

Review Article

Does allergic contact dermatitis from formaldehyde in clothes treated with durable-press chemical finishes exist in the USA?

ANTON C DE GROOT¹ AND HOWARD I. MAIBACH²

¹Schipslootweg 5, 8351 HV Wapserveen, The Netherlands, ²Department of Dermatology, School of Medicine, University of California San Francisco, San Francisco, CA, USA

Recent US studies have presented case series of patient with allergic contact dermatitis (ACD) allegedly caused by formaldehyde in clothes treated with durable-press chemical finishes (DPCF), which are known formaldehyde releasers. However, the amounts of formaldehyde released by modern DPCF are thought to be well below the levels previously estimated to be able to elicit ACD. The objectives of this review are (i) to investigate whether clothes sold in the USA may contain enough free formaldehyde to elicit ACD in previously sensitized individuals and (ii) to assess the validity of US reports on ACD from formaldehyde in DPCF treated clothes. Literature was examined using various resources.

The threshold level for formaldehyde in clothes that may cause ACD in sensitized individuals is unknown; we present data suggesting that levels <200 ppm will be safe for most patients and that textiles will rarely contain higher amounts. All US studies presenting patients with ACD from formaldehyde in clothes had some weaknesses and in no report was the diagnosis proven beyond doubt. Currently, there is no definite proof that textile ACD from formaldehyde in DPCF in the USA exists. Future research should be directed at establishing the elicitation threshold and the amounts of formaldehyde present in textiles.

Key words: allergic contact dermatitis; clothes; durable-press chemical finish; formaldehyde.

© John Wiley & Sons A/S, 2009.

Accepted for publication 2 April 2009

Durable-press chemical finishes (DPCF)* have been used in the clothing industry since the mid-1920s to make cotton and cotton/polyester blend fabrics wrinkle-resistant during wear and laundering. The early chemical finishes based on the condensation product of urea or melamine with formaldehyde contained high amounts of free formaldehyde; 5000–12 000 µg/g (= mg/kg, often – and also in this article – indicated as parts per million = ppm) have been reported in rayon and cotton textiles (1). In the 1950s and 1960s, many cases of allergic contact dermatitis (ACD) from formaldehyde in textiles were reported. Most came from Scandinavia; only a few described US patients with formaldehyde textile

dermatitis. Some affected individuals were sensitized to formaldehyde from other sources (in Scandinavia notably formaldehyde-based antiperspirants), but in many the clothes themselves were considered the cause of sensitization (2).

Since the 1960s textile manufacturers have increasingly moved to the use of finishes with lower levels of formaldehyde such as dimethylol dihydroxyethyleneurea (DMDHEU). By 1981 the industry claimed that the average level contained by textiles made in the US was approximately 100–200 ppm free formaldehyde (3). In the last 25 years, the use of modified DMDHEU (e.g. methylated or glycolated DMDHEU) should have lowered formaldehyde amounts further. These values are well below the levels of 500–750 ppm estimated to be able to elicit ACD in patients allergic to formaldehyde (4, 5). Despite this, several case series of US

*Synonyms used in literature include: formaldehyde-releasing permanent-press finishes, formaldehyde textile resins, textile finish resins, durable-press resins, permanent-press clothing finishes.

patients suffering from ACD to formaldehyde in textiles have recently been published (6–10), and several authors have suggested that textile ACD from finishes is *underreported* (6, 7, 8, 11). This apparent contradiction prompted us to review the subject critically. ACD from DPCF in clothes in US patients: is it underreported and does it exist?[†]

US Reports of Textile Dermatitis from Formaldehyde and DPCF

Case series

In the last 16 years, five US clinical studies have addressed the issue of ACD from formaldehyde and DPCF in textiles (6–10). The results are shown in Tables 1 (general data) and 2 (patch test results). Only one study has been prospective, a study of repeat patch testing in 10 patients previously known to be patch test positive to DPCF (10). Routine testing in consecutive patients with a series of finishes was performed in one study (8), in another, unselected patients were tested only with ethylene urea, melamine/formaldehyde (6). In the others the selection for testing one or more finishes was based on clinical suspicion of textile dermatitis or the selection process was not specified. The diagnosis in two studies was based on the finding of one or more positive patch tests (6, 8), in two others on the basis of positive patch tests in combination with the clinical picture (7, 9). The results of avoidance of the sensitizer (removal of suspected clothing or general advice on safe type of garments) were not specified in two studies, and in two others 'most' or 'a significant proportion' were said to have improved.

