EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

ihcp
Institute for Health and Consumer Protection

Physical and Chemical Exposure Unit

Chemical Release from Textiles

European survey on the release of formaldehyde from textiles

Conducted within the CHEM TEST project
On behalf of DG SANCO

P. Piccinini, C. Senaldi, C. Summa

2007 **EUR 22710 EN**

Mission of the IHCP

The mission of the Institute for Health and Consumer Protection is to provide scientific support to the development and implementation of EU policies related to health and consumer protection.
The institute carries out research to improve the understanding of the potential health risks posed by chemical, physical and biological agents from various sources to which consumers are exposed.

European Commission
Directorate-General Joint Research Centre
Institute for Health and Consumer Protection

Contact information
Address: via E. Fermi 1, 21020 Ispra (VA), Italy
E-mail: paola.piccinini@jrc.it
Tel.: 0039-0332-789124
Fax: 0039-0332-785707

http://www.jrc.cec.eu.int/pce
http://www.jrc.cec.eu.int

LEGAL NOTICE

EUR 22710 EN
ISBN 978-92-79-05215-6
ISSN 1018-5593
Luxembourg: Office for Official Publications of the European Communities

Printed in Italy

CONTENTS

1. Executive summary

Consumers are increasingly exposed to hundreds of potentially hazardous chemicals in their everyday life. These compounds can come into contact with their bodies through three different pathways: inhalation, ingestion and dermal absorption.

Formaldehyde is commonly used in several textile production processes; for example after treatment of substantive dyeing, hardening of casein fibres, as a wool protection agent, anti mould and above all as a cross linking agent in resin finishing.

In some cases, allergic contact dermatitis (ACD) can be attributed to clothing treated with textile finish resins (TFRs), also named durable press resins or permanent press clothing resins. Under normal and foreseeable use, the majority of these resins can release formaldehyde, which has been classified as carcinogenic to humans by IARC (International Agency for Research on Cancer). TFRs are widely used in cotton, cotton/polyester or wrinkle-resistant linen. The frequency of ACD cases due to textile formaldehyde resin has been reported to be between 0.2% and 4.2% after 1990.

The scope of this work was threefold: 1) to make a survey on the level of releasable formaldehyde which can be found in textile products manufactured anywhere in the world and sold on the European market; 2) to develop a method to mimic foreseeable conditions of use better than standard methods EN ISO 14184-1 or 14184-2 do; 3) based on the results of the survey, to evaluate dermal exposure for children and adults.

The focus was put on dermal exposure that can result from the direct contact of the skin with textile products. Therefore the sampling was planned with the objective to cover textile clothing in particular.

A total of 221 samples were purchased in 21 out of 27 EU Member States of the European Union. Although it is not compulsory to indicate the origin on labels in Europe, whenever possible efforts were made to buy samples with labels stating the country of production. Garments were purchased from a variety of sources, including department stores, shops and open air markets, and with various compositions, such as cotton, mixtures with cotton and mixtures with wool.

About 94 % of all the samples were textile clothing, whereas 6 % were classified as linen (bedding pillowcases and sofa cushion covers). The whole population was considered as a target, so clothing samples designed for men, women and children

were analysed (about one third each). With regard to children, samples were purchased both for babies under the age of two and for children up to the age of 14.

Several types of garments were taken into consideration, such as shirts, T-shirts, underwear, socks, pyjamas, trousers and dresses. Some sweaters were also analysed, which can be classified either in direct contact with the skin or not, depending on the scenarios. In the case of shirts, some samples had an “easy care” label and a few also an “Oeko-Tex” label. About 31 % of the samples were printed articles.

To evaluate the release of formaldehyde from textiles, all the samples were analysed with the standard method EN ISO 14184-1 (water extraction), which tries to simulate the real conditions of use though an extraction in water at 40 °C. For comparison purposes, 127 samples were also analysed with the standard method EN ISO 14184-2 (vapour absorption), which mimics possible exposure due to inhalation. Samples were analysed in triplicate and uncertainties at 95 % of probability were calculated for all measurements.

In the absence of European legislation concerning the maximum level of formaldehyde that can be released from textiles, the results of the survey were compared with the limits established by the following two voluntary labelling schemes: the European Ecolabel (Commission Decision 2002/371/EC) and the private Oeko-Tex Standard 100, which consider ecological and consumer protection criteria. The limit is 300 mg/kg for textiles not in direct contact with the skin and decorative materials in both schemes. For textiles in direct contact with the skin, Ecolabel established a limit of 30 mg/kg and Oeko-Tex Standard 100 set 75 mg/kg. Moreover, Oeko-Tex Standard 100 established a limit for textiles for babies which should release less than 20 mg/kg of formaldehyde.

With regard to the water extraction method, 11% of samples intended to come into contact with the skin (including bedding pillowcases and sofa cushion covers) exceeded the limit of 30 mg/kg established in the voluntary labelling scheme Ecolabel. About 3% also exceeded the limit of 75 mg/kg for adults considered by the Oeko-Tex Standard 100. 11% of garments for babies under the age of two showed a release of formaldehyde higher than 20 mg/kg, whereas it should be not detectable both by the Japanese law 112 and Oeko-Tex Standard 100. Two of them also exceeded the Ecolabel limit of 30 mg/kg.

No differences were observed in the release of formaldehyde from samples manufactured in various geographical areas (Europe, China, rest of the world) and

purchased from various sources (shops, department stores and open air markets), as percentages of samples exceeding the Ecolabel limit from the different purchase and manufacturing sources were similar.

All textile categories were represented among the samples which released more than 30 mg/kg of formaldehyde, but shirts seem to be the category with the highest risk of exceeding the limit of 30 mg/kg. Moreover, five out of ten “easy care” labelled shirts went beyond the Ecolabel limit. Similarly, pure cotton and mixtures containing wool seem to release more formaldehyde than garments made of mixtures containing cotton and other fibres.

With regard to the vapour absorption method, 22% of the 127 analysed samples contained a level of formaldehyde higher than the Ecolabel limit of 30 mg/kg. About 12% of the samples released over 75 mg/kg of formaldehyde. 397 mg/kg was the highest measured value. The vapour absorption method gave frequently higher results than the water extraction method for release of formaldehyde of over 30 mg/kg.

With the intention to better simulate the release of formaldehyde that could be enhanced by sweat and rubbing, the EN ISO 14184-1 standard method was modified using some artificial perspiration solutions instead of water as an extraction medium, one for acid and one for basic sweat. In order to increase the effect of rubbing, the extraction was carried out either with a Head Over Heels instrument or, alternatively, with a washing machine generally used to determine colour fastness. To further enhance the rubbing effect, some experiments were carried out with ten 12 mm diameter stainless steel balls in each washing machine vessel. Results obtained with the Head over Heels apparatus were lower than the ones obtained with the usual water bath, most probably due to the fact that the temperature could not be set to 40 °C in this instrument, but only to room temperature (25 °C). On the contrary, results obtained with washing equipement were mainly higher than those obtained with the unmodified EN ISO 14184-1 standard method. The use of stainless steel balls slightly increased the release of formaldehyde from textiles. The comparison of results obtained using different extraction solutions seemed to depend quite a lot on the sample and probably on the type of resin applied and on the finishing conditions. The release of formaldehyde was mainly higher with perspiration simulants than with water, either the acid or the basic one, depending on the sample. In conclusion, to better simulate foreseeable conditions of use, the ideal solution seemed to use sweat

simulants, together with stainless steel balls and washing machine. Moreover the modified method represents a “worst case” scenario compared to the standard one.

Washing equipment was also used to mimic domestic washing. Several washing cycles were performed on sample 112, an “easy care” men’s shirt. After the first washing cycle, released formaldehyde decreased by 90% in the case of the water extraction method and by 40% in the case of the vapour absorption one.

Lastly, Roff’s method was applied to samples that showed the highest results in order to measure the global amount of formaldehyde after hydrolysis of the resin. Measurements were performed in triplicate also in this case. As expected, the total content of formaldehyde after hydrolysis was very high, ranging from about 400 mg/kg to 19000 mg/kg.

Data on formaldehyde release obtained with the water absorption method and with the worst case modified method were used to estimate adult and child dermal exposure following the recommendations of the Technical Guidance Document. From data obtained with the EN-14184-1 standard method and the modified one, the maximum dermal uptakes evaluated in the case of a child were 3.1 and 4.5 mg/kg bw respectively and, in the case of an adult, 1.2 and 1.7 mg/kg bw.

2. Introduction

Consumers are exposed at an increasing rate to hundreds of chemicals which can come into contact with their body through three different pathways: inhalation, ingestion and dermal absorption. Hazardous chemical substances with undesirable effects have been used in several consumer products on the European market. The lack of data on human exposure still represents a major bottleneck in the risk assessment process today; particularly so in the case of data on human exposure to chemicals released from consumer products and articles. A second bottleneck in the assessment of human exposure to chemicals is the lack of validated methodologies to measure the release of chemicals from articles during normal and foreseeable product use.

In the frame of its work on human exposure to chemical stressors released from consumer products and the ChemTest project funded by DG Sanco, the Physical and Chemical Exposure Unit (which is part of DG Joint Research Centre's Institute for Health and Consumer Protection) has conducted a European survey on the level of formaldehyde that can be released from textiles which are in direct contact with the skin. Three purposes were pursued during this work: first of all, to evaluate the real situation on the European market; secondly, to develop a new method that better mimics real conditions of use in comparison to the existing ones; and thirdly, to assess whether the detected amounts of released formaldehyde are hazardous to human health through dermal exposure.

Formaldehyde was chosen because it has been classified as carcinogenic to humans by IARC (International Agency for Research on Cancer)[1] and because of its widespread use in several textile processes. For instance, it is used after treatment of substantive dyeing (to improve wash fastness) and hardening of casein fibres (during wet finishing) and with various aims such as wool protection agent, anti mould, cross linking agent in resin finishing.

In some cases, allergic contact dermatitis (ACD) can be attributed to clothing treated with textile finish resins (TFRs), also named durable press resins or permanent press clothing resins. Under normal and foreseeable use, the majority of these resins can release formaldehyde. TFRs are widely used for cotton, cotton/polyester or wrinkle-resistant linen.[2] The frequency of ACD due to textile formaldehyde resins has been reported to be between 0.2% and 4.2% after 1990.[3-8]

In Europe, no legal restrictions are presently applicable to the content of formaldehyde in textiles, whereas in other countries, such as Japan, limitations have been in place for over thirty years. However, two voluntary labelling schemes are available: the European Ecolabel, introduced with a Commission Decision[9] and focusing more on ecological criteria, and the private Oeko-Tex Standard 100, which also focuses on consumer protection. Both Ecolabel and Oeko-Tex Standard 100 foresee limits for formaldehyde that vary depending on textile categories. In particular, Ecolabel established the limits of 30 mg/kg for formaldehyde released from textiles in direct contact with the skin (75 mg/kg for Oeko-Tex Standard 100) and 300 mg/kg for textiles which have no direct contact with the skin (same limit for Oeko-Tex Standard 100). In addition, Oeko-Tex Standard 100 established that textiles for babies up to two years old should release less than 20 mg/kg.

3. Analytical methods

Two standard methods are available for measuring the release of formaldehyde from textiles: the water extraction method (EN ISO 14184-1)[10] and the vapour absorption method (EN ISO 14184-2)[11].

The first method (EN ISO 14184-1) is based on the extraction of a weighed amount of sample material (approx. 1.0 g) with water at 40 °C for one hour (an oscillating water bath was used). The extract is then filtered and treated with acetylacetone (Nash reactive), with which formaldehyde reacts to give a yellow compound (3,5-diacetyl-1,4-dihydrolutidine). The colour development is obtained in half an hour at 40 °C. The absorbance of the reaction product is measured at 412 nm and the quantification of formaldehyde is performed with the use of external standards.

Picture 1: a) Various steps of method EN ISO 14184-1; b) oscillating water bath.

The second method (EN ISO 14184-2) is based on the absorption in water of formaldehyde vapour released by a weighed amount of sample material (approx. 1.0 g) suspended over water in a sealed jar. The jar is placed in an oven at 49°C for 20 hours. The quantification of formaldehyde in the aqueous solution is performed, as in the previous method, by a colorimetric reaction with Nash reagent.

The quantification limit for both methods is 20 mg/kg and results under this limit should be reported as non detectable, as errors could be high in this case. However, in this study the results of analyses are reported, even if lower than the quantification limit, as no interferences were experienced. All the samples were analysed in triplicate, so that uncertainties at 95 % of probability could be calculated for all measurements.

Sampling was performed by cutting five big specimens, taken from different areas of each garment, into little squares about 1 cm wide. The pieces were then mixed and part of them was weighted to prepare three replicates of about 1 gram each.

Picture 2: a) Sample vessel and b) oven for method EN ISO 14184-2.

The first method was applied to all samples, as it was considered a better approximation of the possible release of formaldehyde in the real conditions of use which can determine dermal exposure. The second method, which was considered to be a better simulation of possible exposure due to inhalation, was applied to 127 samples for comparison purposes.

Table 1: Composition of artificial perspiration solutions.

Basic Perspiration Solution	0.5 g/l $C_6H_9O_2N_3$*HCl*H_2O 5 g/l NaCl 2.5 g/l Na_2HPO_4*$2H_2O$ pH=8.0 using a solution of NaOH 0.1M
Acid Perspiration Solution	0.5 g/l $C_6H_9O_2N_3$*HCl*H_2O 5 g/l NaCl 2.2 g/l NaH_2PO_4*$2H_2O$ pH=5.5 using a solution of NaOH 0.1M

With the intention to better simulate the release of formaldehyde that can be enhanced by sweat and rubbing and to obtain a “worst case” scenario, method EN ISO 14184-1 was modified using some artificial perspiration solutions, one for acid and one for basic sweat, instead of water as an extraction medium. The other conditions of method, temperature and contact time were not modified and the quantification of formaldehyde was performed as usual with the Nash reagent. The compositions of the

two simulants are reported in Table 1. The same simulants are also used in the determination of colour fastness to perspiration following the standard method EN ISO 105-E04[12].

In order to increase the effect of rubbing, instead of the oscillating water bath used for measurements performed with the method EN ISO 14184-1, the extraction was carried out alternatively either with a Head Over Heels instrument (in this case at room temperature of 25 °C) or with a Gyrowash equipment. The sample vessels were rotated up/down during the migration experiment with both kinds of instruments. To further enhance the rubbing effect, some experiments were carried out by adding 10 stainless steel balls, 12 mm diameter, in each sample vessel of the Gyrowash.

Picture 3: a) Head Over Heels equipment; b) sample vessels for the different methods.

Picture 4: a) Gyrowash apparatus; b) sample vessels for Gyrowash.

The influence of washing cycles on the release of formaldehyde was studied on one sample. Washing cycles were performed following the indications of standard method EN ISO 105 C01-C05[13] for colour fastness to washing. The temperature was set at 40 °C for half an hour and 5 g/l of standard soap were used with a bath ratio of 1:50.

Roff's method[14] was applied on the samples that showed the highest results in order to measure the global amount of formaldehyde after hydrolysis of the resin. A weighed amount of sample material (approx. 0.02 g) was hydrolysed in an aqueous solution 12 N sulphuric acid at room temperature overnight. The hydrolysed solution was then filtered and treated with chromotropic acid, with which formaldehyde reacts to give a violet compound. The absorbance of this compound was measured at 570 nm. The quantification of formaldehyde was carried out with the use of external standards and samples were analysed in triplicate.

4. Selection of products

One of the purposes of this work was to make a survey on the level of releasable formaldehyde that can be found in textile products manufactured anywhere in the world and sold on the European market. Focus was put on dermal exposure that can result from direct contact of the skin with textile products; therefore, the sampling was planned with the objective to cover textile clothing in particular and, to a lower extent, bed linen and furnishing textiles (cushion cover for sofa).

The sampling focused on textile articles that could contain formaldehyde due to its use in durable press finishing, which provides dimensional stability and recovery from wrinkling to cotton based fabrics, and as protector in dyeing blends containing wool at high temperatures, in order to avoid damage to the wool. In addition, printed articles, socks and underwear were taken into consideration.

Table 2: Purchase and production countries of samples.

