in the area of a black tattoo and the chemical analysis of pigment revealed high amounts of Fe (13% w/w), Co (14 µg/g) and Ni (12 µg/g). In this study, Fe was found at level of ca. 100 µg/g in black dyes from “Starbrite” and “Millennium” series while it was lower (ca. 6 µg/g) in the other two brands. The other elements were generally at low level exception for Cr (3000 ng/g in “Starbrite” black) and Pb (1500 ng/g in “Diabolo” black).

Blue pigments from minerals include copper (II) carbonate (azurite), sodium aluminium silicate (lapis lazuli), calcium copper silicate (Egyptian blue), copper phthalocyanine, cobalt aluminium oxides and chromium oxides. Copper-based inks appeared to be more stable and less toxic than Co-based pigments; urticarial, granulomatous and pseudolymphomatous reactions were all attributed to Co-containing blue tattoo pigments (Björnberg, 1961; Smith et al., 1975; Blumental et al., 1982; Bagnato et al., 1999). A case of hypersensitivity to Cr found in a light-blue tattoo was

Color									
Commercial name									
Orange	Red				Violet		Yellow		White
Orange	Basic	Bordeaux	Chinese	Port	Light	Violet	Basic	Dark	Intense
70.3 ± 4.4	39.2 ± 2.5	25.9 ± 2.0	21.2 ± 1.7	29.0 ± 1.6	20.9 ± 1.5	44.1 ± 3.0	93.4 ± 6.0	40.7 ± 3.1	112 ± 8
9.14 ± 0.63	7.06 ± 0.34	269 ± 15	6.51 ± 0.21	438 ± 34	199 ± 13	250 ± 14	8.40 ± 0.26	9.16 ± 0.51	5.68 ± 0.40
48.9 ± 1.9	32.8 ± 2.7	60.0 ± 3.1	29.0 ± 1.6	92.3 ± 4.8	68.2 ± 2.7	91.9 ± 5.9	14.5 ± 1.0	57.9 ± 3.9	107 ± 8
21.6 ± 1.4	69.9 ± 5.1	38.3 ± 2.1	75.2 ± 5.4	32.3 ± 1.7	20.4 ± 1.1	45.0 ± 2.7	18.0 ± 1.3	14.7 ± 0.7	48.2 ± 3.0
1276 ± 109	1243 ± 94	884 ± 57	767 ± 60	819 ± 72	1208 ± 94	1722 ± 128	731 ± 65	786 ± 51	1876 ± 168
0.324 ± 0.022	0.813 ± 0.069	1145 ± 80	0.147 ± 0.012	3942 ± 241	1048 ± 80	6304 ± 294	0.488 ± 0.040	0.436 ± 0.036	20.6 ± 1.7
17.6 ± 1.25	25.4 ± 1.7	12.4 ± 0.9	13.9 ± 1.3	14.5 ± 0.9	10.1 ± 0.8	10.9 ± 0.7	18.3 ± 1.1	17.1 ± 1.4	15.1 ± 1.1
165 ± 13	175 ± 9	133 ± 11	253 ± 20	158 ± 9	126 ± 10	187 ± 16	118 ± 7	148 ± 10	138 ± 12
651 ± 49	1399 ± 94	232 ± 19	1556 ± 117	161 ± 13	144 ± 10	186 ± 11	898 ± 76	665 ± 40	887 ± 53
335 ± 14	382 ± 26	583 ± 34	204 ± 19	1407 ± 118	258 ± 23	2046 ± 143	435 ± 37	123 ± 7	409 ± 27
501 ± 32	290 ± 18	257 ± 19	89.5 ± 8.0	231 ± 14	834 ± 60	704 ± 53	175 ± 13	308 ± 24	447 ± 31
84.8 ± 6.7	72.4 ± 6.5	148 ± 13	21.7 ± 1.9	223 ± 15	374 ± 28	797 ± 61	13.5 ± 1.0	23.1 ± 2.0	42.2 ± 2.9
6.68 ± 0.44	5.66 ± 0.47	10.6 ± 0.8	4.99 ± 0.38	19.3 ± 0.8	8.09 ± 0.52	32.1 ± 1.7	6.29 ± 0.40	6.69 ± 0.45	3.92 ± 0.26
22.3 ± 1.6	16.3 ± 1.0	186 ± 15	19.7 ± 1.4	287 ± 17	1186 ± 97	1558 ± 114	29.9 ± 2.1	16.7 ± 1.2	776 ± 57

also described (Tazelaar, 1970). The data here obtained on 8 different types of blue inks showed Cu at very high concentration (i.e., from 558 µg/g to 31,310 µg/g) and Al from 5.64 µg/g to 2963 µg/g. Cobalt (11.1–184 ng/g) and Cr (521–1809 ng/g) were at lower levels. In one blue color (“Starbrite” country blue) a high level of Cd (i.e., 1150 ng/g) was found and in all the three blue pigments from “Diabolo” Pb, Sb, Sr and V were highly concentrated (means of 637 ng/g, 1491 ng/g, 25.9 µg/g and 1899 ng/g, respectively).