The prevalence rate of 'textile dermatitis' (or at least one or more positive patch test reactions to DPCF) in Fowler's, study was 1.2% (8). Carlson et al. had 2% positive patch test reactions to ethylene urea, melamine/formaldehyde and 2.3% to DMDHEU, and considered all to indicate textile dermatitis (6). Sherertz had 11 cases of contact dermatitis related to finishes in clothing among 462 patients (2.4%), but not all patients were patch tested with the finishes (7).

Results of testing with the individual finishes are summarized in Table 2. The studies differed in protocol and their results, therefore, are difficult to compare and, indeed, differ widely. Only two finish allergens have been tested in all studies: DMDHEU and ethylene urea, melamine/formaldehyde. The percentages positive reactions to them in the group of patients with putative textile dermatitis varied and ranged from 9% to 100%. The same

large differences apply to the other finishes. In most studies the older finishes that release larger amounts of formaldehyde were tested. There is little US data available on testing with newer resins that release little formaldehyde (usually indicated as <100 ppm) such as methylated or (otherwise) modified DMDHEU and a finish claimed not to release formaldehyde at all (1,3-dimethyl-4,5-dihydroxyethyleneurea, Fixapret[®] NF; NF = No Formaldehyde) (10).

Patients reacting to finishes often have multiple reactions (the numbers obviously dependent on the number of finishes tested). In Fowler's, study (8) there were 51 positive reactions in 12 patients, an average of 4.3 (in formaldehyde-positive patients 4.9, in formaldehyde-negative patients: 2.3). In Scheman et al. (who tested more finishes and whose patients were all formaldehyde positive) the average number of finish reactions was 4.9 (10). In Metzler-Brenckle and Rietschel in 24 patients the average number was 4.8 (formaldehyde-positive patients: 5.3, formaldehyde-negative patients: 4) (9).

In all but one study, there have been patients who reacted to one or more finishes, but who had a *negative* reaction to formaldehyde 1% aqua. Thus, the percentages of positive reactions to formaldehyde ranged from 67% to 100% (mean 75%, average 79%, not corrected for numbers tested). The mere fact of a negative response to formaldehyde was considered by all authors as proof for the existence of contact allergy to the entire finish molecule, i.e. independent of formaldehyde sensitivity (6–10). No laboratory tests were performed to confirm the presence of formaldehyde or the incriminated finishes in the garments suspected to have caused the dermatitis[‡].

Routine testing with durable-press chemical finishes in general patch test studies

In some studies, notably those of the North American Contact Dermatitis Group (NACDG), the mixture of ethylene urea, melamine/formaldehyde has been routinely tested in all patients with suspected ACD; the results were reported in blocks of 2 years (12–15). The frequency of patch test reactivity to this test allergen ranged from 2.3% to 7.2%. Data on concomitant sensitization to formaldehyde are not available except in the 1994–1996 cohort, in which 88% of the patients reactive to the finish were also patch test positive to formaldehyde (15).

[†]This article discusses the risk for *consumers* to develop allergic contact dermatitis from formaldehyde or DPCF in the clothes they wear. Reports on occupational ACD are excluded.

[‡]In a recent report on a case of occupational ACD, a paediatrician reacted to DPCF, formaldehyde and – on one occasion and only weakly – her surgical uniform. This uniform proved to contain formaldehyde, but the amount was not determined (39).