	Purchase country	Production country
AT	5	
BE	9	
CY	4	
CZ	6	
DE	10	
DK	5	
EE	5	
EL	4	
ES	3	
FR	10	
HU	3	
IE	6	
IT	88	
LT	11	
LU	4	
LV	5	
NL	6	
PL	9	
PT	10	
SK	7	
UK	11	
Europe (except Italy)		48
Italy		10
Outside Europe (except China)		52
China		52
Unknown		59

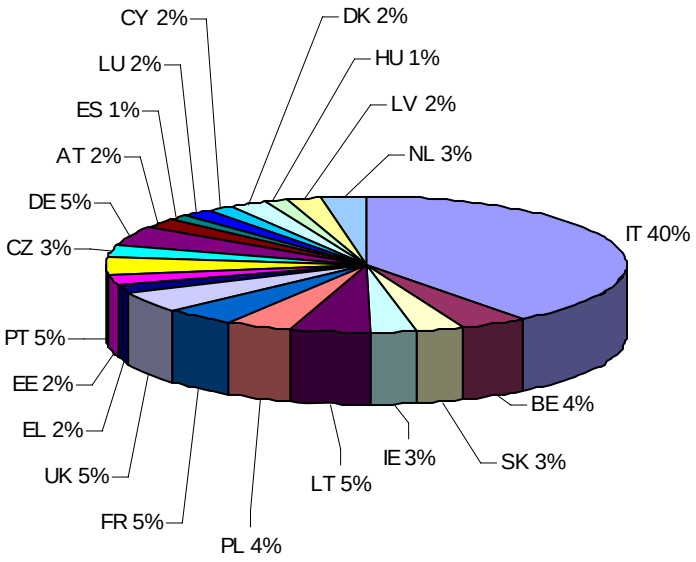


Fig 1: Proportion of samples purchased in European countries.

A total of 221 samples were purchased and analysed. Samples were bought in 21 out of 27 Member States of the European Union, Italy being the most represented for practical reasons.

Although it is not compulsory to indicate the origin on labels in Europe, whenever possible efforts were made to buy samples stating the country of production. About one fourth of samples were produced in Europe, including 5 % in Italy, one fourth in the rest of the world except China, one fourth in China and it was not possible to establish the origin for 27 % of samples.

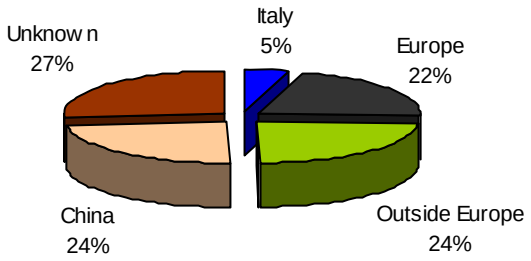


Fig 2: Proportion of samples by manufacturing geographical areas.

Due to the fact that some department stores apply a quality policy that requires producers to guarantee a low release of chemicals from textile products and that this

could bias the results of the survey, samples were purchased from various sources including not only department stores, but also shops and open air market.

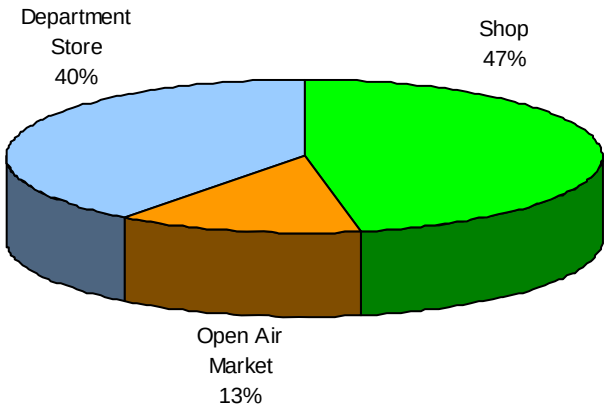


Fig 3: Proportion of samples by sources.

Considering the use of formaldehyde and formaldehyde based resins, samples were chosen made of cotton, mixtures with cotton and mixtures with wool, with a predominance of samples made of pure cotton. In particular, in the case of shirts, samples were preferred if an “easy care” label was present on the product.

About 31 % of the samples were printed articles.

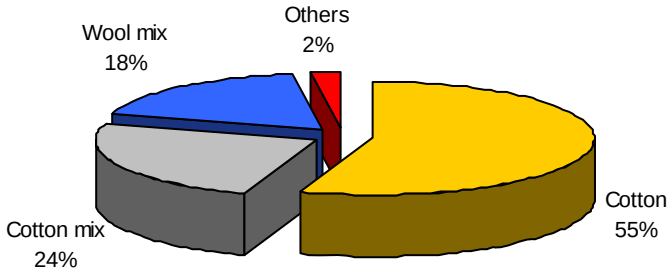


Fig 4: Proportion of samples by composition.

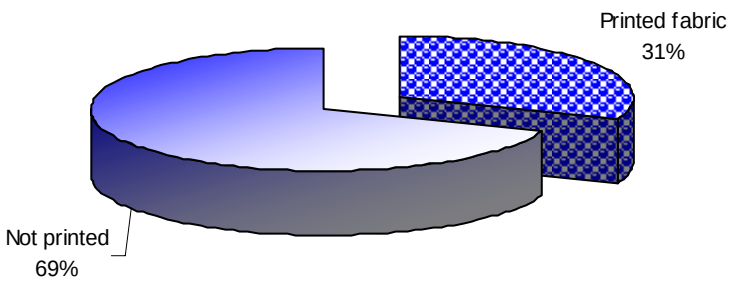


Fig 5: Proportion of printed and not printed samples.

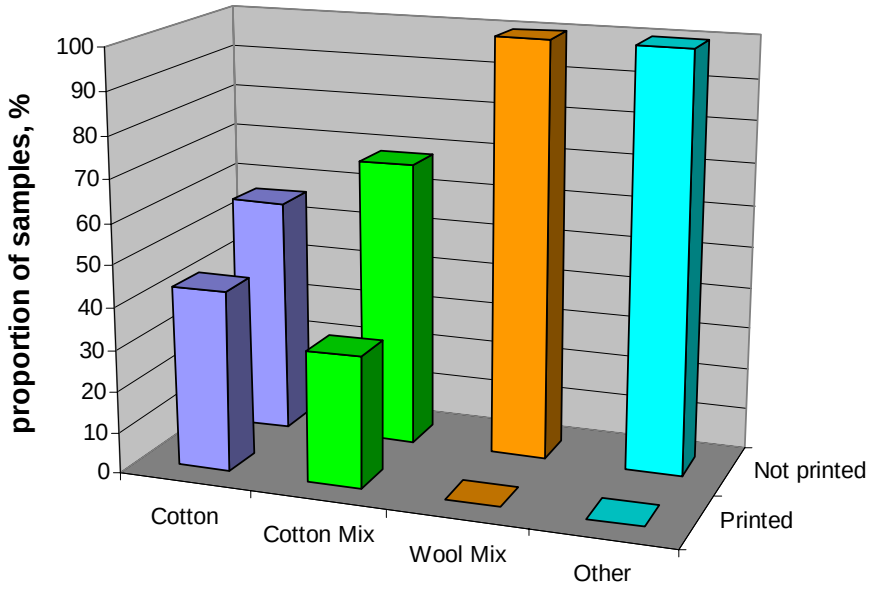


Fig 6: Composition of printed and unprinted samples.

About 94 % of all the samples were textile clothing, while 6 % were classified as linen (bedding pillowcase and sofa cushion covers). The whole population was considered as a target, so clothing samples designed for men, women and children were analysed (about one third each). With regard to children, samples were purchased both for babies under the age of two and for children up to the age of 14; in particular, 47 out of 73 samples made for children were designed for babies.

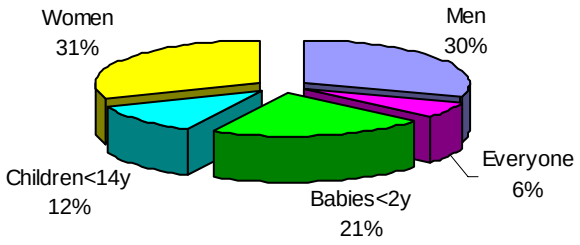


Fig 7: Proportion of samples by target population.

Several types of garments were taken into consideration in this study, principally articles in direct contact with the skin (such as shirts, T-shirts, underwear, socks, pyjamas, trousers and dresses) and articles like sweaters which can be either in direct contact with the skin or not, depending on the scenarios. As already mentioned cushions for sofa were considered to represent furnishing textiles which can be in direct contact with the skin.

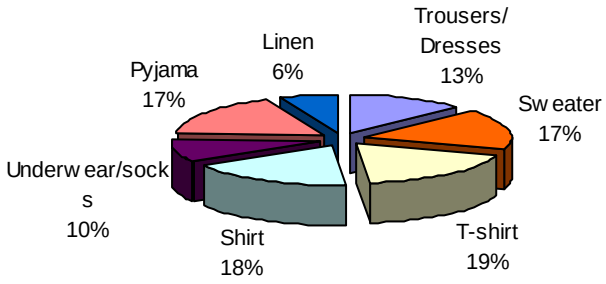


Fig 8: Proportion of samples by textile categories.

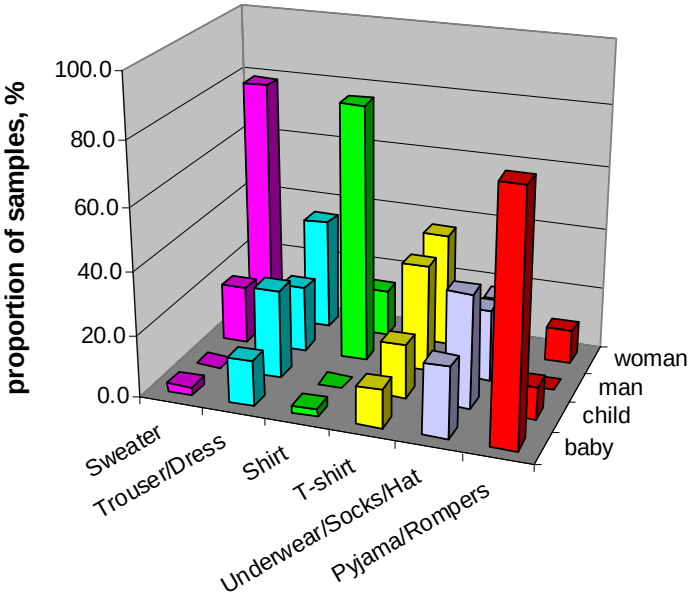


Fig 9: Proportion of samples by target population and textile categories.

5. Results and discussion

Table 1 in Annex I reports the characteristics of all samples. The following abbreviations were used. W (woman), M (man), B 12 m (baby 12 months old), C 3 y (child 3 years old), OAM (open air market), S (shop), DS (department store). The standard abbreviations were used for production countries.

All samples (221) were analysed with standard method EN 14184-1 (water extraction). A total of 127 samples were also analysed with standard method EN 14184-2 (vapour absorption); in particular, all samples showing a release of formaldehyde in water higher than 20 mg/kg. The results are presented in Table 2 in Annex I. Three replicates were analysed for each sample. Results are reported as average plus or minus uncertainty, evaluated at 95 % probability.

Although the quantification limit for both methods is 20 mg/kg, the quantification was performed even in the case of lower concentrations as no interferences were experienced. The calibration curve was extended accordingly.

In the case of samples T205, T208, T209 and T217, measurements A and B were carried out on specimens taken from two different samples of the same article to test if the release of formaldehyde was similar. Results confirmed this hypothesis.

Usually in the case of printed garments, when specimens were not homogeneous because of printed and unprinted parts, a representative sampling was carried out including both parts. For two inhomogeneous printed samples with printed drawings (T088 and T092) three different samplings were carried out: firstly taking only the printed drawings, secondly only the non printed part and thirdly a representative mixture. Results showed no difference for sample T088.

Results obtained with standard method EN ISO 14184-1 (water extraction) are represented in Fig. 10, 11 and 12. In addition, Table 4 reports data for samples which released more than 20 mg/kg of formaldehyde with the same method.

In the absence of European legal restrictions for the content of formaldehyde in textiles, the results of this survey were compared with the limit established by the voluntary labelling schemes Ecolabel and Oeko-Tex Standard 100 (see Table 3). Both schemes consider ecological criteria; Oeko-Tex Standard 100 also put the emphasis on consumer protection.

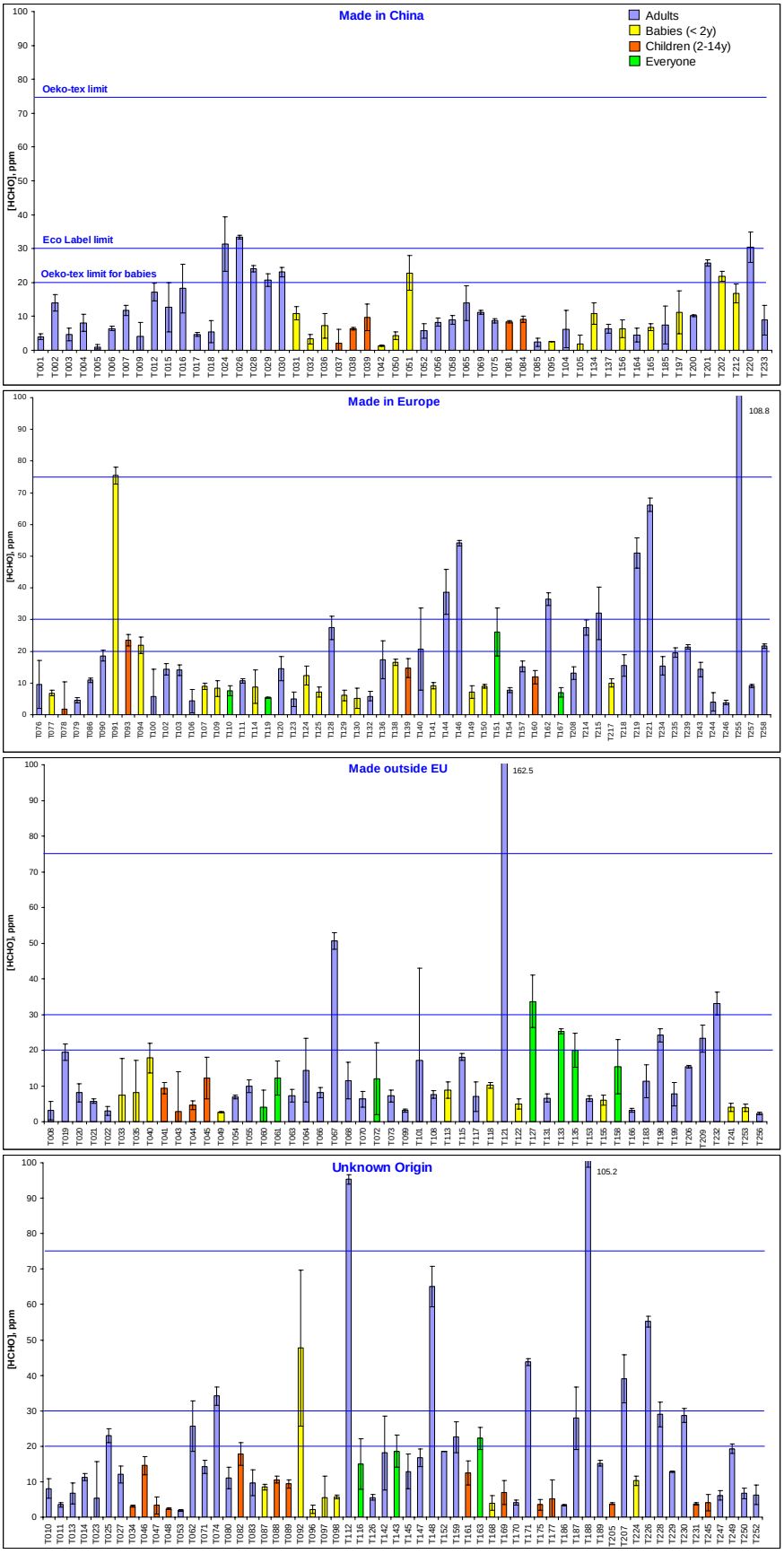


Fig 10: Released formaldehyde by standard method EN ISO 14184-1 (water extraction).