The ochre is the component of the brown pigment. Ochre is composed of iron oxides mixed with clay. In the 4 brown colors studied, Fe ranged 16.4 µg/g–88443 µg/g and resulted to be one of the major component along with Al. Similar observation was made by Timko et al. (2001) who quantified Fe from 57.26% w/w to 79.85% w/w in brown inks and by Kim et al. (2006) where Fe was 72.7% w/w and 65.4% w/w in two brown pigments. The ink called dark chocolate from the “Intenze” series contained very high amounts of toxic elements (Mn, 98,790 ng/g; Pb, 8128 ng/g; Sb, 4116 ng/g; V, 11,049 ng/g) as well as of allergenic elements (Co, 6439 ng/g; Cr, 147,229 ng/g; Ni, 9592 ng/g).

The ingredient used to produce the green pigments is mainly chromium oxide but other compounds as copper salts (Cu phthalocyanine and malachite), lead chromate (chrome yellow) and ferro-ferricyanide (Prussian blue) are also used. The Cr contained in this pigment was responsible for cutaneous sensitisation such as chronic dermatitis or dermatitis herpetiform or eczematous and pseudolymphomatous reactions in the green tattoo areas (Björnberg, 1959; Blumental et al., 1982; Jacob et al., 2008; Loewenthal, 1960). The 6 green colors investigated in this study can be considered Cu derivatives being this metal the main component (552–22,043 µg/g) and samples of the same brand (the “Starbrite” for example) varied widely depending on the brightness (e.g., Cu in deep green was about 40 times higher than that in lime green). Aluminium was the second in terms of concentration (137–2012 µg/g), followed by Fe (16.4–101 µg/g), Cr (1087–4108 ng/g) and Pb (below 1000 ng/g). As regards Ni, three samples (“Starbrite” deep green, “Diabolo” basic and willow green) contained 1–5 ppm of this metal.

Grey pigment is usually a carbon product and can be considered a shade of black. Four grey inks were studied and generally had low levels of metals, exception for Al, Cu and Fe which are, once again, the main components.

Orange can be considered a shade of red. Timko et al. (2001) reported the composition of two orange samples and one was mainly C and the other was made of Ti, C and Al. In the 5 orange inks analyzed, Al was the main component (70.3–2079 µg/g). The remaining metals

were generally low, exceptions were Cr (ca. 5000 ng/g) in the “Starbrite” brite orange, Cd (ca. 3000 ng/g) and Pb (ca. 15,000 ng/g) in the “Intenze” peach.

Red is the color most often associated to the development of skin allergological pathologies. In fact, granulomatous (Sowden et al., 1991; Verdict, 1981), eczematous (Pauluzzi et al., 1998), pseudolymphomatous (Blumental et al., 1982) and lichenoid (Corazza et al., 2002) reactions have