Table 1. General data of studies on allergic contact dermatitis from durable-press chemical finishes (DPCF) in clothes 1990–2008

Place of study	Study period	Type of study	Selection of patients for testing with DPCF	Number of patients tested with DPCF	Number of patients with diagnosed clothing dermatitis	Allergens tested	Diagnosis based on: -	Results of removal of clothes or of general advice on type of garments	Ref
New York and Louisville, USA	1988–1990	retrospective	Routine testing	1022	12 (1.2%) @	DMDHEU; DMPU; EUMF (10% pet); MF; TMAD; UF	Positive patch test reaction only	Not specified	8
Winston-Salem, USA	1988–1991	retrospective	Not specified	Not specified. Total number seen in patch test clinic: 462	11 (2.4%)	DMDHEU; DMPU; EUMF (10% pet); MF; TMAD (5% aqua); UF	Positive patch test reaction 'thought' to be relevant to the presenting problem	'Most patients improved'	7
Chicago, USA	Unknown 1997?	prospective	Patients with positive patch test reactions to 'older' DPCF	10	No diagnosis, only positive patch test reactions to DPCF	All allergens mentioned below this table	NA	NA	10
New Orleans, USA	1994–1999	retrospective	Clinically suspected of textile allergic contact dermatitis	188	24	DMDHEU; DMPU; EUMF MF; TMAD (5% aqua); UF	Two or more positive patch tests + a clinical picture consistent with textile dermatitis	Not specified	9
Cleveland, USA	1999–2004	retrospective	Part routine testing and part based on suspicion of textile dermatitis	852 (EUMF) 398 (DMDHEU) 60 (others)	17 (2.0%) # 9 (2.3%)	DMDHEU; EUMF; others (not specified)	Positive patch test reaction only	"A significant proportion improved"	6

DPCF = Durable-Press Chemical Finishes

@ the numbers presented here differ from those tabulated in the original article, as we have removed the five cases of occupational ACD

questionable (?) reactions were scored as positive

Abbreviations and full chemical names * (column allergens tested):

DDEU: 1,3-Dimethyl-4,5-dihydroxyethyleneurea (Fixapret® NF) 5% aqua
DMDHEU: Dimethylol dihydroxyethyleneurea (Fixapret® CPN) 4.5% aqua
DMDHEU, meth.: Dimethylol dihydroxyethyleneurea, methylated 5% aqua
DMDHEU, mod.1: Dimethylol dihydroxyethyleneurea, modified (Fixapret® ECO) 5% aqua
DMDHEU, mod.2: Dimethylol dihydroxyethyleneurea, modified (Permatfresh® EFR) 5% aqua
DMPU: Dimethylolpropyleneurea (Fixapret® PH) 5% aqua
EUMF: Ethylene urea, melamine/formaldehyde (Fixapret® AC) 5% pet
MF: Melamine/formaldehyde (Kaurit® M70) 7% pet
TMAD: Tetramethylol acetylenediurea (Fixapret® 140) 5% pet
UF: Urea-formaldehyde (Kaurit® S) 10% pet

NA Not applicable

*Nomenclature according to ChemIDplus Advanced (US National Library of Medicine) <http://chem.sis.nlm.nih.gov/chemidplus/> (accessed November 30, 2008)

Table 2. Results of patch testing with durable-press chemical finishes

Ref.	Number pat. tested with durable press allergens	Number pat. with one or more positive patch test reactions	Number of positive reactions to individual durable press allergens and percentages (in brackets) of patients with reactions to durable press allergens										% of patients also reacting to formaldehyde
			DDEU	DMDHEU	DMDHEU methylated	DMDHEU modified 1	DMDHEU modified 2	DMPU	EUMF	MF	TMAD	UF	
8	1022	12		4(33)				10 (83)	11 (92)	10 (83)	8 (67)	8 (67)	75
7	Not specified.	11		1 (9)				2 (18)	1 (9)	2 (18)	1 (9)	10 (91)	73
	Total number seen in patch test clinic: 462												
10	10		2 (20)	10 (100)	1 (10)	1 (10)	2 (20)	4 (40)	6 (60)	7 (70)	8 (80)	5 (50)	100
9	188	24 *		16 (67)				23 (96)	11 (46)	18 (75)	21 (88)	16 (67)	67
6	852 (EUMF)	17							17 (100)				82
	398 (DMDHEU)	9		9 (100)									?
DDEU:	1,3-Dimethyl-4,5-dihydroxyethyleneurea				(Fixapret® NF)								
DMDHEU:	Dimethylol dihydroxyethyleneurea				(Fixapret® CPN)								
DMDHEU, meth.:	Dimethylol dihydroxyethyleneurea, methylated												
DMDHEU, mod.1:	Dimethylol dihydroxyethyleneurea, modified				(Fixapret® ECO)								
DMDHEU, mod.2:	Dimethylol dihydroxyethyleneurea, modified				(Permafresh® EFR)								
DMPU:	Dimethylolpropyleneurea				(Fixapret® PH)								
EUMF:	Ethylene urea, melamine/formaldehyde				(Fixapret® AC)								
MF:	Melamine/formaldehyde				(Kaurit® M70)								
TMAD:	Tetramethylol acetylenediurea				(Fixapret® 140)								
UF:	Urea-formaldehyde				(Kaurit® S)								

*These patients had reactions to at least 2 allergens
Blanks in the table mean that these allergens were not tested.