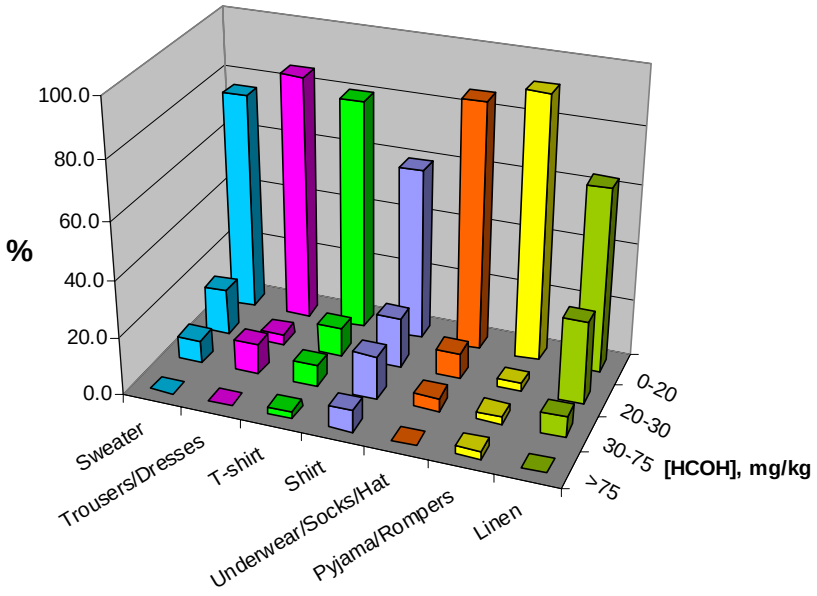


Fig 11: Proportion of samples by released formaldehyde with standard method EN ISO 14184-1 and textile categories.

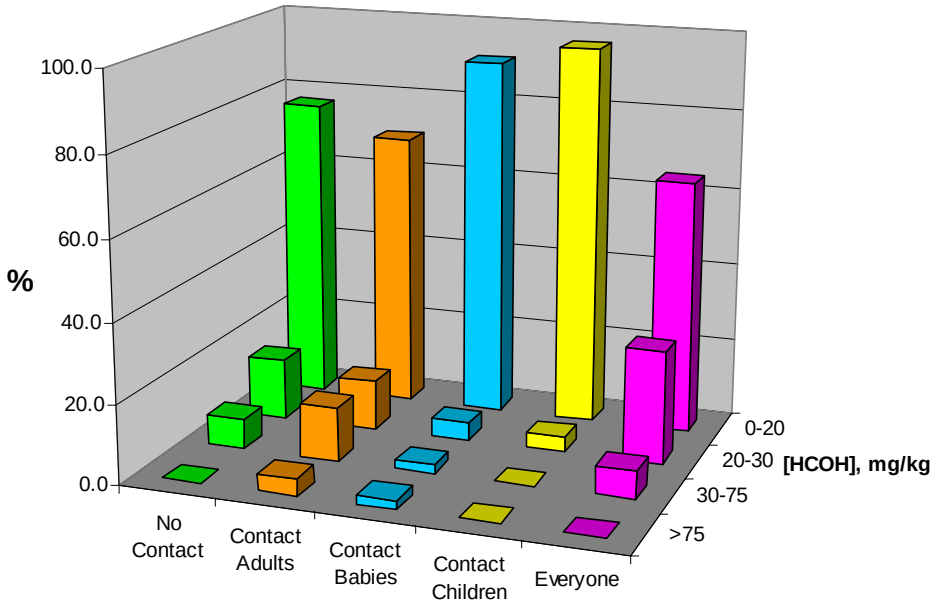


Fig 12: Proportion of samples by released formaldehyde with standard method EN ISO 14184-1 and target population.

Table 3: Limit for formaldehyde release by Ecolabel and Oeko-Tex Standard 100.

	Textiles for babies	Textiles in direct contact with the skin	Textiles with no direct contact with the skin	Decoration material
Ecolabel		30 mg/kg	300 mg/kg	300 mg/kg
Oeko-Tex 100	< 20 mg/kg	75 mg/kg	300 mg/kg	300 mg/kg

Table 4: Released formaldehyde by standard method EN ISO 14184-1 (water extraction).

JRC Code	Declared Composition	Contact	Description	Target	Printed Fabric	Source	Purchase Country	Production Country	Easy Care Oeko Tex	HCHO mg/kg	Unc. 95%
T121	100% Cotton		T-shirt	W	Yes	S	UK	Turkey		162.5	9.3
T255	100% Cotton		shirt	M		S	LV	Germany	EC	108.8	3.1
T188	35% Cotton, 65% PES		shirt	M		S	CY	Unknown	EC	105.2	6.4
T112	100% Cotton		shirt	M		S	FR	Unknown	EC	95.3	1.4
T091	100% Cotton		rompers	B 6 m	Yes	OAM	IT	Italy		75.4	2.6
T221	100% Cotton		shirt	M		S	PT	Spain	EC	66.2	2.1
T148	100% Cotton		shirt	M		DS	DE	Unknown	EC	65.0	5.7
T226	100% Cotton		underware	M	Yes	OAM	NL	Unknown		55.2	1.5
T146	100% Cotton		shirt	M		DS	DE	Slovakia	OT	54.1	0.9
T219	66% Wool, 30% PES, 4% other fibers		trousers	W		DS	PT	Spain		51.0	4.7
T067	100% Cotton		T-shirt	M		DS	IT	Bangladesh		50.7	2.3
T092 mix	100% Cotton		rompers	B 6 m	Yes	S	IT	Unknown		47.7	22.0
T171	100% Cotton		T-shirt	M		DS	LU	Unknown		43.8	1.0
T207	100% Wool		trousers	W		S	DK	Unknown		39.0	6.8
T144	100% Cotton		shirt	M		DS	DE	Germany		38.7	7.1
T162	100% Cotton		shirt	M		S	SK	Slovakia		36.4	2.0
T074	100% Cotton		T-shirt	W		DS	IT	Imported		34.2	2.6
T127	100% Cotton		sofa cushion cover	linen		S	BE	India		33.7	7.3
T026	80% Wool, 15% Viscose, 5% Elastane	no	sweater	W		S	IT	China		33.4	0.6
T232	35% Cotton, 65% PES		shirt	M		DS	IE	Outside Europe		33.1	3.1
T215	60% Wool, 40% PES		trousers	M		S	HU	Europe		32.0	8.3
T024	80% Wool, 20% PA	no	sweater	W		DS	IT	China		31.4	8.0
T220	55% Silk, 45% Cashmere	no	sweater	W		DS	PT	China		30.4	4.4
T228	100% Cotton		underware	M	Yes	OAM	NL	Unknown		29.0	3.5
T230	65% PES, 35% Cotton		shirt	M		S	NL	Unknown		28.7	1.9
T187	35% Cotton, 65% PES		shirt	M		S	CY	Unknown	EC	27.9	8.8
T214	50% Acrylic, 40% Wool, 10% Viscose	no	sweater	M		S	HU	Europe		27.5	2.4
T128	100% Cotton		shirt	M		S	BE	Slovakia	OT/EC	27.4	3.6
T151	100% Cotton		sofa cushion cover	linen		S	DE	Germany		26.1	7.5
T201	53% PES, 45% Wool, 2% Elastane		trousers	W		DS	UK	China		25.8	0.9
T062	35% Cotton, 65% PES		shirt	M	Yes	DS	IT	Imported		25.7	7.1
T133	100% Cotton		bedding pillocase	linen		S	EE	India	OT	25.3	0.7
T198	100% Cotton		shirt	M		S	UK	Morocco		24.2	1.9
T028	50% Wool, 30% Angora, 20% Elastane	no	sweater	W		S	IT	China		24.1	0.9
T093	80% Cotton, 16% PA, 4% Elastane		slip	C 12-14 y	Yes	OAM	BE	Spain		23.5	1.8
T209 av	95% Cotton, 5% Elastane		T-shirt	W	Yes	DS	DK	Turkey		23.3	3.8
T030	50% Acrylic, 40% Wool, 10% Elastane	no	sweater	W		S	IT	China		23.1	1.4
T025	60% Wool, 35% Acrylic, 5% Elastane	no	sweater	W		S	IT	Imported		23.0	1.9
T051	80% Cotton, 20% PES	no	sweater	B 12 m	Yes	DS	IT	China		22.8	5.1
T159	100% Cotton		shirt	W	Yes	S	ES	Imported		22.6	4.4
T163	100% Cotton		sofa cushion cover	linen	Yes	S	SK	Unknown		22.2	3.1
T094	100% Cotton		pyjama	B 18-24 m	Yes	S	IT	Italy		22.0	2.6
T202	77% Cotton, 23% PES		T-shirt	B 9-12 m		S	UK	China		21.9	1.5
T258	100% Cotton		T-shirt	M	Yes	S	LV	Latvia		21.7	0.7
T239	44% PES, 42% Cotton, 14% Viscose		shirt	W		S	PL	Poland		21.4	0.7
T029	70% Wool, 30% PA	no	sweater	W		S	IT	China		20.7	1.8
T140	100% Cotton		T-shirt	M	Yes	DS	CZ	Europe		20.7	13.0
T135	100% Cotton		sofa cushion cover	linen		S	PT	India		20.0	4.7

With regard to results obtained with the water extraction method, 10% of all samples (23 samples out of 221) released more than 30 mg/kg of formaldehyde. The highest value was 162.5 mg/kg, measured on a woman's pure cotton printed T-shirt, bought in a shop in Manchester (United Kingdom) and produced in Turkey.

11% of samples intended for direct contact with the skin (20 out of 183 samples, including bedding pillowcases and sofa cushion covers) exceeded the 30 mg/kg limit established by Commission Decision 2002/371/EC (Ecolabel). About 3% of the samples also exceeded the limit of 75 mg/kg set by the Oeko-Tex Standard 100 for articles in contact with skin.

5 out of 46 (11%) garments for babies under the age of two showed a release of formaldehyde higher than 20 mg/kg, whereas it should be not detectable both according to Oeko-Tex Standard 100 and the Japanese law 112. Two also exceeded the Ecolabel limit of 30 mg/kg (48 and 75 mg/kg respectively).

No sweaters, considered not in direct contact with the skin, went beyond the Ecolabel and Oeko-Tex Standard 100 limit of 300 mg/kg, but three of them contained over 30 mg/kg of formaldehyde.

From the results it appears that some categories of garments are more “at risk” than others. In fact, 22% of the analysed shirts exceeded the Ecolabel limit, whereas the percentages were 11%, 10%, 8%, 7%, 5% and 4% for trousers, T-shirts, sweaters, pillowcases, rompers and underwear respectively. However, it has to be noted that the categories of trousers, underwear and pillowcases contained fewer samples than other categories. Another remarkable result is that five out of ten shirts labelled “easy care” went beyond the Ecolabel limit.

Considering the target populations of this survey, men seem to be more exposed to formaldehyde than women, babies under the age of two and children; the percentages of samples above 30 mg/kg for each category being respectively 20%, 10%, 4% and 0%. However, this result could have been influenced by the fact that the great majority of analysed shirts were for men. If the limit of 20 mg/kg is considered for babies under the age of two and for children up to the age of fourteen, the percentages become 11% and 4% respectively.

In this survey garments made of pure cotton and mixtures containing wool seem to release more formaldehyde than those made of mixtures containing cotton; the percentages of samples exceeding the limit of 30 mg/kg being 12%, 15% and 4% respectively.

Conclusive considerations considering the sample production area cannot be drawn due to similar percentages and to uncertainty caused by the number of samples with unknown origin. The percentages of samples exceeding the Ecolabel limit compared to the total number of samples in each production area were 14%, 8%, 6% and 13% for Europe, outside Europe, China and unknown origin respectively.

Also in the case of the different sources where samples were bought, no important differences resulted from the survey. In fact, the percentages of samples with more than 30 mg/kg for each category were 12% for shops, 11% for big department stores and 7% for open air markets.

Results obtained with standard method EN ISO 14184-2 are reported in Figures 13, 14 and 15. In addition, Table 5 reports data for samples which released more than 20 mg/kg of formaldehyde with the same method.

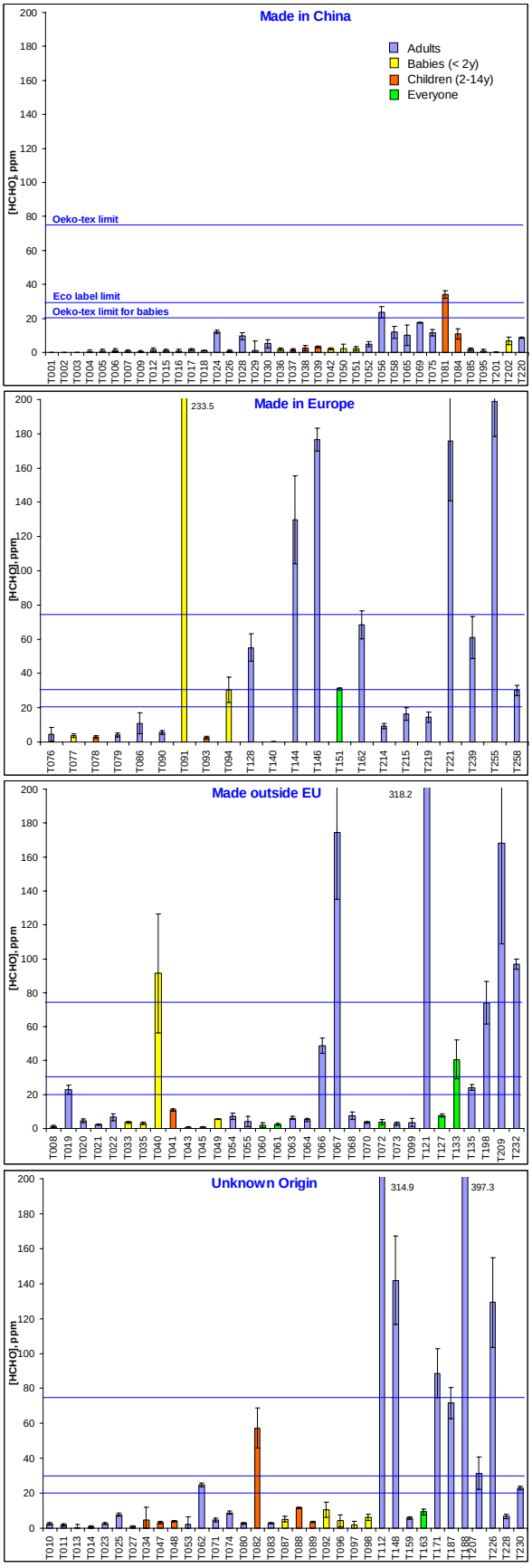


Fig 13: Released formaldehyde by standard method EN ISO 14184-2 (vapour absorption).

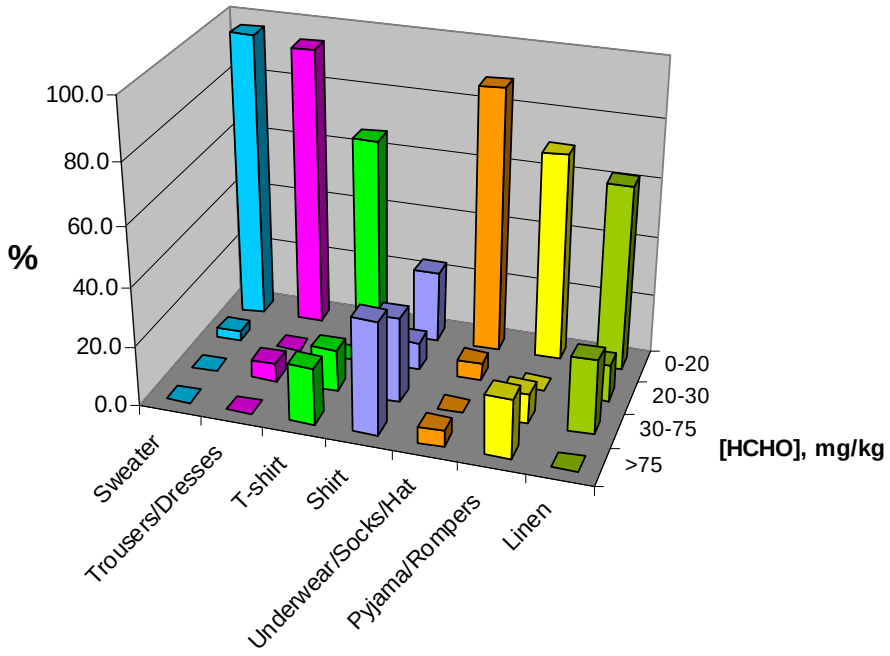


Fig 14: Proportion of samples by released formaldehyde with standard method EN ISO 14184-2 and textile categories.