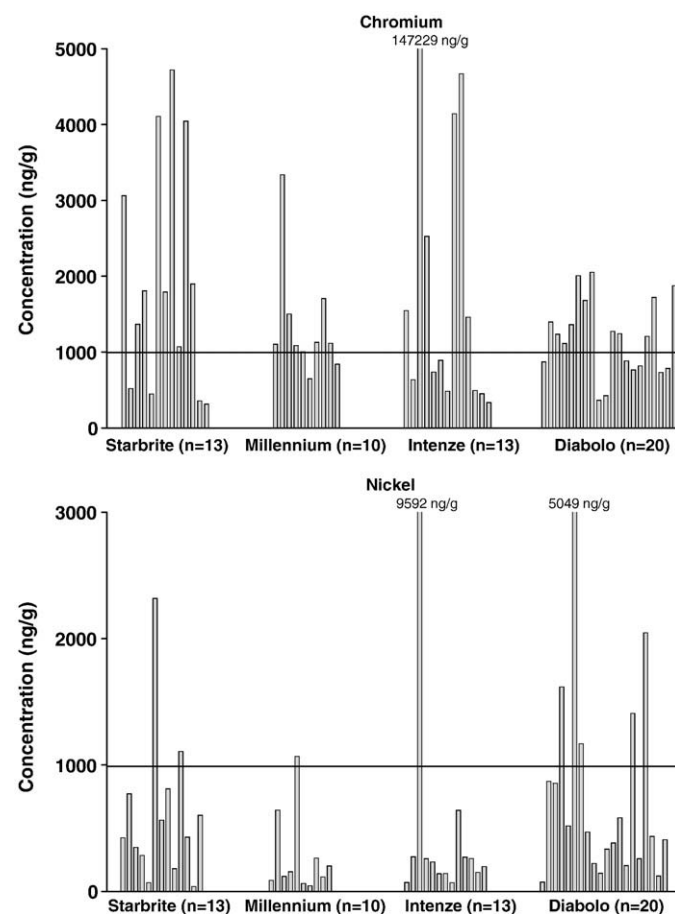


Fig. 1. Tattoo ink concentration of Cr and Ni compared to the safe allergological limit of 1 ppm (horizontal line).

been observed. The red coloring is usually due to mercury sulphide; in alternative, cadmium sulphide and cadmium selenide might be also used as well as iron oxide (rust) and ferric hydrate (sienna/red ochre). In this study, all the 8 red samples had Al, Ba and Fe as the highest metals, while Cd and Hg were at traces or even under the LoQ level. Two red inks in the “Intenze” series showed Cr at ca. 4000 ng/g, the red inks by “Diabolo” contained Ni at 1400 ng/g and Cu above 1 mg/g.

The common metallic salt used for violet-colored tattoos contains Mn. Skin diseases due to this element seem to be quite rare. Nguyen and Allen (1979) reported Mn as the possible cause of swelling and itching in the purplish site of the tattoo. Moreover, erythema and scaling in the purple region of a tattoo and cutaneous granuloma around Mn particles was described (Schwartz et al., 1987). The presence of Mn in the samples under study is relatively low with the highest level in the violent violet by “Millenium” (1265 ng/g). Vanadium was over 1000 ng/g in five different violets.

The yellow pigment is achieved by cadmium sulphide. The characteristic of this compound is the marked photoconducting property. For this reason, cases of skin sensitization such as swelling due to phototoxic reactions when the yellow inks are exposed to light are reported (Tindall and Smith, 1962; Björnberg, 1963; Nguyen and Allen, 1979). In consideration of the very low Cd levels in all the brands (below 249 ng/g), the possibilities to create a toxic risk for the health should be rather poor.

White pigments are nowadays derived from titanium dioxide naturally present in the environment as anatase or rutile. This compound has been used to replace the adoption of other salts such as barium sulphate and the most toxic lead carbonate or lead white. In this study, the white inks showed low contents of Pb and Ba, and Al was the main metal (112–5868 µg/g). A new trendy color used in tattoos is pink. The rose pink of “Intenze” was a mix of red pigments and titanium dioxide-based white. The metal with the highest concentration was Al (1727 µg/g) followed by Cu and Fe. This color contained also relatively high level of Sr (2.64 µg/g) and V (1510 ng/g).

4. Conclusions

The practice of tattooing is largely adopted worldwide, but the inorganic components of pigments injected into the skin are known to cause chronic or systemic pathologies. The situation is troubled by the fact that no official controls on pigments used in tattooing practices are existing and this lack of controls does not make users aware about the risk for their health.

In this view, the aim of this study was to characterize the metal composition of 56 tattoo inks from market and to draw attention to the associated risk for human health. Data indicated that the relative metal contribution to the tattoo ink compositions was highly variable between samples, brands and even among like-colored pigments. Aluminium, Ba, Cu, Fe and Sr were the main metals. Allergenic metals as Cr, Ni and Co were above the safe allergological limit of 1 ppm in 35, 9 and 1 cases, respectively. Toxic elements as Cd, Mn, Pb, Sb and V were over the 1 ppm in a few cases, while Hg was in traces.

It should be taken into account that the time of contact between skin and tattoos is rather long and this allows a continuative exposure to toxic and/or allergenic metals with consequent accumulation

in the body. For this reason it urges that authorities regulate permanent tattooing dyes and makeup. Moreover, it is unacceptable that companies that provide materials to be used in tattoo practice are unwilling to provide detailed information about chemical composition of the materials injected into the skin.

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