The reactions were scored as 'relevant' (i.e. that the positive patch test reaction indicates the existence of clothing ACD) in 29–66% of the positive cases (albeit including 'probable relevance' and 'possible relevance'). 'Definite relevance' was established in only 0.9–7.7%. In these reports, the diagnosis was based on positive patch test reactions plus a 'textile pattern' of contact dermatitis.

Another chemical finish tested by the NACDG is DMDHEU. Of 4889 patients tested with DMDHEU 4.5% aqua, 1.1% had a positive reaction. No case was determined to be 'definitely relevant', in 19% was relevance 'probable' and in 43% 'possible' (15). In a similar study from the Mayo clinic, 411 (selected from a group of 3850) patients were tested and 1.9% had a positive reaction, of which 75% was defined as 'relevant' (16). Note that both the members of the NACDG and the Mayo Clinics often function as tertiary referral centres, where many patients are not followed-up after completing of patch testing, which makes establishing relevance clearly problematic. The risk of relevance being overestimated was also indicated by the NACDG itself (13). In addition, as specific data were not provided and the allergen tested (ethylene urea, melamine/formaldehyde) is a patch test mixture rather than a DPCF currently used in clothes, we suspect that these data may have limited value for today's textiles.

Discussion

The tentative interpretations of these studies were that textile dermatitis from DPCF is not infrequent (1.2–2.4% of the patch test population), that the problem is probably underestimated and underdiagnosed; that formaldehyde is the most important allergen, that formaldehyde *alone* is not a suitable screening agent for textile ACD; and that the DPCF themselves in up to 30% of the patients are the sensitizers. It is also implicitly concluded that the diagnosis can be based on positive patch tests alone (6, 8) or on the combination of patch test results + the clinical picture of a 'textile dermatitis pattern' (7, 9) and that clothes on the US market contain sufficient formaldehyde to elicit ACD. Can these conclusions be validly drawn from the data presented and other available information?

Is formaldehyde always the allergen?

In some studies, all patients with DPCF contact allergy/ACD reacted to formaldehyde (17, 18). Between 1991 and 2001, 863 patients were tested at the Finnish Institute of Occupational Health with melamine/formaldehyde and 15 (1.7%) had

a positive reaction. All also reacted to formaldehyde. Details were not provided (18). Andersen and Hamann (17) found that all 10 patients with relevant reactions to one or more DPCF also had a positive patch test reaction to formaldehyde 2% in water and thus concluded that testing with finishes has no added value. Of the 10 patients known to react to 'older' resins presented by Metzler-Brenckle and Rietschel (9), all were also allergic to formaldehyde. These data would suggest that formaldehyde sensitivity identifies all cases of textile ACD from DPCF.

However, this is not always the case. In the NACDG 1994–1996 cohort, there were 155 positive reactions to ethylene urea, melamine/formaldehyde. Of these, 12% did *not* react to formaldehyde (15). In the US studies discussed above, 18–33% of the patients diagnosed with textile dermatitis from DPCF were formaldehyde-negative (Table 2). The authors concluded that: (i) formaldehyde is not a good screen for textile dermatitis caused by allergy to DPCF (as it may miss up to 30% of such patients) and (ii) in these cases the finish molecules themselves must be the sensitizer, independent of formaldehyde sensitivity. Interestingly, the mentioning of the DPCF *per se* as sensitizer is only made in conjunction with *negative* patch tests to formaldehyde, so apparently, in the cases of positive reactions to DPCF *and* formaldehyde, formaldehyde is accepted as the textile dermatitis allergen.