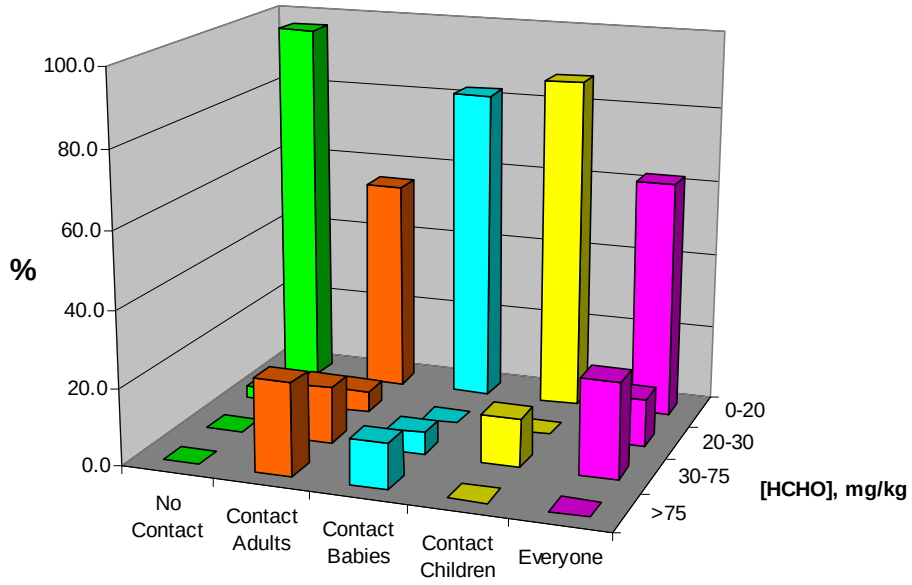


Fig 15: Proportion of samples by released formaldehyde with standard method EN ISO 14184-2 and target population.

Table 5: Released formaldehyde by standard method EN ISO 14184-2 (vapour absorption).

JRC Code	Declared Composition	Contact	Description	Target	Printed Fabric	Source	Purchase Country	Production Country	Easy Care Oeko Tex	HCHO mg/kg	unc.
T188	35% Cotton, 65% PES		shirt	M		S	CY	U	EC	397.3	27.7
T121	100% Cotton		T-shirt	W	Yes	S	UK	Turkey		318.2	15.4
T112	100% Cotton		shirt	M		S	FR	U	EC	314.9	22.2
T091	100% Cotton		rompers	B 6 m	Yes	OAM	IT	Italy		233.5	18.3
T255	100% Cotton		shirt	M		U	LV	Germany	EC	198.7	20.4
T146	100% Cotton		shirt	M		DS	DE	Slovakia	OT	176.5	6.7
T221	100% Cotton		shirt	M		S	PT	Spain	EC	175.7	34.7
T067	100% Cotton		T-shirt	M		DS	IT	Bangladesh		174.4	39.3
T209 av	95% Cotton, 5% Elastane		T-shirt	W	Yes	DS	DK	Turkey		168.0	59.0
T148	100% Cotton		shirt	M		DS	DE	U	EC	141.8	25.3
T144	100% Cotton		shirt	M		DS	DE	Germany		129.8	25.7
T226	100% Cotton		underware	M	Yes	OAM	NL	U		129.2	25.8
T232	35% Cotton, 65% PES		shirt	M		DS	IE	Outside Europe		96.8	3.1
T040	100% Cotton		pyjama	B 12 m		DS	IT	India		91.5	35.1
T171	100% Cotton		T-shirt	M		DS	LU	U		88.7	13.9
T198	100% Cotton		shirt	M		S	UK	Morocco		74.1	12.5
T187	35% Cotton, 65% PES		shirt	M		S	CY	U	EC	71.7	8.9
T162	100% Cotton		shirt	M		S	SK	Slovakia		68.4	8.1
T239	44% PES, 42% Cotton, 14% Viscose		shirt	W		U	PL	Poland		60.9	12.2
T082	65% Cotton, 35% PES		T-shirt	C 6 y	Yes	OAM	IT	Imported		57.3	11.4
T128	100% Cotton		shirt	M		S	BE	Slovakia	EC/OT	55.2	8.1
T066	65% PES, 35% Cotton		shirt	W		DS	IT	Bangladesh		48.9	4.5
T133	100% Cotton		pillowcase B	linen		S	EE	India	OT	40.7	11.5
T081	85% Cotton, 15% PES		T-shirt	C 10 y	Yes	OAM	IT	China		34.1	2.4
T207	100% Wool		trousers	W		S	DK	U		31.4	9.3
T151	100% Cotton		pillowcase S	linen		S	DE	Germany		31.1	0.5
T094	100% Cotton		pyjama	B 18-24 m	Yes	S	IT	Italy		30.6	7.4
T258	100% Cotton		T-shirt	M	Yes	U	LV	Latvia		30.0	3.0
T062	35% Cotton, 65% PES		shirt	M	Yes	DS	IT	Imported		24.8	1.1
T135	100% Cotton		pillowcase S	linen		S	PT	India		24.2	1.8
T056	100% Cotton		slip	M		DS	IT	China		23.6	3.3
T230	65% PES, 35% Cotton		shirt	M		S	NL	U		22.9	1.0
T019	100% Cotton	no	sweater	M		DS	IT	Turkey		22.9	2.8
T215	60% Wool, 40% PES		trousers	M		S	HU	Europe		16.4	3.8
T202	77% Cotton, 23% PES		T-shirt	B 9-12 m		S	UK	China		6.7	2.3

With regard to the vapour absorption method, the Ecolabel limit of 30 mg/kg was exceeded by 22% of the samples. About 12% of the samples released more than 75 mg/kg of formaldehyde, 397 mg/kg being the highest measured value for a man's cotton/polyester shirt, bought in a shop in Nicosia (Cyprus) with an unknown production country.

Results obtained using the two standard methods were often in the same range; however, sometimes the difference was not negligible. This is not surprising because different conditions are used for the migration step. The comparison of results obtained with the two methods is reported in Figures 16 and 17. In Fig. 17 the concentrations of formaldehyde measured with the two methods are reported on the x,y scales, so that all samples are represented by a point in the space. Points above the bisector line are samples in which the level of formaldehyde measured by the vapour absorption method was higher than the level measured with the other method. The picture seems to suggest that for high releases of formaldehyde (> 30 mg/kg) the EN-14184-2 standard method (vapour absorption) gives higher results than the EN-14184-1 (water extraction), whereas for lower concentration the opposite is more often true.

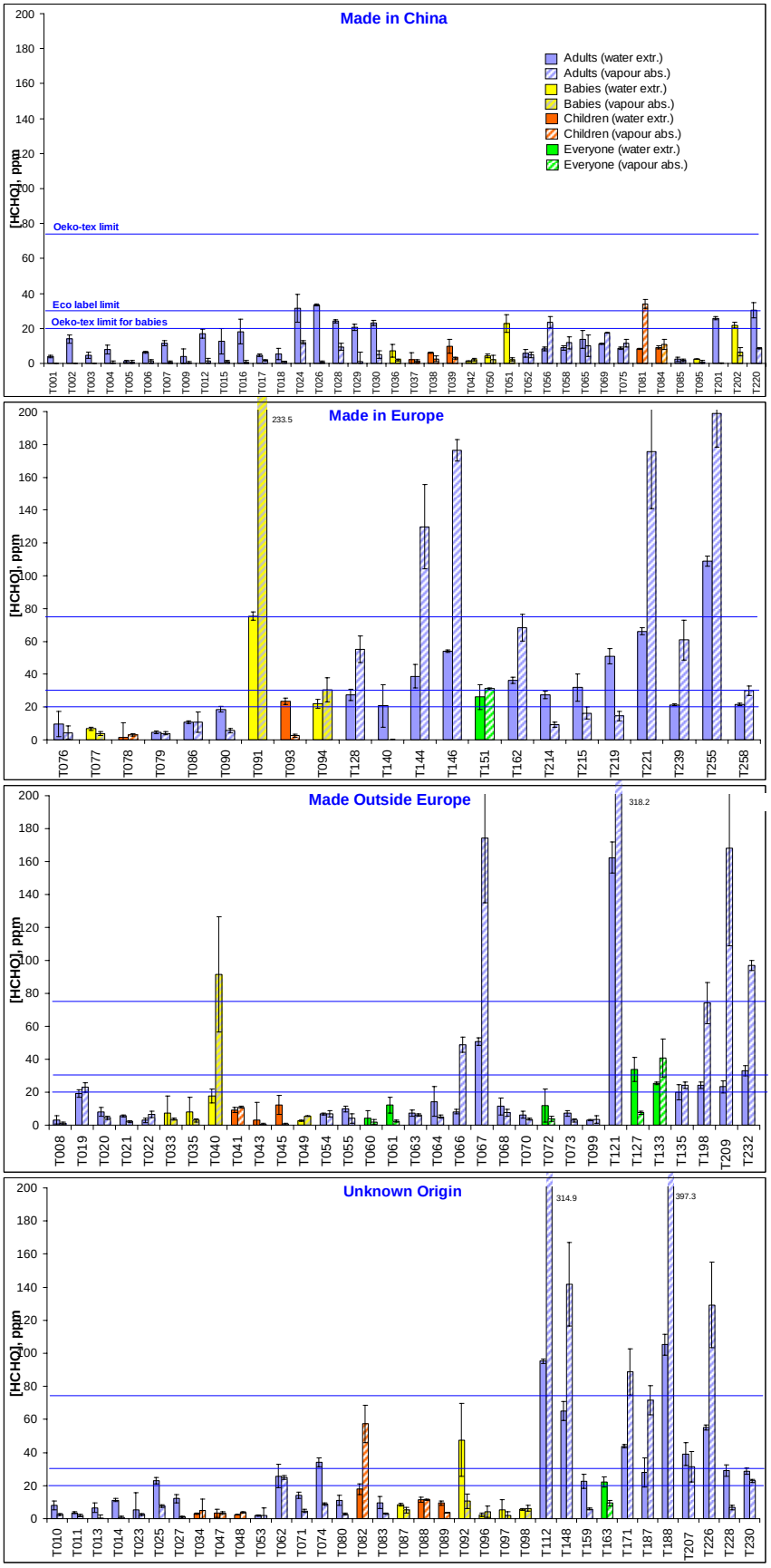


Fig 16: Comparison of results obtained by standard method EN ISO 14184-1 and EN ISO 14184-2.

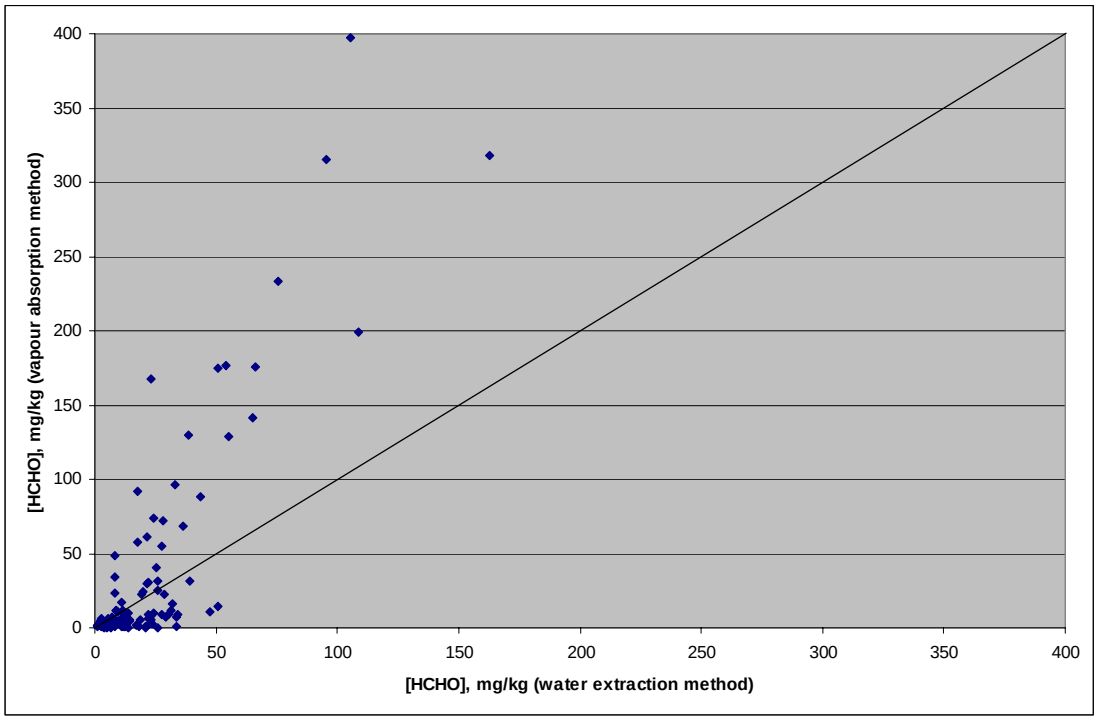
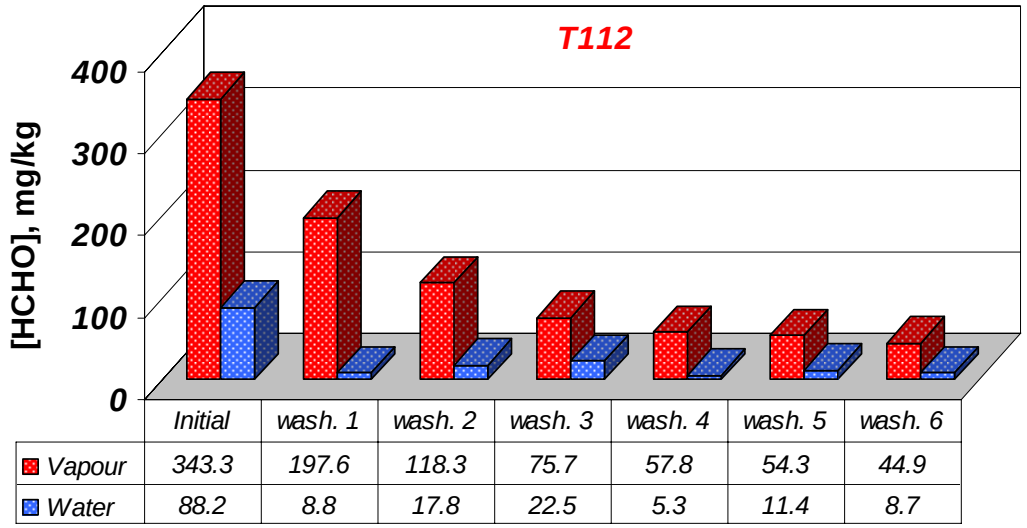


Fig 17: Comparison of results obtained by standard methods EN ISO 14184-1 and EN ISO 14184-2.

The influence of washing cycles on the release of formaldehyde was evaluated using sample 112, an “easy care” labelled pure cotton man’s shirt, as the content of formaldehyde was fairly high with both standard methods. Three specimens (triplicate) were analysed, then washed and analysed again and so on for seven washing cycles. Both standard methods were considered. As evident in Fig. 18, starting from 88 mg/kg of formaldehyde released from the unwashed article, after the first washing cycle the formaldehyde released with standard method EN-14184-1 dropped to less than 20 mg/kg (about one tenth of the original value and lower than the Ecolabel limit); then with further washing cycles the level remained low. Using standard method EN-14184-2, the level of formaldehyde released from the unwashed shirt was 343 mg/kg. This concentration gradually decreased with the number of washing cycles, but the level of formaldehyde remained higher than 30 mg/kg even after seven washing cycles (almost 45 mg/kg) and seemed to attain a plateau at about 20% of the original released level.

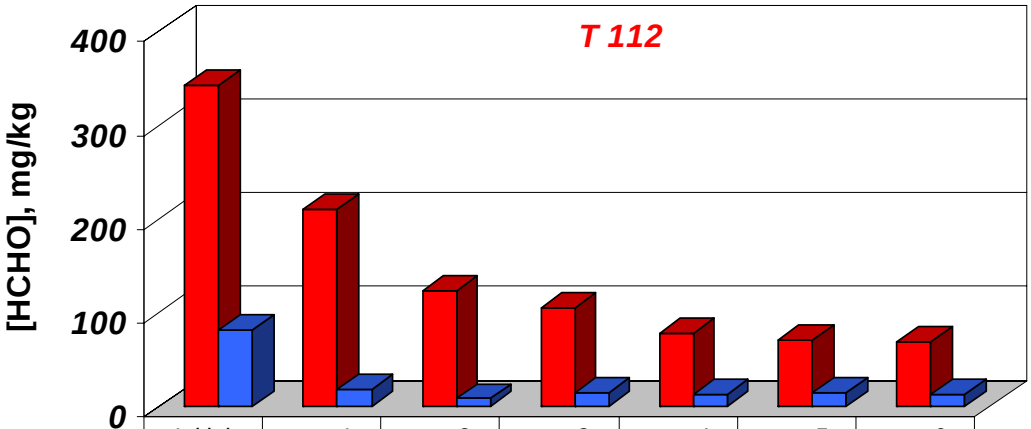
A different test was performed to study the release of formaldehyde by carrying out the migration test on the same specimens several times. Also in this case, results were calculated as averages of three replicates and both standard methods were considered.

