U.P.B. Sci. Bull., Series B, Vol. 76, Iss. 1, 2014 ISSN 1454 – 2331

SANOGENETIC ANALYSIS OF HAZARDOUS SUBSTANCES IN LEATHER USED IN FOOTWEAR MANUFACTURING

Mirela PANTAZI[1]

Footwear is a complex product, comprising various materials which are made using a wide range of chemicals. Some of these chemicals are hazardous for health and for the environment. Converting raw hides into finished products requires a number of complex treatments, for which large amounts of chemicals and water are used.

The purpose of this study is to provide information on the harmful substances in various types of leather used in footwear manufacturing.

Keywords: footwear, health, toxic compounds, metal ions, azo dyes, pentachlorophenol

1. Introduction

The leather industry generates large amounts of wastewaters rich in organic compounds which are large consumers of degradation oxygen, salts and various other chemicals. It also generates solid wastes in the form of sludge from wastewater treatment and leather wastes which pollute the environment [1]. Some of the chemicals used in processing remain in the leather, and therefore, in the footwear. Footwear is a complex product made of different materials whose manufacturing process requires various chemicals. Eventually, the finished product contains a cocktail of chemicals. Throughout the lifecycle, from leather processing to the finished footwear, the resulting wastes and chemicals contained by some of them may be hazardous for health and for the environment. [2]. In footwear, chemicals can be found in the form of constituents of materials, adhesives and dyes or used as additives, to provide a material with specific improved properties such as resistance, stability etc.

Footwear comprises various types of materials, such as: leather, leather substitutes, rubber, textiles etc. Chemicals are added often to these materials to improve certain properties (for instance, emollients, dyes and fireproof substances), which may contain toxic substances such as salts of metal ions of Cr, Hg, Zn, Pb, Cu etc. [3], azo dyes [4], contaminants and residues from chemicals used in the manufacturing stages, such as formaldehyde, vinyl chloride [5].

[1] PhD student, Faculty of Applied Chemistry and Materials Science, University POLITEHNICA of Bucharest, Romania, pantazimirela@yahoo.com

Materials used in footwear manufacturing and compounds entering their composition come into contact with the skin of the foot and may influence its comfort and health state, causing sweat, allergic reactions, microorganism development [6] etc.

The skin is usually an effective barrier against metal absorption. However, metals may cause negative reactions, such as: irritations and allergic contact dermatitis, rash, granuloma and systemic toxicity. Cutaneous penetration of metals is influenced by several factors, namely: oxidation, molecular weight, liposolubility, reactivity and nature of metal compounds (salts) [7].

All forms of mercury (*Hg*) are absorbed through the biological membranes, including the mucous membrane and skin [8, 9]. Mercury accumulates in the body and reacts with groups of sulfhydryl proteins, which affect both enzyme activity and the structure and function of membranes [10]. Mercury allergy is relatively common, due to the widely used mercury-containing products (drugs, disinfectants based on mercury salts) [7,11].

Lipophilic organic compounds of lead (*Pb*) easily penetrate skin, while the inorganic form is weakly absorbed due to its capacity to bind to proteins. *In vitro* penetration of Pb oxides in the human and animal skin has not been proved [12].

In contact with the skin, cadmium (*Cd*) has the ability to bind to epidermal keratin which may explain the insignificant values of *in vitro* human skin penetration [13, 14, 15]. However, its potential percutaneous hazard has been proven in animals, but the absorbed amount is unknown [16]. Evidence of cadmium contact sensitization in humans is inconclusive, because most of the patients showing a positive reaction to performed tests did not have any proof of direct contact of skin with any material containing this metal. Also, most of the positive reactions did not occur upon retesting [17]. No evidence of allergenicity was found [18].

Copper (*Cu*) is very reactive with biological tissues [19]. Copper absorption was noticed even after accidental depositions of finely divided metal on the skin [20]. Topically applied, lipophilic copper compounds significantly penetrate the skin and have anti-inflammatory and anti-arthritic activity; the presence of Cu(II) in these complexes is considered essential for their effectiveness [21, 22]. It rarely causes hypersensitivity [18].