What no author has speculated on, is that the cases of negative reactions to formaldehyde (in all studies tested 1% in water), may actually have been *false-negative*. Formaldehyde is a 'difficult' allergen and false-negative reactions are not infrequent. Trattner et al. (19) between 1992 and 1996 tested 3734 consecutive patients with formaldehyde in two concentrations, 1% aqua and 2% aqua. 121 patient had one or two positive reactions shown to be relevant. About half of these reacted to both 1% and 2%, but 39 (32%) reacted to formaldehyde 2% *only*. This implies, that – assuming the authors correctly interpreted the reactions as allergic – >30% of patients tested with formaldehyde 1% aqua will be *false-negative*! (19) Pontén et al. also found that patch testing with 2% detected more than twice as many individuals allergic to formaldehyde, most of them reacting to the 2% test substance only (20). Thus the 18–33% negative reactions in the studies on textile dermatitis discussed here (mean 25%, average 21%, not corrected for numbers tested) all fall within the range of what is expected to be false-negative.

We suggest that there are three other indications that many reactions to formaldehyde may have been false-negative:

- (1) In Fowler et al. (8) three patients were formaldehyde-negative. Two had – despite being formaldehyde-negative – a positive patch test reaction to the formaldehyde-releaser quaternium-15.
- (2) In the same study, two of the formaldehyde-negative patients (including the one *not* reacting to quaternium-15) had positive patch test reactions to three different DPCF. In both cases the patients reacted to finishes structurally so different that cross-reactions between them are unlikely. They do, however, all release medium to high amounts of formaldehyde, which may thus have been the common determinant.
- (3) In Sherertz (7), 11 patients reacted to one or more finishes. Eight also reacted to formaldehyde; of these, seven also reacted to at least one other formaldehyde releaser. All three formaldehyde-negative patients, however, reacted *only* to urea-formaldehyde. We suspect that these patients may well have been weakly allergic to formaldehyde, leading to a false-negative reaction to formaldehyde, to the absence of a positive reaction to other formaldehyde releasers but to a *positive* reaction to urea-formaldehyde (as it releases very high amounts of formaldehyde) (Table 3).

Interestingly, the possibility of false-negative reactions to formaldehyde has been made by Fowler (8). He has not infrequently seen cases of negative reactions to formaldehyde 1% but definite, relevant positives to 2% concentrations. Therefore, Fowler advises that if formaldehyde allergy is strongly suspected, testing should be done with both 1% and 2% concentrations (26). The Swedish contact dermatitis group has recently switched from testing formaldehyde in the standard 1% to a 2% concentration because of false-negative reactions to 1% (Magnus Bruze, personal communication, 2008). Unfortunately, in no study discussed here has the patient been retested with either 1% or 2% formaldehyde. In the absence of this, we suspect that many, possibly all, negative reactions in the

studies (6–9) may have been false-negative, which has already been suggested in a German publication over 10 years ago (27).

Are the durable-press finish chemical sensitizers per se?

What proof is there that – as suggested by authors of the studies described above – DPCF themselves can be sensitizers? In fact, these investigators provide none. The concept is entirely based on the absence of positive patch test reactions to formaldehyde in a number of patients diagnosed with textile dermatitis. As discussed above, these reactions were most likely false-negative. In addition, in most such cases, the patients reacted to the older high formaldehyde-releasing finishes such as urea-formaldehyde (which are according to some unlikely to be used in consumer clothes currently (12)) or to ethylene urea, melamine/formaldehyde, which is a patch test mixture and apparently not a finish used as such.

In one study (10) several newer *low* formaldehyde-releasing finishes showed positive patch test reactions: modified 1,3-dimethyl-4,5-dihydroxyethyleneurea preparations (Fixapret® ECO), methylated DMDHEU (Freerez® PKF) and two other 'new' finishes only mentioned by trade names (which can currently not be found in chemical online databases). Although all these patients were allergic to formaldehyde, it could be argued that the amount of formaldehyde in the test preparations should be so low, that formaldehyde sensitivity cannot be held responsible for the positive patch test to them, and this certainly holds true for 1,3-dimethyl-4,5-dihydroxyethyleneurea (Fixapret® NF), which does not release any formaldehyde.