As expected, over subsequent extractions, the level of released formaldehyde decreased; this is true for both methods.



	Initial	wash. 1	wash. 2	wash. 3	wash. 4	wash. 5	wash. 6
Vapour	343.3	197.6	118.3	75.7	57.8	54.3	44.9
Water	88.2	8.8	17.8	22.5	5.3	11.4	8.7

Fig 18: Influence of subsequent washing cycles on the release of formaldehyde.



	Initial	extr. 1	extr. 2	extr. 3	extr. 4	extr. 5	extr. 6
Vapour	342.3	210	122.5	105.5	78.5	70.9	69.3
Water	81.9	17.8	8.2	14.6	12.4	14.2	13.4

Fig 19: Influence of subsequent extractions on the release of formaldehyde.

Humid conditions and high temperatures like the ones promoted by the presence of sweat and rubbing, for example under the armpits, are likely to increase the tendency of formaldehyde to be released from clothing in direct contact with skin. In an attempt to simulate this situation and to obtain a “worst case” scenario, some modifications were brought to the standard method EN ISO 14184-1.

A first series of experiments was performed on three samples with high formaldehyde release. The performance of three different extraction solutions (water, acid and basic artificial perspiration solutions) was compared, using both a normal oscillating water bath at 40 °C (as normally used for standard method EN ISO 14184-1) and a Head Over Heels instrument (see Picture 3). The Head Over Heels equipment was used with the intention to increase the rubbing effect: the extraction bottles containing samples were rotated up/down at a speed of 60 rpm. Unfortunately, in this case it was impossible to set a specified temperature, so the migration process was carried out at a room temperature of 25 °C.

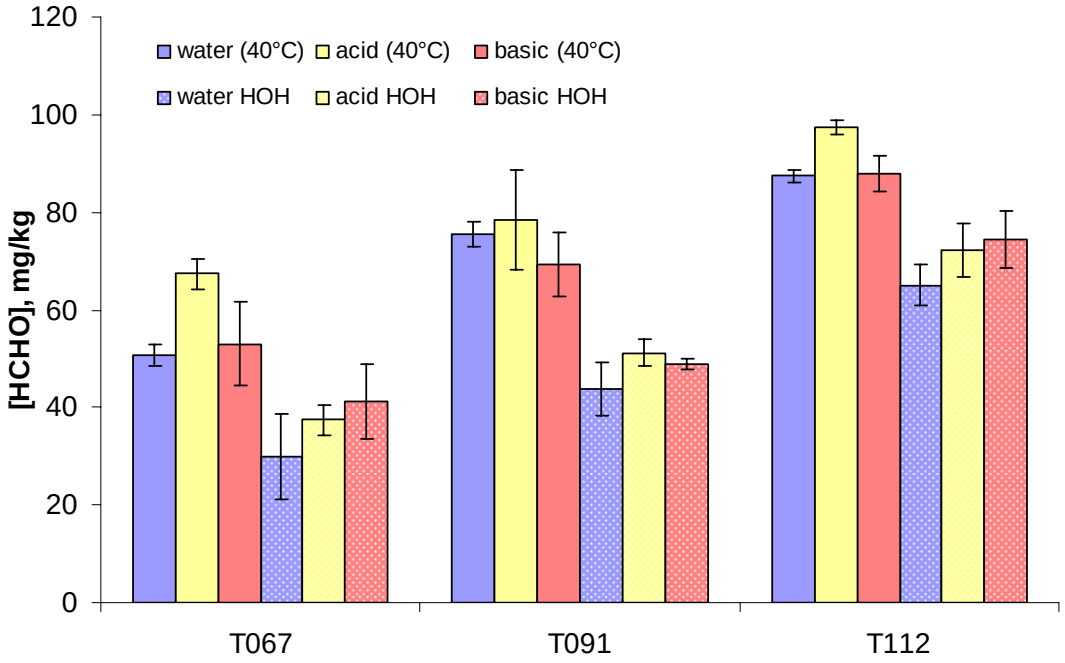


Fig 20: Influence of rubbing on the release of formaldehyde.

The analysed samples were T067, T091 and T112, a T-shirt, a rompers and a shirt respectively, all made of pure cotton. As reported in Fig. 20, the Head Over Heels extraction was less efficient than the one carried out in the oscillating water bath, most probably only because of the lower temperature (25 °C instead of 40 °C). In fact, this parameter can certainly have a high impact on migration processes. Comparing the different extraction media using the water bath, the acid perspiration solution seemed to be the most efficient for these samples.

In order to increase the rubbing effect while maintaining the temperature of the migration process constant at 40 °C, a Gyrowash equipment (see Picture 4) normally

used for testing colour fastness was employed. To further increase this effect, some experiments were performed adding 10 stainless steel balls, 12 mm diameter, in each sample holder of the Gyrowash. As in the case of Head Over Heels, specimens were placed in extraction vessels which were fixed to a cylinder which rotated on its own axis.

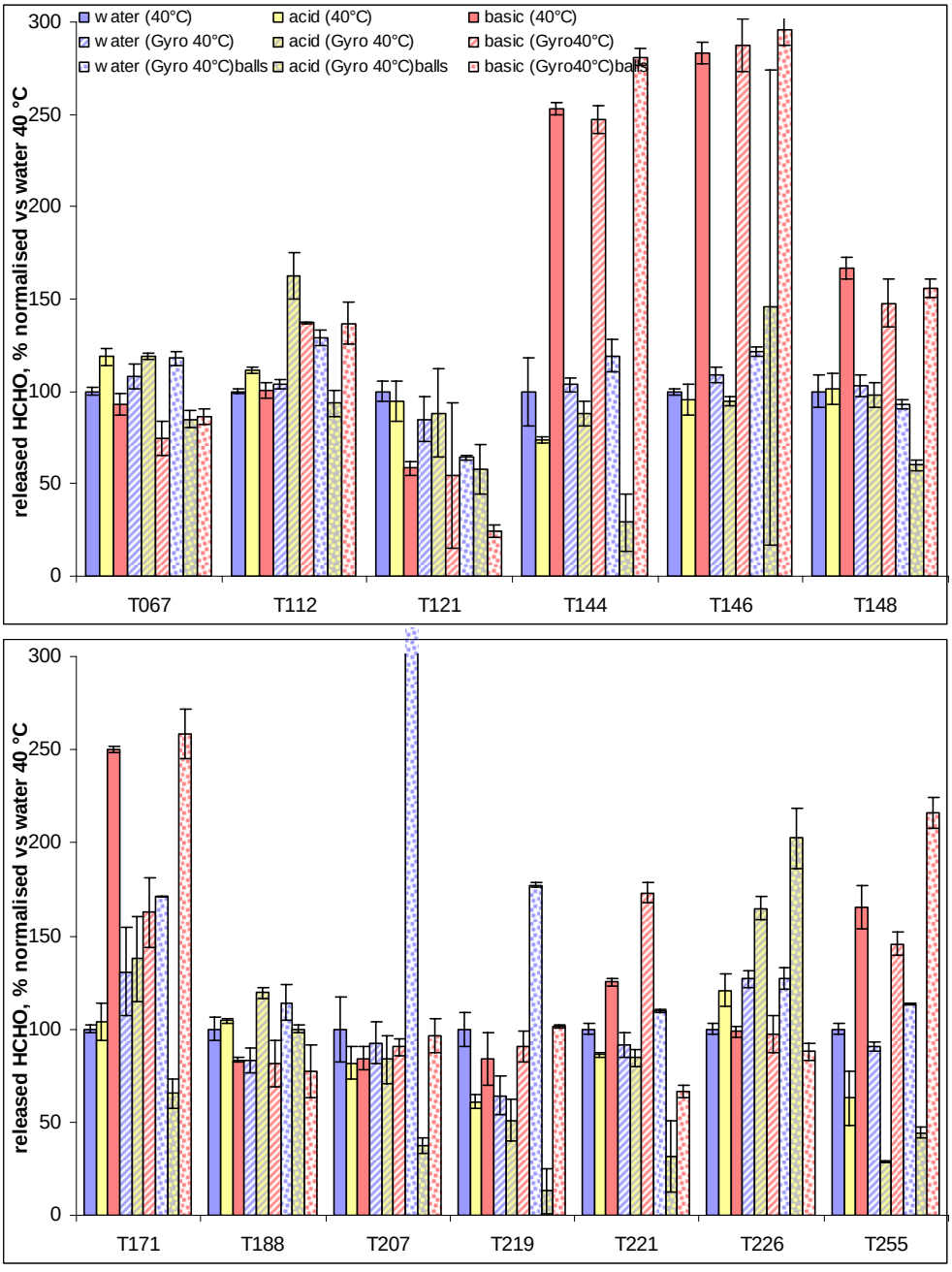


Fig 21: Comparison of water bath and Gyrowash extraction.

Table 6: Released formaldehyde by EN ISO 14184-1 standard method modified with simulants, Gyrowash and stainless steel balls.

	[HCHO], mg/kg								
JRC	water bath, 40 °C			Gyrowash, 40 °C			Gyrowash 40 °C, stainless steel balls		
code	water	acid	basic	water	acid	basic	water	acid	basic
T067	66.0 ± 1.4	78.4 ± 3.5	61.4 ± 3.5	71.6 ± 4.8	78.4 ± 1.3	49.2 ± 4.6	77.9 ± 3.0	56.1 ± 2.4	56.9 ± 2.3
T112	95.3 ± 1.4	106.3 ± 1.5	95.9 ± 3.9	99.2 ± 2.3	154.8 ± 19.3	130.8 ± 0.5	123.0 ± 5.6	89.2 ± 6.2	130.2 ± 14.7
T121	162.5 ± 9.3	154.0 ± 16.3	95.1 ± 3.7	138.2 ± 17.2	143.6 ± 34.5	88.5 ± 35.0	104.5 ± 1.5	93.9 ± 12.5	39.9 ± 1.3
T144	38.7 ± 7.1	28.6 ± 0.5	97.9 ± 3.3	40.1 ± 1.5	34.0 ± 2.3	95.6 ± 7.1	46.1 ± 4.0	11.2 ± 1.7	108.8 ± 4.7
T146	54.1 ± 0.9	51.7 ± 4.3	153.3 ± 9.0	59.1 ± 2.5	51.2 ± 1.2	155.4 ± 22.5	65.8 ± 1.6	78.7 ± 101.1	160.1 ± 14.1
T148	65 ± 5.7	66.0 ± 5.5	108.3 ± 6.2	67.0 ± 3.9	63.8 ± 4.4	96.0 ± 12.6	60.6 ± 1.6	39.1 ± 1.1	101.4 ± 4.9
T171	43.8 ± 1.0	45.5 ± 4.5	109.5 ± 1.6	57.3 ± 13.5	60.3 ± 13.8	71.2 ± 13.5	74.9 ± 0.1	28.6 ± 2.3	113.3 ± 15.2
T188	105.2 ± 6.4	110.0 ± 1.4	87.8 ± 0.9	87.4 ± 5.9	125.5 ± 3.8	85.7 ± 10.4	120.2 ± 11.5	105.1 ± 2.0	81.2 ± 11.6
T207	39.0 ± 6.8	31.9 ± 2.8	32.8 ± 2.0	36.1 ± 4.1	32.7 ± 4.2	35.3 ± 1.6	123.2 ± 1.5	14.6 ± 0.6	37.7 ± 3.5
T219	51.0 ± 4.7	31.1 ± 1.1	42.9 ± 6.0	32.8 ± 3.5	26.0 ± 2.9	46.3 ± 3.8	90.4 ± 1.2	6.7 ± 0.8	51.7 ± 0.4
T221	66.2 ± 2.1	57.0 ± 0.8	82.9 ± 1.9	60.5 ± 3.8	56.0 ± 2.6	114.5 ± 6.1	72.8 ± 0.6	20.8 ± 4.0	44.0 ± 1.5
T226	55.2 ± 1.5	66.7 ± 5.9	54.5 ± 1.6	70.1 ± 3.1	90.9 ± 5.7	53.6 ± 5.2	70.2 ± 4.2	111.8 ± 18.2	48.4 ± 2.1
T255	108.8 ± 3.1	68.3 ± 9.7	180.1 ± 20.9	98.5 ± 2.1	31.2 ± 0.1	158.5 ± 10.1	123.4 ± 0.4	48.1 ± 1.4	235.3 ± 19.9

Some problems were experienced when the acid perspiration solution was used in combination with stainless steel balls 304, as at the end of the migration process, the solution was lightly coloured after the colorimetric reaction even in the absence of a sample, thus creating interferences in the quantitative determination of formaldehyde. For these reasons, the results obtained with this method are probably affected by a systematic error.

The results in Fig. 21 and Table 6 show that the majority of samples released the highest quantity of formaldehyde when tested in the Gyrowash (11 out of 13), thus confirming that the rubbing effect is an important parameter in the release of chemicals from textiles. Seven out of eleven samples released more formaldehyde when stainless steel balls were used. In addition, considering the fact that of the remaining four samples, three released a higher quantity of formaldehyde in the Gyrowash without balls with the acid perspiration solution and that interferences were experienced with this simulant in combination with balls, it can be concluded that the "worst case" can usually be obtained by modifying standard method EN ISO 14184-1 using a Gyrowash for the migration step and stainless steel balls to increase the rubbing effect. In the case of the acid perspiration solution, balls should be made by stainless steel that are resistant to this solution.

Considering now the effect of substituting water with an artificial perspiration solution, the greatest proportion of samples (10 out of 13) showed the highest release of formaldehyde in the presence of sweat simulants, six of them with the basic one and four of them with the acid simulant. The increase in formaldehyde release is quite significant, in fact for ten samples it was more than 150% and up to 300% when compared with the result obtained with the unchanged standard method, i.e. water

extraction in oscillating water bath. For all the studied samples the "worst case" scenario was represented by a release of formaldehyde higher than 75 mg/kg. This is also true for sample T146 which is a shirt labelled Oeko-Tex Standard 100. The highest release was 235 mg/kg in the case of sample T255 in Gyrowash with stainless steel balls and basic perspiration solution.

The fact that the highest release ("worst case") was not always measured with the same simulant is not surprising if we consider that samples were probably treated with different resins which can have a different chemical behaviour.

Globally, the results confirmed the idea that to better mimic real conditions of use and to obtain a "worst case" release, method EN ISO 14184-1 should be modified using artificial perspiration solutions, both the acid and the basic one, and using Gyrowash to increase the rubbing effect.

Table 7: Comparison total amount of formaldehyde and released formaldehyde.

	water extraction	**vapour absorption**	**after hydrolisis**
JRC code	**[HCOH] mg/kg**	**[HCOH] mg/kg**	**[HCOH] total mg/kg**
T067	50.7 ± 2.3 (3)	174.4 ± 39.3 (3)	806.4 ± 308.8 (3)
T091	75.4 ± 2.6 (3)	233.5 ± 18.3 (3)	2034.8 ± 622.4 (3)
T112	95.3 ± 1.4 (3)	314.9 ± 22.2 (3)	9354.6 ± 2098.4 (3)
T121	162.5 ± 9.3 (3)	318.2 ± 15.4 (3)	872.2 ± 238.5 (3)
T144	38.7 ± 7.1 (3)	129.8 ± 25.7 (3)	12769.9 ± 802.7 (3)
T146	54.1 ± 0.9 (3)	176.5 ± 6.7 (3)	18198.8 ± 3343.8 (3)
T148	65.0 ± 5.7 (3)	141.8 ± 25.3 (3)	14462.1 ± 1625.6 (3)
T171	43.8 ± 1.0 (3)	88.7 ± 13.9 (3)	13903.6 ± 4064.2 (3)
T188	105.2 ± 6.4 (3)	397.3 ± 27.7 (3)	1334.3 ± 508.7 (3)
T219	51.0 ± 4.7 (3)	14.5 ± 2.8 (3)	383.8 ± 799.9 (3)
T221	66.2 ± 2.1 (3)	175.7 ± 34.7 (3)	11260.5 ± 1687.5 (3)
T226	55.2 ± 1.5 (3)	129.2± 25.8 (3)	2465.1 ± 1776.1 (3)
T255	108.8 ± 3.1 (3)	198.7 ± 20.4 (3)	18646.9 ± 4605.2 (3)

The total content of formaldehyde was measured with Roff's method after the hydrolysis of the resin on the same samples that showed the highest formaldehyde release. Also in this case, measurements were performed in triplicate. As expected, the total quantity of formaldehyde was very high, ranging from about 400 mg/kg to 19000 mg/kg depending on the samples.