Currently, 80-85% of leather used in footwear manufacturing is chromium tanned (*total Cr*) [23] and it is not surprising that trivalent chromium (*CrIII*) is found in high concentrations in footwear. In the case of leather footwear, the finished product must not contain chromium VI [24]. Human skin penetration by both chromium III and chromium VI was proved [18, 25]. Low levels of Cr(VI) can cause allergic contact dermatitis. Patients with allergy to Cr(VI) may react to a single exposure of 1 mg/kg-3mg/kg of Cr(VI) [26, 27]. The effect of chromium ions released from leather is influenced by conditions of wearing, such as humidity, pH, microbiological contamination and pre-existing skin diseases. This means that even footwear with low levels of Cr(VI) may show, under certain conditions, risk to chromium allergy. People who have already developed allergy to Cr(VI) may be so sensitive that they react to Cr(VI) values below the detection level, and the higher the allergen dose, the higher the risk of allergy.

Azo dyes can penetrate human skin and, similar to skin cells, they have azo bonds reducing enzymes, which can lead to the formation of carcinogenic aromatic amines [28]. Similar enzymes have also been found in skin bacteria [29]. Azo dyes can be dissolved from leather through sweat, which facilitates cutaneous absorption [30]. Azo dyes producing carcinogenic aromatic amines must not be present in any consumer good.

The contact of *formaldehyde* with the skin is the most significant way of exposure for sensitization [31, 32]. In Europe, 2-3% of patients suspected of having contact dermatitis have positive reactions to testing, and in USA, 8-9% [33]. There are cases of allergic contact dermatitis caused by formaldehyde residues in clothing, after chemical finishing [34, 35]. The amount of free and hydrolyzed formaldehyde in footwear components must not exceed, for leather, the amount of 150 mg/kg [24].

Pentachlorophenol in contact with the skin may have respiratory [36] and hematologic [37] effects. Also, dermal effects may appear (redness and pain as a result of immersing hands in a pentachlorophenol 0.4% solution for 10 minutes) [38]. Numerous central nervous system toxicity signs were reported in case reports of patients exposed to high levels of pentachlorophenol in contact with skin and inhalation exposure. Effects such as delirium and intermittent convulsions [39] and irritability [36, 40] were noticed.

This paper aims at characterizing five samples of materials used in the footwear in terms of content of metal ions, azo dyes, pentachlorophenol and formaldehyde, as follows: Cr tanned leather (PCr), vegetable tanned and retanned leather (PTan), Ti-tanned and vegetable retanned leather (PTi-Tan), Ti-tanned and Al-retanned leather (PTi-Al), and synthetic leather (PS), and studying the effect of these substances upon direct contact with the skin of the foot.

2. Materials and Methods

Five types of materials were analyzed in this study: Cr tanned leather (PCr), vegetable tanned and retanned leather (PTan), Ti-tanned and vegetable retanned leather (PTi-Tan), Ti-tanned and Al-retanned leather (PTi-Al), and synthetic leather (PS).

Analyses performed to characterize leather and leather substitutes and the methods used are presented in Table 1.

Table 1

Analyses performed to characterize leather and leather substitutes

No.	Parameter	Method used	Equipment used
1	Volatile matter	SR EN ISO 4684–2006	gravimetric
2	Ash	SR EN ISO 4047–2002	gravimetric
3	Total nitrogen	SR ISO 5397-1996	
4	Dermal substance	SR ISO 5397–1996	
5	Chromium oxide	SR EN ISO 5398/1–2008	
6	Hg	directly from solid samples	Moilestone DMA-80 model Hg analyzer
7	Pb	from ashes	Control AA 700 Analytik Jena
8	Cd	from ashes	Control AA 700 Analytik Jena
9	Cu	from ashes	Control AA 700 Analytik Jena
10	Cr(total)	from ashes	Control AA 700 Analytik Jena
11	Chromium VI	SR ISO 17075:2008.	Spectrophotometer UV/VIS V-550
12	Azo dyes	SR EN ISO 17234-1:2010, test sample prepared according to SR EN ISO 4044:2008.	High-Performance Liquid Chromatography with Diode-Array Detection (HPLC/DAD).
13	Pentachlorophenol	SR EN ISO 17070:2007. test sample prepared according to SR EN ISO 4044:2008.	Gas Chromatograph Focus GS- Mass Spectrometer DSQ II
14	Formaldehyde	SR EN ISO 17226-1:2008 test sample prepared according to SR EN ISO 4044:2008.	High-Performance Liquid Chromatography with Diode-Array Detection (HPLC/DAD).

The sanogenetic study consisted in the following procedure:

The study was performed on a number of 17 children, 8 girls and 9 boys aged 3-7. For the study, PCr and PTi-Tan leather footwear was used, in 2 models as wearing samples.