In that study, to the newer low formaldehyde finishes, there were nine reactions in three patients. Two patients had a total of nine positive reactions each and the third had eight. Over half of these were strong (+++) reactions, whereas 8/9 reactions to the new finishes were weak positive (+). We thus suspect that in no case can contact allergy to the

Table 3. Formaldehyde release by various chemical finishes ^{3,6,8,10,21,22,23,24,25}

Abbreviation	Chemical name	Trade name	Formaldehyde release*
DDEU	1,3-Dimethyl-4,5-dihydroxyethyleneurea	Fixapret	NF none
DMDHEU	Dimethylol dihydroxyethyleneurea	Fixapret CPN	medium
DMDHEU, meth.	Dimethylol dihydroxyethyleneurea, methylated	Freerez PKF	low
DMDHEU, mod.1	Dimethylol dihydroxyethyleneurea, modified	Fixapret ECO	low
DMDHEU, mod.2	Dimethylol dihydroxyethyleneurea, modified	Permafresh EFR	low
DMPU	Dimethylolpropyleneurea	Fixapret PH	high
EUMF	Ethylene urea, melamine/formaldehyde	Fixapret AC	very high (?)
MF	Melamine/formaldehyde	Kaurit M70	very high
TMAD	Tetramethylol acetylenediurea	Fixapret 140	high
UF	Urea-formaldehyde	Kaurit S	very high

very high: >1000 ppm; high: 300–1000 ppm; medium: 100–300 ppm; low: <100 ppm; all in µg/gr fabric (ppm).

*estimation of formaldehyde release varies (considerably) between publications

newer resins be accepted as proven because of the very great risk of false-positivity due to the Excited Skin Syndrome (10)[§].

In modern textile technology, the methylol groups of the DPCF cross-link with the hydroxyl (OH) groups of the cellulosic textile fibres to form stable ether bonds. We suspect that after adequate curing very few DPCF molecules remain in the textiles. We feel that is unlikely that such low levels are capable of sensitizing people from wearing clothes containing the finishes (27).

Clinical picture: how reliable is it for predicting clothing allergic contact dermatitis (ACD)?

In the studies discussed here, the diagnosis of textile ACD to DPCF was based on one or more positive patch test reactions, or such reactions *plus* a clinical picture consistent with textile dermatitis ('textile pattern dermatitis'). How reliable are these clinical findings?

Textile dermatitis is said 'classically' to conform to a pattern that coincides with places on the skin, where clothing may fit tightly. Common eruption sites include the posterior neck, the upper back, lateral thorax (i.e. anterior and posterior axillary folds), waistband, and flexor surfaces, with relative sparing of the undergarment areas. This pattern of textile-related ACD points out the importance of non-immunologic factors such as pressure, friction, heat, and perspiration to the ultimate clinical response (6, 7). The face is usually spared, but patients who also react to formaldehyde-releasing preservatives may have involvement at any areas on which personal care products are used (6). However, in one report, some patients with textile dermatitis (based on a positive patch test only!) had diffuse or generalized dermatitis, even erythroderma (8) and Scheman et al. begin their introduction stating that 'Affected individuals are often almost erythrodermic' (10).

Not only the distribution but also the morphology may vary. Individual lesions may be papular, urticarial or vesicular in the acute or subacute phase and purpuric lesions have also been observed (29). With chronicity, scaling and lichenified patches may occur. The lesions may be arranged in follicular, linear, irregular, or nummular plaques or 'sheets' (7).

It thus appears that textile dermatitis may come in many forms. Indeed, Sherertz concluded that 'a wide variety of clinical patterns has been seen in confirmed cases of contact allergy to fabric finish, dyes, or other fabric components, underscoring the difficulty in relying on clinical recognition alone' (7). This suggests that the clinical picture may not be

reliable to predict clothing ACD and thus has little diagnostic power. Indeed, Carlson et al. (6) tested 60 patients 'for whom there was a high degree of clinical suspicion for textile dermatitis' with several allergens from the ChemotechniqueTM (Chemotechnique Diagnostics, Malmö, Sweden) textile series, but only six patients (10%) had positive reactions (of which four were even 'questionable'!). Metzler-Brenckle and Rietschel (9) tested 188 patients 'with suspected allergic textile dermatitis' and only 35 (19%) had positive reactions. And among 428 Danish patients suspected to suffer from textile dermatitis, only 15 (6%) were found to have positive reactions to durable-press allergens (17).