On these samples, results showed that the total amount of formaldehyde was generally in inverse relation to the quantity of released formaldehyde in the water extraction method. In fact, samples with the highest global amount of formaldehyde (higher than 10000 mg/kg) showed the lowest per cent release (lower than 1%),

whereas samples with total concentration lower than 2500 mg/kg showed a per cent release from 2 to almost 20%. Obviously the proportion of the release is very much dependent on the type of resin used in the finishing and also on the conditions applied for the finishing. For these reasons, generalisations are not possible.

In order to assess human dermal exposure to formaldehyde released from textiles, the following equation, used in a study made by the Danish Environmental Protection Agency[15] and taken from the Technical Guidance Document (TGD)[16] after modification to the exposure scenario, was considered:

$$U_{derm} = \frac{Q_{prod} * Fc_{prod} * F_{AREA,derm} * N_{event}}{BW}$$

Where:

U_{derm}	is the potential uptake of the compound	mg/kg bw/day
Q_{prod}	is the amount of textile	kg
Fc_{prod}	is the fraction of compound in the textile	mg/kg
$F_{AREA,derm}$	is the fraction of exposed skin	
N_{event}	number of exposure events	per day
BW	bodyweight (bw)	kg

The amount of textile in this study was considered as 500 g for an adult. In fact, it has to be noted that for the assessment of dermal exposure, full coverage of the body excepting head, hands and feet is usually used. TGD considers a total body area of 19400 cm^2 for men and 16900 cm^2 for women, the average being 18150 cm^2 with an estimated area including head, neck and feet of 2981 cm^2. Considering an exposed body surface for an adult corresponding to about 85% of the total body area, that is 15000 cm^2, and a textile of 333 g/m^2, the weight of textile that covers the exposed body surface is about 500 g. In the case of a child of about one year old, the total body surface is estimated as 6700 cm^2, the exposed body surface would be about 5700 cm^2 and the weight of textile needed to cover this area is about 190 g.

Body weights of 70 kg and 10 kg for adults and children respectively were considered, as recommended in the TGD.

The potential dermal uptake should be multiplied by the absorption factor (F_{ab}) that takes the dermal absorption into consideration. However, in the absence of information regarding this parameter, a dermal absorption of 100% was used, as suggested in the TGD.

Data on formaldehyde release obtained with the water extraction standard method (EN ISO 14184-1) and with the worst case modified method (varying with the sample, usually Gyrowash and stainless steel balls with either acid or basic perspiration solution) were used to estimate adult and child exposure as reported below.

Calculation example:

Adult dermal exposure: 162.5 (mg/kg) x 0.5 (kg)/ 70 (kg bw) = 1.1607 mg/kg bw

Child dermal exposure: 162.5 (mg/kg) x 0.19 (kg)/ 10 (kg bw) = 3.0875 mg/kg bw

Table 8: Dermal uptake of formaldehyde.

		water	dermal exposure		worst case	dermal exposure	
JRC Code	Declared Composition	HCHO mg/kg	adult mg/kg bw	child mg/kg bw	HCHO mg/kg	adult mg/kg bw	child mg/kg bw
T121	100% Cotton	162.5	1.1607	3.0875	162.5	1.1607	3.0875
T255	100% Cotton	108.8	0.7771	2.0672	235.3	1.6807	4.4707
T188	35% Cotton, 65% PES	105.2	0.7514	1.9988	125.5	0.8964	2.3845
T112	100% Cotton	95.3	0.6807	1.8107	154.8	1.1057	2.9412
T091	100% Cotton	75.4	0.5386	1.4326			
T221	100% Cotton	66.2	0.4729	1.2578	114.5	0.8179	2.1755
T148	100% Cotton	65.0	0.4643	1.2350	108.3	0.7736	2.0577
T226	100% Cotton	55.2	0.3943	1.0488	111.8	0.7986	2.1242
T146	100% Cotton	54.1	0.3864	1.0279	160.1	1.1436	3.0419
T219	66% Wool, 30% PES, 4% other fibers	51.0	0.3643	0.9690	90.4	0.6457	1.7176
T067	100% Cotton	50.7	0.3621	0.9633	78.4	0.5600	1.4896
T092 mix	100% Cotton	47.7	0.3407	0.9063			
T171	100% Cotton	43.8	0.3129	0.8322	113.3	0.8093	2.1527
T207	100% Wool	39.0	0.2786	0.7410	123.2	0.8800	2.3408
T144	100% Cotton	38.7	0.2764	0.7353	108.8	0.7771	2.0672
T162	100% Cotton	36.4	0.2600	0.6916			
T074	100% Cotton	34.2	0.2443	0.6498			
T127	100% Cotton	33.7	0.2407	0.6403			
T026	80% Wool, 15% Viscose, 5% Elastane	33.4	0.2386	0.6346			
T232	35% Cotton, 65% PES	33.1	0.2364	0.6289			
T215	60% Wool, 40% PES	32.0	0.2286	0.6080			
T024	80% Wool, 20% PA	31.4	0.2243	0.5966			
T220	55% Silk, 45% Cashmere	30.4	0.2171	0.5776			
T228	100% Cotton	29.0	0.2071	0.5510			
T230	65% PES, 35% Cotton	28.7	0.2050	0.5453			
T187	35% Cotton, 65% PES	27.9	0.1993	0.5301			
T214	50% Acrylic, 40% Wool, 10% Viscose	27.5	0.1964	0.5225			
T128	100% Cotton	27.4	0.1957	0.5206			
T151	100% Cotton	26.1	0.1864	0.4959			
T201	53% PES, 45% Wool, 2% Elastane	25.8	0.1843	0.4902			
T062	35% Cotton, 65% PES	25.7	0.1836	0.4883			
T133	100% Cotton	25.3	0.1807	0.4807			
T198	100% Cotton	24.2	0.1729	0.4598			
T028	50% Wool, 30% Angora, 20% Elastane	24.1	0.1721	0.4579			
T093	80% Cotton, 16% PA, 4% Elastane	23.5	0.1679	0.4465			
T209 av	95% Cotton, 5% Elastane	23.3	0.1664	0.4427			
T030	50% Acrylic, 40% Wool, 10% Elastane	23.1	0.1650	0.4389			
T025	60% Wool, 35% Acrylic, 5% Elastane	23.0	0.1643	0.4370			
T051	80% Cotton, 20% PES	22.8	0.1629	0.4332			
T159	100% Cotton	22.6	0.1614	0.4294			
T163	100% Cotton	22.2	0.1586	0.4218			
T094	100% Cotton	22.0	0.1571	0.4180			
T202	77% Cotton, 23% PES	21.9	0.1564	0.4161			
T258	100% Cotton	21.7	0.1550	0.4123			
T239	44% PES, 42% Cotton, 14% Viscose	21.4	0.1529	0.4066			
T029	70% Wool, 30% PA	20.7	0.1479	0.3933			
T140	100% Cotton	20.7	0.1479	0.3933			
T135	100% Cotton	20.0	0.1429	0.3800			

The highest estimated dermal uptakes, based on the data obtained with the standard method, were 1.2 and 3.1 mg/kg bw for adult and child respectively, for a pure cotton

printed T-shirt. Using the data obtained with the modified method to obtain a worst case scenario, the highest dermal exposures were 1.7 and 4.5 mg/kg bw for adult and child respectively, for a pure cotton “easy care” shirt.

6. Conclusions

A European survey on the level of formaldehyde released from textiles, in particular textile clothing, produced all over the world has been performed. The selection of fabrics was planned among textile products that are believed to contain formaldehyde, in order to cover as many different types of fibres and type of fabrics as possible. Seven categories were considered: 1) trousers and dresses; 2) underwear, socks and hats; 3) sweaters; 4) rompers and pyjamas; 5) shirts; 6) T-shirts; 7) bedding pillowcases and sofa cushion covers. The whole population was considered as target, i.e. men, women, babies under the age of two and children up to 14 years old. Samples were bought in 21 Member States of the European Union, from different sources (shops, department stores and open air market), with different compositions (pure cotton, cotton mixtures and wool mixtures) and various production countries or areas, e.g. Europe, China, rest of the world. Part of them was printed and some were "easy care" or Oeko-Tex labelled.

A total of 221 samples were analysed with standard method EN ISO 14184-1 (water extraction) and 127 with standard method EN ISO 14184-2 (vapour absorption). Measurements were performed in triplicate and uncertainties were calculated at 95 % of probability.

In the case of the water extraction method, 11% of samples intended to be in direct contact with skin exceeded the limit established by Commission Decision 2002/371/EC (Ecolabel), i.e. 30 mg/kg. About 3% were higher than 75 mg/kg, which is the limit set by Oeko-Tex Standard 100. In the case of babies under the age of two, 11% of garments released more than 20 mg/kg of formaldehyde, which is the Oeko-Tex Standard 100 limit for babies.

The sample manufacturing area (Europe, China, rest of the world) and the purchase sources (shops, department stores and open air markets) do not seem to influence the results, as percentages of samples exceeding the Ecolabel limit from the different purchase and manufacturing sources are similar.

All textile categories were represented among the samples which released more than 30 mg/kg of formaldehyde, but shirts seem to be the category with the highest risk of exceeding the limit of 30 mg/kg (22% of them). Moreover, five out of ten "easy care" labelled shirts exceeded the Ecolabel limit. Similarly, pure cotton and mixtures

containing wool seem to release more formaldehyde than garments made of mixtures containing cotton and other fibres.

Considering the vapour absorption method, 22% of samples released more than 30 mg/kg of formaldehyde and 12% more than 75 mg/kg, 397 mg/kg being the highest measured value.

Results obtained with the two standard methods were usually in the same range for low levels of formaldehyde; however for releases of over 30 mg/kg, the vapour absorption method gives frequently higher results than the water extraction method.

Domestic washing effectively reduces the level of released formaldehyde. After the first washing cycle with the water extraction method, the level of formaldehyde was reduced to 10% of the initial value and decreased to 60% in the case of the vapour absorption method.

The standard method EN ISO 14184-1 was modified to better mimic the real conditions of use of garments. Artificial perspiration solutions (acid and basic sweat), washing machine generally used to determine colour fastness and stainless steel balls were used to increase the rubbing effect and to better reproduce the real conditions of direct skin-textile contact. The release of formaldehyde was maximised with this newly developed method.

Following the recommendations of the Technical Guidance Document, release data were used to estimate the dermal exposure of an adult and a child. The maximum estimated dermal uptakes were 1.7 and 4.5 mg/kg bw for an adult and a child respectively, with calculation based on data obtained with the modified method. The maximum estimated dermal uptakes calculated based on data obtained with the standard method EN ISO 14184-1 were 1.2 and 3.1 mg/kg bw for an adult and a child respectively.

7. References

[1] IARC Press Release 153, 2004, http://www.iarc.fr/ENG/Press_Releases/archives/pr153a.html

[2] Le Coz C., Clothing. In: Textbook of Contact Dermatitis 3rd edition. Rycroft RJG, Menné T, Frosch PJ, Lepoittevin JP (Eds), pp. 727-749. Springer, Berlin, Heidelberg, Germany.

[3] Hovding G., Contact eczema due to formaldehyde in resin-finished textiles, Acta Derm Venereol, **41**, 194, 1961.

[4] Epstein E, Maibach HI, Formaldehyde allergy, Arch Dermatol, **94**, 186, 1966.

[5] Fowler JF Jr, Skinner SM, Belsito DV., Allergic contact dermatitis from resins in permanent press clothing: an underdiagnosed cause of generalized dermatitis, Am J Acad Dermatol, **27**, 962-968, 1992.

[6] Sherertz EF., Clothing dermatitis. Practical aspects for the clinician, Am J Contact Dermat, **3**, 55-64, 1992.

[7] Fuentes Cuesta MM, Blanco Carmona JG, Herrero Gil D et al., Dermatitis alérgica de contacto por textiles, Alergol Inmunol Clin, **15**, 88-92, 2000.

[8] Lazarov A, Trattner A, Abraham D, David M., Frequency of textile dye and resin sensitization in patients with contact dermatitis in Israel, Contact Dermatitis, **46 (2)**, 119-120, 2002.

[9] Commission Decision 2002/371/EC (15 May 2002) establishing the ecological criteria for the award of the Community eco-label to textile products and amending Decision 1999/178/EC *(Official Journal L133 of 18.5.2002, p. 0029-0041)*.

[10] EN ISO 14184-1 (2000) Textiles – Determination of formaldehyde. Free and hydrolised formaldehyde (water extraction method).

[11] EN ISO 14184-2 (2000) Textiles – Determination of formaldehyde. Released formaldehyde (vapour absorption method).

[12] EN ISO 105-E04 (1998) Textiles – Tests for colour fastness. Colour fastness to perspiration.

[13] EN ISO 105-C01-C05 (1989) Textiles – Tests for colour fastness. Colour fastness to washing.

[14] Roff W. J., The determination of the formaldehyde yield of cellulose textiles with formaldehyde, urea-formaldehyde or melamine-formaldehyde, J. Text. Inst., **47**, T309-T318, 1956.

[15] EllebæK Laursen S., Hansen J., Drøjdahl A., Hansen O., Pommer K., Pedersen E., Bernth N., Survey of chemical compounds in textile fabrics, **23**, 2003.

[16] European Chemicals Bureau, Technical Guidance Document on Risk Assessment, 1996.

Annex I

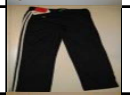
Results

Table 1: Description of samples.

JRC Code	Picture	Declared Composition	Description	Target	Printed Fabric	Source	Purchase Country	Production Country	Easy Care Oeko Tex
T001		80% Cotton, 20% Viscose	sweater	W		OAM	IT	China	
T002		60% Wool, 35% Acrylic, 5% Elastane	sweater	W		OAM	IT	China	
T003		80% Wool, 15% Acrylic, 5% Elastane	sweater	W		OAM	IT	China	
T004		80% Wool, 15% Acrylic, 5% Elastane	sweater	W		OAM	IT	China	
T005		80% Wool, 20% Cotton	sweater	W		OAM	IT	China	
T006		90% Wool (Merinos), 10% Elastane	sweater	W		OAM	IT	China	
T007		55% Wool, 30% Acrylic, 15% Elastane	sweater	W		OAM	IT	China	
T008		70% Acrylic, 30% Wool (Merinos)	sweater	W		DS	IT	Bangladesh	
T009		50% Wool, 50% Acrylic	sweater	W		OAM	IT	China	
T010		55% Wool, 45% Acrylic	sweater	M		OAM	IT	Imported	
T011		100% Cotton	sweater	M		OAM	IT	Imported	
T012		50% Wool, 50% Acrylic	sweater	W		OAM	IT	China	
T013		70% Wool, 22% PA, 8% Elastane	sweater	W		OAM	IT	Imported	
T014		70% Wool, 22% PA, 8% Elastane	sweater	W		OAM	IT	Imported	
T015		70% Wool, 30% Acrylic	sweater	W		S	IT	China	
T016		90% Wool, 10% Elastane	sweater	W		S	IT	China	
T017		90% Wool, 10% Elastane	sweater	W		S	IT	China	
T018		90% Wool, 10% Elastane	sweater	W		S	IT	China	
T019		100% Cotton	sweater	M		DS	IT	Turkey	
T020		100% Cotton	sweater	M		DS	IT	Bangladesh	

JRC Code	Picture	Declared Composition	Description	Target	Printed Fabric	Source	Purchase Country	Production Country	Easy Care Oeko Tex
T021		100% Cotton	trousers	M		DS	IT	Bangladesh	
T022		70% Acrylic, 30% Wool	sweater	W		DS	IT	Thailandia	
T023		97% Cotton, 3% Elastane	trousers	W		S	IT	Imported	
T024		80% Wool, 20% PA	sweater	W		DS	IT	China	
T025		60% Wool, 35% Acrylic, 5% Elastane	sweater	W		S	IT	Imported	
T026		80% Wool, 15% Viscose, 5% Elastane	sweater	W		S	IT	China	
T027		80% Wool, 20% Viscose	sweater	W		S	IT	Imported	
T028		50% Wool, 30% Angora, 20% Elastane	sweater	W		S	IT	China	
T029		70% Wool, 30% PA	sweater	W		S	IT	China	
T030		50% Acrylic, 40% Wool, 10% Elastane	sweater	W		S	IT	China	
T031		65% PES, 35% Cotton	hat	B 24 m	Yes	DS	IT	China	
T032		100% Cotton	hat	B 24 m	Yes	DS	IT	China	
T033		100% Cotton	T-shirt	B 24 m		DS	IT	Bangladesh	
T034		100% Cotton	T-shirt	C 5-6 y		DS	IT	Imported	
T035		100% Cotton	T-shirt	B 12 m		DS	IT	Bangladesh	
T036		59% Cotton, 40% PES, 1% Elastane	shirt	B 18 m		DS	IT	China	
T037		100% Cotton	trousers	C 3-7 y	Yes	DS	IT	China	
T038		100% Cotton	dress	C 3 y		DS	IT	China	
T039		100% Cotton	trousers	C 8 y		DS	IT	China	
T040		100% Cotton	pyjama	B 12 m		DS	IT	India	
T041		100% Cotton	T-shirt	C 3 y		DS	IT	Bangladesh	