Initially, foot anthropometric data were acquired with the 3D scanner in order to correctly size lasts for each subject, which leads to a good design and manufacture of customized footwear for test subjects. After creating the lasts, the compatibility between foot and last was checked in terms of dimension (i.e. the positioning of the foot inside the shoe - inconsistency between the shape and inner dimensions of the shoe lead to erosions, bursitis and calluses, redness etc.), using the LAST – MAKER software (Fig. 1). The correct correspondence of the foot shape and the last shape was noticed, and then wearing samples were created and distributed to children (Fig. 2).

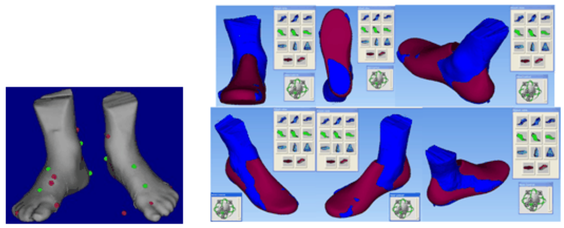

Fig. 1. Compatibility between foot and last in terms of dimension

Subjects were asked to wear the shoes daily (for a two-month period), for 8 hours, without socks.

Fig. 2. Distribution of footwear samples for wearing

Checks were done according to the characterization sheet of footwear worn. The sheet comprises a series of data on the conditions of wearing (climatic conditions: cold and warm, dry and humid weather (spring, summer), outdoors and indoors; wearing period: 8 hours wear, 16 hours rest, as well as data resulting from observations on wearing (wearing sensation, health state of the foot etc.).

3. Results and Discussions

Characterization of leather samples, in terms of composition of specific substances, is presented in Table 2.

Table 2

Characterization of leather in terms of composition of specific substances

Characteristics, MU	Measured values				
	PCr	PTan	PTi-Tan	PTi-Al	PS
Volatile matter, %	47.70	12.78	12.20	14.89	14.30
Ash, %	9.37*	1.00*	10.60*	13.55*	4.29*
Total nitrogen, %	16.08*	11.61*	9.76*	13.55*	15.27*
Dermal substance,%	90.37*	65.25*	54.85*	76.15*	85.82*
Chromium oxide, %	5.62*	-	-	-	-

** Values obtained are reported to dry substance content.*

Content of toxic heavy metals, Cr, Cd, Pb, Hg, Cu and Zn present in the various leather samples is listed in Table 3.

Table 3

Content of metal ions

Characteristics, MU	Limit value, EN 71-3:1995 BS	Measured values				
		PCr	PTan	PTi-Tan	PTi-Al	PS
Hg, mg/kg	60	45.13	91.06	144.96	34.25	12.09
Pb, mg/kg	90	1.53	0.90	3.63	12.85	<0.43
Cd, mg/kg	75	<0.57	<0.57	<0.57	<0.57	<0.57
Cu, mg/kg	-	11.49	12.99	3.99	4.47	1.86
Zn, mg/kg	-	<Lap	2.96	<Lap	<Lap	8.39
Cr (total), mg/kg	60	458,98	35.59	143.58	36.82	9.73
Cr(VI), mg/kg	0,02	n.d. (<3)	n.d. (<3)	n.d. (<3)	n.d. (<3)	n.d. (<3)

Values obtained are reported to dry substance content.

Limit values are imposed by BS EN 71-3:1995 standard, *Safety of toys. Specification for migration of certain elements* - this part of this European Standard specifies requirements and test methods for the migration of the elements antimony, arsenic, barium, cadmium, chromium, lead, mercury and selenium from toy materials and from parts of toys except materials not accessible.

Cadmium content was lower than the limit value of 75 mg/kg [41] and moreover, it is known that there is no conclusive evidence of sensitization upon contact determined by this element in humans [18]. *Lead* content was lower than the limit value of 90 mg/kg in BS EN 71-3. For *copper* and *zinc* there are no limit values imposed yet in BS EN 71-3. As they rarely cause hypersensitivity [18], we can assume that these substances, in measured concentrations, are not hazardous for health.