This implies that a clinical picture suggestive of textile ACD—often used as a criterion for making this diagnosis (9)—is in the vast majority (in these studies 80–94%) of the cases actually *not* caused by textile allergy. Thus, clinical findings may have limited diagnostic power.

Do clothes on the US market contain enough formaldehyde to cause allergic contact dermatitis (ACD)?

To answer this question, we must first determine which level is capable of causing ACD and how much formaldehyde in clothes is safe for allergic patients.

How much formaldehyde in clothes is safe for patients allergic to formaldehyde? The threshold level of free and releasable formaldehyde in clothes that will produce clinical dermatitis in a formaldehyde-allergic patient is unknown. Fisher et al. published information obtained by communication with US manufacturers of textiles, which stated that US fabrics so identified contained no more than 0.075% (750 ppm) of free formaldehyde. These authors failed to reproduce formaldehyde dermatitis in 20 patients known to be allergic to formaldehyde by having them wear clothing made of these fabrics containing, according to their manufacturers, between 300 and 750 ppm of free formaldehyde (4).

The study of Berrens et al. (5) is often quoted as an indication that the threshold level is 500 ppm. However, these authors, after quantitatively assaying clothing from the Netherlands, arbitrarily advised their patients not to wear those articles of clothing that contained more than 0.05% (500 ppm) of free formaldehyde. Presumably based on these studies, the threshold for ACD from textile finishes is often suggested to be 500–750 ppm free formaldehyde in the garment (8, 30), but we can safely say that nobody knows for sure.

Some investigators have assessed the threshold level for formaldehyde in *cosmetics* to produce contact dermatitis in formaldehyde-sensitive patients.

[§]Positive patch test reactions to these newer low/no formaldehyde DPCF have been observed in Israeli patients. However, the presence of these finishes in suspected clothes was not studied (28).

Levels of 130 ppm did not produce reactions in patients applying the cosmetic product twice daily to the face for 2 weeks (31). Levels of 370 ppm, however, cause reactions in 20% of the patients, and thus the safe level (in this setting) should lie between 130 and 370 ppm. Note, however, that cosmetics are applied to the skin and often rubbed in and that these experiments were done on the face, which is much more sensitive to contact dermatitis than the arms, legs, and trunk. On the basis of these data, we *tentatively* conclude that levels of <200 ppm in textiles should be safe for most patients allergic to formaldehyde. It will surely be argued that Jordan et al. demonstrated far lower thresholds (30 ppm), but their experiments were conducted in different circumstances favouring reactions to low concentrations (32).

What is known about the current content of formaldehyde in clothes in the USA?

Technical possibilities. The older resins based on urea-formaldehyde and melamine/formaldehyde released large amounts of formaldehyde, which caused dermatitis. With the introduction of the cyclized urea derivatives such as DMDHEU, the levels were drastically lowered to 100–500 ppm. Currently, the industry has the technical possibility to lower formaldehyde levels to <100 ppm by using modern finishes such as modified (glycolated, methylated, etc.) DMDHEU (Table 3). It can even produce non-formaldehyde finishes including 1,3-dimethyl-4,5-dihydroxyethyleneurea (Fixapret® NF). Problems of these non-formaldehyde reactants are that they are difficult-to-cure and more expensive than DMDHEU, have poor durable-press properties, and yellow treated white fabrics, so they are not widely used in clothes (33).

Legislation. Some countries legally limit the formaldehyde content of textile products to reduce the risk of contact dermatitis and other adverse effects among their populations. Japan was the first in 1973 [which led to a sharp decrease in the prevalence of sensitization to formaldehyde in the years thereafter (34)] followed by Finland (35). Other countries with legal limitations include China, Norway, France, Japan, and the Netherlands. The regulations differ, but usually garments for babies and infants should contain <20–30 ppm formaldehyde, for clothes in direct contact with the skin a maximum of 75–100 ppm and for clothing and textiles without direct skin there are upper limits of 300–400 ppm formaldehyde.