JRC Code	Picture	Declared Composition	Description	Target	Printed Fabric	Source	Purchase Country	Production Country	Easy Care Oeko Tex
T042		100% Cotton	trousers	B 18 m		DS	IT	China	
T043		80% Cotton, 15% PA, 5% Elastane	socks	C 6-8 y		DS	IT	Syria	
T044		80% Cotton, 15% PA, 5% Elastane	socks	C 6-8 y		DS	IT	Syria	
T045		80% Cotton, 15% PA, 5% Elastane	socks	C 6-8 y		DS	IT	Syria	
T046		80% Cotton, 15% PA, 5% Elastane	socks	C 6-8 y		DS	IT	Imported	
T047		80% Cotton, 15% PA, 5% Elastane	socks	C 6-8 y		DS	IT	Imported	
T048		80% Cotton, 15% PA, 5% Elastane	socks	C 6-8 y		DS	IT	Imported	
T049		100% Cotton	pyjama	B 24 m	Yes	DS	IT	India	
T050		80% Cotton, 20% PES	trousers	B 12 m	Yes	DS	IT	China	
T051		80% Cotton, 20% PES	sweater	B 12 m	Yes	DS	IT	China	
T052		75% Cotton, 23% PA, 2% Elastane	socks	W		DS	IT	China	
T053		100% Cotton	trousers	M		DS	IT	Imported	
T054		100% Cotton	T-shirt	M		DS	IT	Bangladesh	
T055		100% Cotton	trousers	M		DS	IT	Bangladesh	
T056		100% Cotton	slip	M	Yes	DS	IT	China	
T058		100% Cotton	slip	M	Yes	DS	IT	China	
T060		100% Cotton	sofa cushion cover	EB		DS	IT	India	
T061		100% Cotton	sofa cushion cover	EB		DS	IT	India	
T062		35% Cotton, 65% PES	shirt	M	Yes	DS	IT	Imported	
T063		100% Cotton	pyjama	W		DS	IT	India	
T064		65% PES, 35% Cotton	shirt	M		DS	IT	Bangladesh	

JRC Code	Picture	Declared Composition	Description	Target	Printed Fabric	Source	Purchase Country	Production Country	Easy Care Oeko Tex
T065		65% PES, 35% Cotton	shirt	M		DS	IT	China	
T066		65% PES, 35% Cotton	shirt	W		DS	IT	Bangladesh	
T067		100% Cotton	T-shirt	M		DS	IT	Bangladesh	
T068		100% Cotton	trousers	W		DS	IT	Bangladesh	
T069		100% Cotton	pyjama	W	Yes	DS	IT	China	
T070		100% Cotton	T-shirt	W		DS	IT	Bangladesh	
T071		100% Cotton	sweater	W		DS	IT	Imported	
T072		100% Cotton	towel	EB		DS	IT	Pakistan	
T073		100% Cotton	T-shirt	W		DS	IT	Turkey	
T074		100% Cotton	T-shirt	W		DS	IT	Imported	
T075		100% Cotton	pyjama	W	Yes	DS	IT	China	
T076		95% Cotton, 5% Elastane	socks	M		S	IT	Italy	
T077		84% Cotton, 16% PA	socks	B 24 m		S	IT	Italy	
T078		84% Cotton, 16% PA	socks	C 3 y		S	IT	Italy	
T079		95% Cotton, 5% Elastane	socks	W		S	IT	Italy	
T080		75% Cotton, 20% PA, 5% Elastane	socks	W		OAM	BE	Not Known	
T081		85% Cotton, 15% PES	T-shirt	C 10 y	Yes	OAM	IT	China	
T082		65% Cotton, 35% PES	T-shirt	C 6 y	Yes	OAM	IT	Imported	
T083		80% Acrylic, 20% PA	socks	W		OAM	BE	Not Known	
T084		100% Cotton	trousers	C 8 y	Yes	OAM	IT	China	
T085		80% Cotton, 20% PES	trousers	W		OAM	IT	China	

JRC Code	Picture	Declared Composition	Description	Target	Printed Fabric	Source	Purchase Country	Production Country	Easy Care Oeko Tex
T086		95% Viscose, 5% Elastane	T-shirt	W		OAM	IT	Italy	
T087		100% Cotton	pyjama	B 24 m	Yes	OAM	BE	Not Known	
T088		100% Cotton	T-shirt	C 6 y	Yes	OAM	BE	Not Known	
T089		100% Cotton	T-shirt	C 5 y		OAM	BE	Not Known	
T090		55% Viscose, 45% Linen	trousers	W		OAM	BE	Europe	
T091		100% Cotton	rompers	B 6 m	Yes	OAM	IT	Italy	
T092		100% Cotton	rompers	B 6 m	Yes	S	IT	Not Known	
T093		80% Cotton, 16% PA, 4% Elastane	slip	C 12-14 y	Yes	OAM	BE	Spain	
T094		100% Cotton	pyjama	B 18-24 m	Yes	S	IT	Italy	
T095		written in chinese	socks	B 12 m		S	SK	China	
T096		65% Cotton, 35% PES	T-shirt	B 18 m	Yes	S	SK	Not Known	
T097		82% Cotton, 14% PA, 3% PES, 1% Elastane	socks	B 18 m		S	SK	Not Known	
T098		100% Cotton	rompers	B 9-12 m	Yes	S	SK	Not Known	
T099		65% Cotton, 35% PES	shirt	W		S	SK	Vietnam	
T100		100% Cotton	T-shirt	W		S	IE	Romania	
T101		55% Cotton, 45% PES	shirt	M		S	IE	Bangladesh	
T102		100% Cotton	T-shirt	M		S	LT	Lithuania	
T103		100% Cotton	T-shirt	M	Yes	S	LT	Lithuania	
T104		100% Cotton	T-shirt	M	Yes	S	LT	China	
T105		100% Cotton	rompers	B 6 m	Yes	S	LT	China	
T106		100% Cotton	shirt	M	Yes	S	LT	Germany	

JRC Code	Picture	Declared Composition	Description	Target	Printed Fabric	Source	Purchase Country	Production Country	Easy Care Oeko Tex
T107		100% Cotton	rompers	B 6 m	Yes	S	PL	Poland	
T108		100% Cotton	T-shirt	W	Yes	S	PL	Turkey	
T109		100% Cotton	infant romper	B 6 m	Yes	S	PL	Poland	
T110		100% Cotton	sofa cushion cover	EB		S	PL	Poland	
T111		100% Cotton	T-shirt	M	Yes	S	PL	Poland	
T112		100% Cotton	shirt	M		S	FR	Not Known	EC
T113		100% Cotton	rompers	B 6 m	Yes	DS	FR	Tunisia	
T114		77% Cotton , 23% PES	rompers	B 12 m	Yes	DS	FR	France	
T115		100% Cotton	shirt	M		DS	FR	Turkey	
T116		100% Cotton	sofa cushion cover	EB		DS	FR	Not Known	
T117		93% Cotton, 7% Elastane	T-shirt	W	Yes	S	FR	Turkey	
T118		100% Cotton	pyjama	B 24 m	Yes	S	UK	Indonesia	
T119		42% PES, 31% Acrylic, 27% Cotton	sofa cushion cover	EB		S	UK	United Kingdon	
T120		100% Cotton	shirt	M	Yes	S	UK	Portugal	
T121		100% Cotton	T-shirt	W	Yes	S	UK	Turkey	
T122		100% Cotton	rompers	B 6 m	Yes	S	UK	Egypt	
T123		100% Cotton	T-shirt	M		S	EL	Greece	
T124		100% Cotton	pyjama	B 12 m	Yes	S	EL	Greece	
T125		50% Cotton, 50% PES	rompers	B 9 m	Yes	S	EL	Europe	
T126		100% Cotton	shirt	M		S	EL	Not Known	
T127		100% Cotton	sofa cushion cover	EB		S	BE	India	

JRC Code	Picture	Declared Composition	Description	Target	Printed Fabric	Source	Purchase Country	Production Country	Easy Care Oeko Tex
T128		100% Cotton	shirt	M		S	BE	Slovakia	OT / EC
T129		100% Cotton	pyjama	B 18 m	Yes	S	EE	Estonia	
T130		100% Cotton	rompers	B 3 m		S	EE	Estonia	
T131		65% Cotton, 35% PES	shirt	M		S	EE	Turkey	
T132		100% Cotton	T-shirt	W	Yes	S	EE	Estonia	
T133		100% Cotton	bedding pillowcase	EB		S	EE	India	OT
T134		100% Cotton	rompers	B 18 m	Yes	S	PT	China	
T135		100% Cotton	sofa cushion cover	EB		S	PT	India	
T136		100% Cotton	T-shirt	M	Yes	DS	PT	Italy	
T137		100% Cotton	shirt	W	Yes	DS	PT	China	
T138		100% Cotton	dress	B 12 m	Yes	S	PT	Spain	
T139		100% Cotton	pyjama	C 3 y	Yes	DS	CZ	Czeck rep.	
T140		100% Cotton	T-shirt	M	Yes	DS	CZ	Europe	
T141		75% Cotton, 25% Acrylic	rompers	B 3 m	Yes	DS	CZ	Czeck rep.	
T142		100% Cotton	shirt	M		DS	CZ	Not Known	
T143		100% Cotton	bedding pillowcase	EB	Yes	DS	CZ	Not Known	OT
T144		100% Cotton	shirt	M		DS	DE	Germany	
T145		100% Cotton	shirt	M		DS	DE	Not Known	EC
T146		100% Cotton	shirt	M		DS	DE	Slovakia	OT
T147		100% Cotton	shirt	M		DS	DE	Not Known	
T148		100% Cotton	shirt	M		DS	DE	Not Known	EC

JRC Code	Picture	Declared Composition	Description	Target	Printed Fabric	Source	Purchase Country	Production Country	Easy Care Oeko Tex
T149		100% Cotton	rompers	B 6 m	Yes	S	DE	Netherland	
T150		100% Cotton	rompers	B 9 m	Yes	S	DE	Germany	
T151		100% Cotton	sofa cushion cover	EB		S	DE	Germany	
T152		100% Cotton	shirt	W		S	DE	Not Known	
T153		100% Cotton	T-shirt	W	Yes	S	DE	Bangladesh	
T154		100% Cotton	T-shirt	W	Yes	S	AT	Germany	
T155		100% Cotton	rompers	B 6 m	Yes	DS	AT	Turkey	
T156		100% Cotton	rompers	B 1 m		DS	AT	China	
T157		100% Cotton	shirt	M		S	AT	Europe	
T158		100% Cotton	sofa cushion cover	EB		S	AT	India	
T159		100% Cotton	shirt	W	Yes	S	ES	Imported	
T160		67% PES, 33% Cotton	pyjama	C 4 y	Yes	S	ES	Spain	
T161		100% Cotton	rompers	C 3 y		S	ES	Not Known	
T162		100% Cotton	shirt	M		S	SK	Slovakia	
T163		100% Cotton	sofa cushion cover	EB	Yes	S	SK	Not Known	
T164		100% Cotton	T-shirt	M		DS	FR	China	
T165		100% Cotton	rompers	B 1 m	Yes	DS	FR	China	
T166		100% Cotton	shirt	M		S	FR	Turkey	EC
T167		100% Cotton	sofa cushion cover	EB		DS	FR	France	
T168		65% Cotton, 35% PES	rompers	B 1 m		DS	LU	Not Known	
T169		100% Cotton	pyjama	C 4 y	Yes	DS	LU	Not Known	

JRC Code	Picture	Declared Composition	Description	Target	Printed Fabric	Source	Purchase Country	Production Country	Easy Care Oeko Tex
T170		100% Cotton	shirt	M		DS	LU	Not Known	EC
T171		100% Cotton	T-shirt	M		DS	LU	Not Known	
T175		100% Cotton	trousers	C 4 y		DS	IT	Not Known	
T177		100% Cotton	trousers	C 8 y		DS	IT	Imported	
T183		100% Cotton	shirt	M		DS	IT	Bangladesh	
T185		98% Cotton, 2% Lycra	T-shirt	M		S	CY	China	
T186		100% Cupro	shirt	M		S	CY	Not Known	
T187		35% Cotton, 65% PES	shirt	M		S	CY	Not Known	EC
T188		35% Cotton, 65% PES	shirt	M		S	CY	Not Known	EC
T189		100% Wool	trousers	M		S	CZ	Not Known	
T197		100% Cotton	T-shirt	B 18 m	Yes	S	UK	China	
T198		100% Cotton	shirt	M		S	UK	Morocco	
T199		100% Cotton	T-shirt	W	Yes	S	UK	UnitedArabianEmirates	
T200		70% Lambwool, 20% Angora, 10% PA	sweater	W		S	UK	China	
T201		53% PES, 45% Wool, 2% Elastane	trousers	W		DS	UK	China	
T202		77% Cotton, 23% PES	T-shirt	B 9-12 m		S	UK	China	
T205		100% Cotton	T-shirt	C 11-12 y		DS	DK	Not Known	
T206		100% Cotton	shirt	M		DS	DK	Turkey	
T207		100% Wool	trousers	W		S	DK	Not Known	
T208		80% Wool, 20% PA	sweater	W		DS	DK	Italy	
T209		95% Cotton, 5% Elastane	T-shirt	W	Yes	DS	DK	Turkey	

JRC Code	Picture	Declared Composition	Description	Target	Printed Fabric	Source	Purchase Country	Production Country	Easy Care Oeko Tex
T212		100% Cotton	rompers	B 1 m		S	HU	China	
T214		50% Acrylic, 40% Wool, 10% Viscose	sweater	M		S	HU	Europe	
T215		60% Wool, 40% PES	trousers	M		S	HU	Europe	
T217		80% Cotton, 20% PES	trousers	B 3-6 m	Yes	DS	PT	Portugal	
T218		92% Cotton, 8% Elastane	T-shirt	W	Yes	S	PT	Spain	
T219		66% Wool, 30% PES, 4% other fibers	trousers	W		DS	PT	Spain	
T220		55% Silk, 45% Cashmere	sweater	W		DS	PT	China	
T221		100% Cotton	shirt	M		S	PT	Spain	EC
T224		80% Cotton, 20% PA	rompers	B 3 m		OAM	NL	Not Known	
T226		100% Cotton	underware	M	Yes	OAM	NL	Not Known	
T228		100% Cotton	underware	M	Yes	OAM	NL	Not Known	
T229		100% Cotton	shirt	M		S	NL	Not Known	
T230		65% PES, 35% Cotton	shirt	M		S	NL	Not Known	
T231		100% Cotton	dress	C 4-6 y		S	NL	Not Known	
T232		35% Cotton, 65% PES	shirt	M		DS	IE	Outside Europe	
T233		100% Cotton	T-shirt	M	Yes	DS	IE	China	
T234		30% Mohar, 10% Wool, 60% Acrylic	sweater	W		S	IE	Italy	
T235		98% Wool, 2% Elastane	trousers	W		S	IE	Romania	
T239		44% PES, 42% Cotton, 14% Viscose	shirt	W		S	PL	Poland	
T241		80% Cotton, 20% Viscose	rompers	B 3 m	Yes	S	PL	Turkey	
T243		Wool-PES	trousers	W		S	PL	Poland	

JRC Code	Picture	Declared Composition	Description	Target	Printed Fabric	Source	Purchase Country	Production Country	Easy Care Oeko Tex
T244		80% Acrylic, 20% Wool	sweater	W		S	PL	Poland	
T245		97% Cotton, 3% Elastane	trousers	C 4 y		S	LT	Not Known	
T246		100% Cotton	T-shirt	W		S	LT	Lithuania	
T247		100% Wool	trousers	W		S	LT	Not Known	
T249		80% Wool, 20% PA	sweater	M		S	LT	Not Known	
T250		55% Cotton, 45% PES	shirt	M		S	LT	Not Known	
T252		100% Cotton	pyjama	W	Yes	S	LT	Not Known	
T253		80% Cotton, 20% Viscose	rompers	B 3 m		S	LV	Turkey	
T255		100% Cotton	shirt	M		S	LV	Germany	EC
T256		80% Wool, 20% Acrylic	sweater	M		S	LV	Oman	
T257		100% Wool	trousers	M		S	LV	Russia	
T258		100% Cotton	T-shirt	M	Yes	S	LV	Latvia	