The metal with the highest concentration was *chromium*. The highest total chromium value is that of chromium-tanned leather, 458.98 mg/kg, followed by the vegetable tanned and titanium-retanned leather, 143.58 mg/kg. Both exceed the limit value of 60 mg/kg [41]. In contrast, chromium content in synthetic leather was only 12.09 mg/kg. Regarding chromium allergy, there are few studies on the threshold levels identified for Cr(III). In the study of Nethercott et al. 1994, only 1 of 54 patients have reacted to Cr(III), which corresponds to a threshold concentration of 33 $\mu g/cm^2$ (1100 mg/kg**)** [42]. Quantitative analysis shows that

Cr(VI) content did not exceed the limit of 3 mg/kg for any type of analyzed leather, therefore the risk of allergy is low. However, people who have already developed allergies to Cr(VI) can be so sensitive that they react even to values of Cr(VI) below the detection level.

The limit value in BS EN 71-3 for *mercury* concentration in children's shoes coming into contact with skin is 60 mg/kg. In the study, mercury concentration in the vegetable tanned and titanium-retanned leather is higher than the limit value provided in BS EN 71-3.

Content of toxic organic substances is given in Table 4.

Table 4

Content of toxic organic substances

Characteristics, MU	Limit value, BS EN 71-9 :2005+A1 :2007	Measured values				
		PCr	PTan	PTi-Tan	PTi-Al	PS
Azo dyes, mg/kg	10	n.d. (<30)	n.d. (<30)	n.d. (<30)	n.d. (<30)	n.d. (<30)
Pentachlorophenol, mg/kg	5	n.d. (<0.1)	n.d. (<0.1)	n.d. (<0.1)	n.d. (<0.1)	n.d. (<0.1)
Free formaldehyde, mg/kg	30	n.d. (<15)	n.d. (<15)	n.d. (<15)	n.d. (<15)	n.d. (<15)

Values obtained are reported to dry substance content.

Limit values are imposed by BS EN 71-9:2005+A1:2007 standard, *Safety of toys. Organic chemical compounds. Requirements* - this Part 9 of the document EN 71 for safety of toys specifies requirements for the migration or content of certain hazardous organic chemical compounds from/in certain toys and toy materials

As a result of analyses, it is found that values of *azo dye* concentrations are below the detection limit (30 mg/kg), which corresponds to EC requirements, but the limit according to standard BS EN 71-9 :2005+A1 :2007 is 10 mg/kg [43]. *Pentachlorophenol* concentrations, in all types of leather are both below the detection limit, of 0.1 mg/kg, and below the limit value in BS EN 71-9 :2005+A1 :2007, of 5 mg/kg [43]. No values have exceeded the detection limit of 15 mg/kg for *formaldehyde,* extremely allergenic and carcinogenic compound. The limit value according to standard BS EN 71-9 :2005+A1 :2007 is 30 mg/kg [43].

Results of testing footwear by wearing

Analyzing the remarks of subjects after about 2 months of wearing the footwear, it was found that the shoes gave good results, maintaining both their shape and hygiene and comfort characteristics. It is particularly noticed that while wearing, the sensation is that of comfortable shoes, and the climate inside the shoes is dry, without abundant sweat. The health state of the foot: no wearing wounds, no wounds before wearing, no wounds after wearing, normal sweat. Regarding natural leather lining, it corresponds in terms of sanogenetic characteristics, and subjects have responded negatively, throughout the wearing period, to allergies caused by hazardous substances in leather.

4. Conclusions

The study focused on identifying hazardous substances in various types of materials used in footwear manufacturing, which come into contact with the skin of the foot. It is extremely important that the materials contain no harmful substances at all or, if that is not possible, only a small amount of such substances. Analyzing the values of toxic substance concentrations in the studied samples and the results obtained when testing the footwear by wearing, we can conclude that the five types of leather are recommended for footwear manufacturing, as they do not have negative effects on health (they do not contain hazardous substances in harmful concentrations). However, it is recommended that, in order to avoid easy absorption of harmful substances, people wear socks, as they constitute a barrier against the direct contact of human skin with the leather surface of footwear.

Acknowledgement

The work has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Romanian Ministry of Labour, Family and Social Protection through the Financial Agreements POSDRU/107/1.5/S/76909.