Table 2: Released formaldehyde by methods EN ISO 14184-1 and EN ISO 14184-2.

	water extraction	vapour absorption		water extraction	vapour absorption
JRC code	[HCHO] mg/kg	[HCHO] mg/kg	JRC code	[HCHO] mg/kg	[HCHO] mg/kg
T001	4.0 ± 0.8	ND	**T114**	8.8 ± 5.3	
T002	14.0 ± 2.4	ND	**T115**	18.1 ± 1.0	
T003	4.7 ± 1.9	ND	**T116**	15.0 ± 7.1	
T004	8.1 ± 2.5	0.5 ± 0.9	**T117**	7.0 ± 4.2	
T005	1.0 ± 0.7	0.8 ± 1.1	**T118**	10.2 ± 0.8	
T006	6.4 ± 0.6	1.3 ± 0.8	**T119**	5.4 ± 0.2	
T007	11.7 ± 1.5	0.8 ± 0.7	**T120**	14.6 ± 3.8	
T008	3.1 ± 2.5	1.1 ± 0.7	**T121**	162.5 ± 9.3	318.2 ± 15.4
T009	4.1 ± 2.3	0.5 ± 0.7	**T122**	4.9 ± 1.4	
T010	8.1 ± 2.8	2.5 ± 0.7	**T123**	4.9 ± 2.3	
T011	3.5 ± 0.6	1.8 ± 0.8	**T124**	12.4 ± 3.0	
T012	17.1 ± 2.6	1.6 ± 1.2	**T125**	7.2 ± 1.6	
T013	6.7 ± 3.0	0.4 ± 1.9	**T126**	5.6 ± 0.8	
T014	11.3 ± 1.0	0.7 ± 0.7	**T127**	33.7 ± 7.3	7.6 ± 0.9
T015	12.7 ± 7.3	1.2 ± 0.5	**T128**	27.4 ± 3.6	55.2 ± 8.1
T016	18.2 ± 7.1	0.9 ± 0.9	**T129**	6.1 ± 1.7	
T017	4.7 ± 0.6	1.7 ± 0.4	**T130**	5.2 ± 3.2	
T018	5.5 ± 3.3	1.1 ± 0.0	**T131**	6.6 ± 1.2	
T019	19.4 ± 2.3	22.9 ± 2.8	**T132**	5.8 ± 1.5	
T020	8.1 ± 2.6	4.5 ± 1.0	**T133**	25.3 ± 0.7	40.7 ± 11.5
T021	5.7 ± 0.6	2.2 ± 0.5	**T134**	10.8 ± 3.1	
T022	3.0 ± 1.3	6.6 ± 2.0	**T135**	20.0 ± 4.7	24.2 ± 1.8
T023	5.3 ± 10.4	2.6 ± 0.5	**T136**	17.3 ± 6.0	
T024	31.4 ± 8.0	12.1 ± 0.9	**T137**	6.4 ± 1.3	
T025	23.0 ± 1.9	7.8 ± 0.8	**T138**	16.6 ± 1.0	
T026	33.4 ± 0.6	0.9 ± 0.5	**T139**	14.8 ± 3.0	
T027	12.1 ± 2.4	1.0 ± 0.6	**T140**	20.7 ± 13.0	ND
T028	24.1 ± 0.9	9.6 ± 2.1	**T141**	9.2 ± 1.0	
T029	20.7 ± 1.8	1.2 ± 5.4	**T142**	18.1 ± 10.5	
T030	23.1 ± 1.4	5.1 ± 2.3	**T143**	18.6 ± 4.5	
T031	10.9 ± 1.9		**T144**	38.7 ± 7.1	129.8 ± 25.7
T032	3.3 ± 1.4		**T145**	12.9 ± 4.9	
T033	7.5 ± 10.2	3.6 ± 0.7	**T146**	54.1 ± 0.9	176.5 ± 6.7
T034	3.1 ± 0.3	4.8 ± 7.1	**T147**	16.8 ± 2.5	
T035	8.2 ± 8.9	3.0 ± 0.9	**T148**	65.0 ± 5.7	141.8 ± 25.3
T036	7.2 ± 3.6	2.0 ± 0.7	**T149**	7.1 ± 2.0	
T037	2.0 ± 4.1	1.5 ± 0.8	**T150**	8.9 ± 0.6	
T038	6.3 ± 0.4	2.7 ± 1.6	**T151**	26.1 ± 7.5	31.1 ± 0.5
T039	9.7 ± 4.0	3.2 ± 0.6	**T152**	18.6 ± 0.0	
T040	17.8 ± 4.2	91.5 ± 35.1	**T153**	6.4 ± 0.8	
T041	9.3 ± 1.6	10.9 ± 0.7	**T154**	7.8 ± 0.8	
T042	1.3 ± 0.1	2.1 ± 0.7	**T155**	6.0 ± 1.4	
T043	2.9 ± 11.1	0.5 ± 0.8	**T156**	6.3 ± 2.6	
T044	4.6 ± 1.3		**T157**	15.2 ± 1.7	
T045	12.2 ± 5.8	0.6 ± 0.7	**T158**	15.4 ± 7.6	
T046	14.6 ± 2.6		**T159**	22.6 ± 4.4	5.9 ± 0.7
T047	3.3 ± 2.4	3.4 ± 0.7	**T160**	11.9 ± 2.1	
T048	2.4 ± 0.2	3.9 ± 0.3	**T161**	12.5 ± 3.4	
T049	2.7 ± 0.2	5.5 ± 0.2	**T162**	36.4 ± 2.0	68.4 ± 8.1
T050	4.3 ± 1.1	2.1 ± 2.6	**T163**	22.2 ± 3.1	9.4 ± 1.7
T051	22.8 ± 5.1	2.3 ± 1.0	**T164**	4.5 ± 2.0	
T052	5.7 ± 2.1	4.9 ± 1.5	**T165**	6.8 ± 1.1	
T053	1.9 ± 0.3	2.1 ± 4.3	**T166**	3.2 ± 0.5	

	water extraction	vapour absorption		water extraction	vapour absorption
JRC code	[HCHO] mg/kg	[HCHO] mg/kg	JRC code	[HCHO] mg/kg	[HCHO] mg/kg
T054	6.9 ± 0.6	7.0 ± 1.9	**T167**	7.0 ± 1.5	
T055	9.9 ± 1.7	4.1 ± 3.0	**T168**	4.0 ± 2.1	
T056	8.3 ± 1.2	23.6 ± 3.3	**T169**	6.9 ± 3.4	
T058	9.0 ± 1.3	11.8 ± 3.4	**T170**	4.1 ± 0.7	
T060	4.1 ± 4.8	2.0 ± 1.5	**T171**	43.8 ± 1.0	88.7 ± 13.9
T061	12.2 ± 4.8	2.4 ± 0.6	**T175**	3.5 ± 1.5	
T062	25.7 ± 7.1	24.8 ± 1.1	**T177**	5.2 ± 5.3	
T063	7.3 ± 1.8	6.1 ± 0.9	**T183**	11.4 ± 4.6	
T064	14.4 ± 8.9	5.1 ± 0.9	**T185**	7.5 ± 5.6	
T065	13.9 ± 5.1	10.1 ± 6.1	**T186**	3.4 ± 0.2	
T066	8.2 ± 1.4	48.9 ± 4.5	**T187**	27.9 ± 8.8	71.7 ± 8.9
T067	50.7 ± 2.3	174.4 ± 39.3	**T188**	105.2 ± 6.4	397.3 ± 27.7
T068	11.5 ± 5.2	7.6 ± 2.2	**T189**	15.2 ± 0.8	
T069	11.2 ± 0.5	17.5 ± 0.2	**T197**	11.2 ± 6.3	
T070	6.3 ± 2.2	3.6 ± 0.5	**T198**	24.2 ± 1.9	74.1 ± 12.5
T071	14.2 ± 1.9	4.7 ± 1.0	**T199**	7.7 ± 3.2	
T072	12.0 ± 10.1	3.8 ± 1.4	**T200**	10.2 ± 0.3	
T073	7.2 ± 1.7	2.9 ± 1.0	**T201**	25.8 ± 0.9	ND
T074	34.2 ± 2.6	8.8 ± 0.9	**T202**	21.9 ± 1.5	6.7 ± 2.3
T075	8.7 ± 0.6	11.6 ± 2.0	**T205 A**	3.9 ± 0.8	
T076	9.6 ± 7.6	4.4 ± 4.0	**T205 B**	3.7 ± 0.7	
T077	6.8 ± 0.9	3.8 ± 1.1	**T206**	15.4 ± 0.4	
T078	1.7 ± 8.7	3.1 ± 0.7	**T207**	39.0 ± 6.8	31.4 ± 9.3
T079	4.5 ± 0.8	4.0 ± 1.1	**T208 A**	12.0 ± 1.0	
T080	11.1 ± 3.0	2.8 ± 0.5	**T208 B**	14.3 ± 5.6	
T081	8.4 ± 0.3	34.1 ± 2.4	**T209 A**	20.2 ± 1.8	168.0 ± 59.0
T082	17.9 ± 3.2	57.3 ± 11.4	**T209 B**	26.5 ± 3.7	
T083	9.7 ± 3.6	2.9 ± 0.4	**T212**	16.7 ± 2.8	
T084	9.2 ± 0.9	10.9 ± 2.9	**T214**	27.5 ± 2.4	9.3 ± 1.4
T085	2.4 ± 1.2	1.9 ± 0.8	**T215**	32.0 ± 8.3	16.4 ± 3.8
T086	10.9 ± 0.7	10.9 ± 6.2	**T217A**	13.7 ± 3.8	
T087	8.5 ± 0.8	5.2 ± 1.6	**T217B**	14.4 ± 2.4	
T088(nodraw)	11.5 ± 1.7 (2)	11.6 ± 0.4	**T218**	15.6 ± 3.4	
T088(onlydraw)	13.9 ± 0.1 (2)		**T219**	51.0 ± 4.7	14.5 ± 2.8
T088(mix)	12.3 ± 0.3 (2)		**T220**	30.4 ± 4.4	8.6 ± 0.3
T089	9.4 ± 1.2	3.7 ± 0.3	**T221**	66.2 ± 2.1	175.7 ± 34.7
T090	18.6 ± 1.7	5.6 ± 1.2	**T224**	10.3 ± 1.3	
T091	75.4 ± 2.6	233.5 ± 18.3	**T226**	55.2 ± 1.5	129.2± 25.8
T092(mix)	47.7 ± 22.0	10.6 ± 4.4	**T228**	29.0 ± 3.5	6.8 ± 1.3
T092(nodraw)	8.2 ± 3.2 (2)	7.2 ± 2.3	**T229**	12.9 ± 0.2	
T092(onlydra)	27.5 ± 106.6 (2)		**T230**	28.7 ± 1.9	22.9 ± 1.0
T093	23.5 ± 1.8	2.6 ± 0.9	**T231**	3.7 ± 0.4	
T094	22.0 ± 2.6	30.6 ± 7.4	**T232**	33.1 ± 3.1	96.8 ± 3.1
T095	2.6 ± 0.1	0.7 ± 1.1	**T233**	8.9 ± 4.4	
T096	2.2 ± 1.1	4.3 ± 3.5	**T234**	15.4 ± 2.9	
T097	5.5 ± 6.0	1.8 ± 2.3	**T235**	19.6 ± 1.5	
T098	5.7 ± 0.6	6.2 ± 1.7	**T239**	21.4 ± 0.7	60.9 ± 12.2
T099	3.1 ± 0.5	3.5 ± 2.4	**T241**	4.0 ± 1.2	
T100	5.7 ± 8.6		**T243**	14.3 ± 2.3	
T101	17.2 ± 25.8		**T244**	4.0 ± 2.9	
T102	14.3 ± 1.8		**T245**	4.1 ± 2.4	
T103	14.1 ± 1.7		**T246**	3.8 ± 0.7	
T104	6.2 ± 5.5		**T247**	6.1 ± 1.3	
T105	1.8 ± 2.7		**T249**	19.3 ± 1.3	
T106	4.3 ± 3.7		**T250**	6.7 ± 1.5	

	water extraction	vapour absorption		water extraction	vapour absorption
JRC code	[HCHO] mg/kg	[HCHO] mg/kg	JRC code	[HCHO] mg/kg	[HCHO] mg/kg
T107	8.9 ± 1.0		**T252**	6.3 ± 2.8	
T108	7.6 ± 1.1		**T253**	3.9 ± 1.0	
T109	8.3 ± 2.5		**T255**	108.8 ± 3.1	198.7 ± 20.4
T110	7.5 ± 1.6		**T256**	2.3 ± 0.3	
T111	10.7 ± 0.7		**T257**	9.1 ± 0.5	
T112	95.3 ± 1.4	314.9 ± 22.2	**T258**	21.7 ± 0.7	30.0 ± 3.0
T113	8.8 ± 2.3				

European Commission

EUR 22710 EN
Directorate General Joint Research Centre
Institute for Health and Consumer Protection
Title: European survey on the release of formaldehyde from textiles
Authors: P. Piccinini, C. Senaldi, C. Summa
Luxembourg: Office for Official Publications of the European Communities
2007 – 54 pp. – 21.0 x 29.7 cm
EUR - Scientific and Technical Research series; ISSN 1018-5593
ISBN 978-92-79-05215-6

Abstract

A European survey on the level of formaldehyde released from textiles, in particular textile clothing, produced all over the world was performed. The selection of fabrics was planned among textile products that are supposed to contain formaldehyde, in order to cover as many different types of fibres and type of garments as possible. The whole population was considered as target. Samples were bought in 21 Member States of the European Union, from different sources, with different compositions and various production countries or areas. Part of them was printed and some were “easy care” or Oeko-Tex labelled. A total of 221 samples were analysed with standard method EN ISO 14184-1 (water extraction) and 127 with standard method EN ISO 14184-2 (vapour absorption). Measurements were performed in triplicate and uncertainties were calculated at 95 % of probability.

In the case of the water extraction method, 11% of samples intended to be in direct contact with skin released over 30 mg/kg, which is the limit established by the voluntary labelling scheme Ecolabel (Commission Decision 2002/371/EC). About 3% released more than 75 mg/kg, which is the limit set by the private voluntary labelling scheme Oeko-Tex Standard 100. In the case of babies under the age of two, 11% of garments released more than 20 mg/kg of formaldehyde, which is the Oeko-Tex Standard 100 limit for babies. The sample manufacturing area (Europe, China, rest of the world) and the purchase sources (shops, department stores and open air markets) do not seem to influence the results. Shirts seem to be the garment category with the highest risk of exceeding the limit of 30 mg/kg (22% of them). Moreover, five out of ten “easy care” labelled shirts exceeded the Ecolabel limit. Similarly, pure cotton and mixtures containing wool seem to release more formaldehyde than garments made of mixtures containing cotton and other fibres.

Considering the vapour absorption method, 22% of samples released more than 30 mg/kg of formaldehyde and 12% more than 75 mg/kg, 397 mg/kg being the highest measured value. Results obtained with the two standard methods were usually in the same range for low levels of formaldehyde; however for releases of over 30 mg/kg, the vapour absorption method gives constantly higher results than the water extraction method.

The influence of domestic washing was investigated. It effectively reduces the level of released formaldehyde. After the first washing cycle with the water extraction method, the level of formaldehyde was reduced to 10% of the initial value and decreased to 60% in the case of the vapour absorption method.

A new method was developed, which mimic the real conditions of use of garments better than the standard method EN ISO 14184-1. Artificial perspiration solutions (acid and basic sweat), washing machine, generally used to determine colour fastness, and stainless steel balls were used to increase the rubbing effect and to better reproduce the real conditions of direct skin-textile contact. The release of formaldehyde was maximised with this newly developed method.

Following the recommendations of the Technical Guidance Document, release data were used to estimate the dermal exposure of an adult and a child. The maximum estimated dermal uptakes were 1.7 and 4.5 mg/kg bw for an adult and a child respectively, with calculation based on data obtained with the modified method. The maximum estimated dermal uptakes calculated based on data obtained with the standard method EN ISO 14184-1 were 1.2 and 3.1 mg/kg bw for an adult and a child respectively.

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

LB-NA-22710-EN-C

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

ISBN 978-92-79-05215-6

Publications Office
Publications.eu.int