R E F E R E N C E S

[1] *G. Chirita, M. Chirita*, Tratat de chimie si tehnologia pieilor si blanurilor (Treaty of Chemistry and tehnology of Leather and Fur), **vol.1**, Gheorghe Asachi, Iasi, 1999, pp 12- 21
[2] *D.S. Ştefan, M. Pantazi, I. Meghea*, „Opportunities for capitalisation of leather and footwear waste by composting", 12th International Multidisciplinary scientific GeoConference SGEM, Section: Ecology and Environmental Protection, Albena, Bulgaria, 2012, pp 587-595
[3] *D.S. Ştefan, I. Meghea*, „Study of biodegradation of leather tanned with chromium and vegetal compounds", 11th International Multidisciplinary scientific GeoConference SGEM, Section: Ecology and Environmental Protection, 20-25, June, Albena, Bulgaria, 2011, pp 221-228
[4] *B.-Y. Chen, K.-W. Lin, Y.-M. Wang, C.-A. Yen*, „Revealing interactive toxicity of aromatic amines to azo dyer decolorizer" in Journal of Hazardous Materials 166, 2009, pp 187-194
[5] *K.Bienkiewicz*, Fundamentals of Lether Manufacture, Eduard Roether: KG., 1993, pp 26-38

[6] *D.S. Stefan, R. Dima, M. Pantazi, M. Ferdes and A. Meghea*, “Identifying Microorganisms Able to Perform Biodegradation of Leather Industry Waste” in Molecular Crystals and Liquid Crystals, ISSN: 1542-1406, no. 555, 2012, pp.323-331
[7] *P. Sartorelli, L. Montomoli, A.G. Sisinni*, “Percutaneous penetration of metals and their effects on skin” in Prevent Res 2012; 2 (2): 158-164
[8] *M.C. Battigelli*, „Mercury” in Environmental and Occupational Medicine, (W.N. Rom, ed.), Little, Brown, Boston, 1983, pp. 449–463
[9] *J.B. Hursh, T.W. Clarkson, E.F. Miles, L.A. Goldsmith*, „Percutaneous absorption of mercury vapor by man”, Arch of Environ Health 1989; 44: 120-127
[10] *A.B. Lerner*, „Effect of ions on melanin formation” in J. Invest. Dermatol. 18:47–52 (1952)
[11] *V. Neagu, C. Luca, S. Ştefan, M. Ştefan, I. Untea*, “Unconventional ion exchange resins and their retention properties of Hg^{2+} ions” in Reactive & Functional Polymers, 67, 12, pp 1433-1439, 7 pg, 2007
[12] *W.C. Bress, J.H. Bidanset*, „Percutaneous in vivo and in vitro absorption of lead” in Vet Hum Toxicol 1991; 33: 212-214
[13] *R.C. Wester, D.A. W. Bucks and H.I. Maibach*, „Percutaneous absorption of hazardous substances from soil” in Dermatotoxicology, 4th ed. (F. Marzulli and H. I. Maibach, eds.), Hemisphere Publishing Corporation, New York, 1991, pp. 110–122
[14] *R.C. Wester, H.I. Maibach, L. Sedik, J. Melendres, S. DiZio and M. Wade*, „In vitro percutaneous absorption of cadmium from water and soil into human skin” in Fund. Appl. Toxicol., 1992, 19:1–5
[15] *E.C. Foulkes*, „Absorption of cadmium” in Cadmium (E. C. Foulkes, ed.), Springer-Verlag, Berlin, 1986, pp. 75–100
[16] *J.E. Wahlberg*, „Percutaneous toxicity of metal compounds” in Arch. Environ. Health, 1965, 11:201–204
[17] *J.E. Wahlberg*, „Routine patch testing with cadmium chloride” in Contact Dermatitis, 1977, 3:293–296
[18] *R.S. Guy, J.J. Hostynek, R.S. H i n z, C.R. Lorence*, Metals and the Skin, Topical Effects and Systemic Absorption, ISBN: 0-8247-9385-4, New York, 1999
[19] *G. Oster and M.P. Salgo*, „The copper intrauterine device and its mode of action” in N. Engl. J. Med., 1975, 293:432–438
[20] *Y. Bentur, G. Koren, M. McGuigan and S.P. Spielberg*, „An unusual skin exposure to copper; clinical and pharmacokinetic evaluation” in J. Toxicol. Clin. Toxicol., 1988, 26:371–380
[21] *M.W. Whitehouse, K.D. Rainsford, N.G. Ardlie, I.G. Young and K. Brune*, „Alternatives to aspirin, derived from biological sources” in Agents Actions, 1977, (Suppl. 1):43–57
[22] *S.J. Beveridge, M.W. Whitehouse and W.R. Walker*, „Lipophilic copper(II) formulations: some correlations between their composition and anti-inflammatory/antiarthritic activity when applied to the skin of rats” in Agents Actions, 1982, 12:225–231
[23] *R. Meyndt, H.-P. Germann*, “Investigations on the hydrophobing of chrome-free leather” in Lederinstitut Gerberschule Reutlingen (LGR) Germany, 2006, pp 12
[24] DECIZIA COMISIEI din 9 iulie 2009 de stabilire a criteriilor ecologice de acordare a etichetei ecologice comunitare pentru incaltaminte
[25] *F.L. Filon, F.D. D’Agostin, M. Crosera, G. Adami, M. Bovenzi, G. Maina*, “In vitro absorption of metal powders through intact and damaged skin” in Toxicology in Vitro no. 23, 2009, pp. 570-579
[26] *M.J. Marqués, A. Salvador, A.S. Morales-Rubio, M. de la Guardia*, “Analytical methodologies for chromium speciation in solid matrices: a survey of literature” in Fresenius´ Journal of Analytical Chemistry no. 362, 1998, pp. 239-248
[27] *J.J. Hostýnek*, “Factors determining percutaneous metal absorption” in Food and Chemical Toxicology no. 41, 2002, pp. 327-345

[28] *S.W. Collier, J.E. Storm, R.L. Bronaugh*, “Reduction of azo dyes during in vitro percutaneous absorption” in Toxicology and Applied Pharmacology no. 118, 1993, pp. 73-79
[29] *T. Platzek, C. Lang, G. Grohmann, U. Gi, W.Baltes*, “Formation of carcinogenic aromatic amine from an azo dye by human skin bacteria in vitro” in Human Experimental Toxicology no. 18, 1999, pp. 552-559
[30] *M.J. Zeilmaker, E.D. Kroese, P. van Haperen, M.P. van Veen, H.J. Bremmer, H.J. van Kranen, M.F.A. Wouters, J.A. Janus*, “Cancer risk assessment of azo dyes and aromatic amines from garment and footwear” in Rijksinstituut voor volksgezondheid en milieu, RIVM report 601503014, 1999
[31] *M.A. Flyvholm*, “Contact allergens inregistered chemical products” in Contact Dermatitis, 1991; 25(1):49-56
[32] *H.C. Reich, E.M. Warshaw*, “Allergic contact dermatitis from formaldehyde textile resins” in Dermatitis, 2010 , 21(2):65-76
[33] *I. Lang, T. Bruckner, G. Triebig*, “Formaldehyde and chemosensory irritationin humans: A controlled human exposure study” in Regul Toxicol Pharmacol, 2008, 50(1):23–36
[34] *S. Nedorost, E. Warshaw, S. Jacob, R. Katta, M. Zirwas, S. Andrew*, “Allergic contact dermatitis caused by durable-press finishes does exist in the USA” in Contact Dermatitis, 2010, 63(4):233-4
[35] *D. Slodownik, J. Williams, B. Tate, M. Tam, J. Cahill, K. Frowen et al.*, “Textile allergy - the Melbourne experience” in Contact Dermatitis, 2011, 65(1):38-42
[36] *J.E. Smith, L.E. Loveless, E.A. Belden*, „Pentachlorophenol poisoning in newborn infants—St. Louis, Missouri, April-August 1967” in MMWR Morb Mortal Wkly Rep, 1996, 45:545-548
[37] *H.J. Roberts*, „Pentachlorophenol-associated aplastic anemia, red cell aplasia, leukemia and other blood disorders” in J Fla Med Assoc, 1990, 77:86-90
[38] *A. Bevenue, J. Wilson, L.J. Casarett et al.*, „A survey of pentachlorophenol content in human urine” in Bull Environ Contam Toxicol, 1990, 2:319-332
[39] *J.B. Chapman, P. Robson*, „Pentachlorophenol poisoning from bath water” in Lancet, 1965, 1:1266-1267
[40] *A.M. Robson, J.M. Kissane, H.N. Elvick et al.*, „Pentachlorophenol poisoning in a nursery for newborn infants: I. Clinical features and treatment” in J Pediatr, 1969, 75:309-316
[41] BS EN 71-3, 1995, “Safety of Toys. Specification for Migration of Certain Elements”, British Standard Institution, pp:1-24.
[42] *J. Nethercott, D. Paustenbach, R. Adams, Fowler, J. Marks, C. Morton, J. Taylor, S. Horowitz, B. Finley*, ”A study of chromium induced allergic contact dermatitis with 54 voluenteers: implications for environmental risk assessment” in Occupational and Environmental Medicine, 1994, 51:371-380
[43] BS EN 71-9:2005+A1:2007, Safety of toys. Organic chemical compounds. Requirements.