Voluntary restrictions. While currently there are no US standards or regulations associated with formaldehyde in clothing and textiles, the American Apparel and Footwear Association (AAFA) (the national trade association) published a 2008 Restricted Substance List (RSL) requesting that its

members (367 companies) abide voluntarily to the standards listed. For formaldehyde, the RSL suggests no detectable formaldehyde for infant clothing (0–36 months), a maximum of 75 ppm for clothes for people >36 months with direct skin contact and 300 ppm for textiles with no direct skin contact (36).

The International Association for Research and Testing in the Field of Textile Ecology (Oeko-Tex), which represents a large group of worldwide textile research institutes, developed the Oeko-Tex 100 standards. These voluntary standards place limitations on free formaldehyde in clothing and textiles similar to the AAFA guidelines (www.oeko-tex.com). Their tag is a stamp of approval that informs the consumer that the textile does not contain dangerous levels of harmful substances.

Analyses of formaldehyde in textiles. There is little published information on the content of formaldehyde in textiles in the USA and other countries. In a 1985 study, Mathews et al. (37) obtained average values of formaldehyde released from 180 randomly selected fabrics to be 117 ± 140 , 58 ± 72 , 19 ± 17 , and 31 ± 29 ppm for top-weight (shirt), bottom-weight (pant), knit, and flatgood categories, respectively. Formaldehyde releases of less than 100 ppm were measured from 86% of these fabrics (37).

The Finnish Customs Laboratory between 1988 and 1993 analysed yearly >1400 imported textiles for formaldehyde content with the acetylacetone method. In 1988, 8.3% of the samples contained 100–300 ppm formaldehyde, which had lowered to 4.4% in 1993. The percentage of samples containing >300 ppm dropped drastically from 3.9% to 0.3% and the maximum found concentration decreased from 2200 to 643 ppm (35).

Scheman et al. in 1998 investigated 16 randomly selected samples of cellulose-containing fabrics for testing on formaldehyde content with the Schiff reagent method and a commercially available Merck formaldehyde test (10). Nine specimens were manufactured in the US and seven samples elsewhere (Indonesia, Taiwan, Lesotho, Brunei, Thailand). In eight samples (50%) no formaldehyde was detected, in seven (44%) formaldehyde was found in concentrations <200 ppm and only one garment proved to contain >200 ppm formaldehyde. The latter specimen was retested using the official Japanese Law 112 method and contained only 24 ppm free formaldehyde (10).

Brookstein (personal communication 2008), using a Morapex extractor/formaldimeter system (www.treepoint.com), tested 11 young men's durable-press treated khaki pants for free formaldehyde. The free formaldehyde measurements ranged from <20 to 136 ppm. Only two of the 11 pairs of pants had

free formaldehyde in excess of 100 ppm. The free formaldehyde measurements for 12 young men's dress shirts ranged from <20 to 126 ppm. Only one of the dress shirts had free formaldehyde in excess of 100 ppm. The tests were not repeated after washing. In Australia, in 2007, a broad range of clothing on the Australian market was tested for residual formaldehyde content. Formaldehyde was not detected (38).

Note that the results of formaldehyde testing depend on the methodology (3, 35). Different methods can yield strongly discordant results! Twenty fabrics were investigated in Finland with the official Japanese 112 method and with the AATCC-112 method. In all cases, far higher results were obtained with the AATCC-112 methods with a mean ratio of 4.4! In the older studies, determinations of formaldehyde were primarily done with the chromotropic acid procedure, which is considered to produce much higher results than the currently used acetylacetone procedures (Japan Law 112, AATCC-112) (3, 35).

It thus appears (i) that the US textile industry has the possibility and the intention (voluntary restrictions) to provide low formaldehyde (<100 ppm) garments, (ii) that clothes imported from countries with textile formaldehyde legislation are likely to be safe, and (iii) that recent US investigations have demonstrated low and safe levels in clothes bought in the USA. We therefore suspect that it is unlikely that a substantial part of clothes worn in the USA will contain levels of formaldehyde that may be unsafe for formaldehyde-sensitive individuals.

To back up our statements (or have them contradicted) studies should be performed to determine formaldehyde levels in clothes sold on the US market. In July 2008, the Congress of the United States passed the Consumer Products Safety Commission Modernization Act of 2008. In that Act section 234 says: 'Not later than 2 years after the date of enactment of this Act, the Comptroller General, in consultation with the Commission, shall conduct a study on the use of formaldehyde in the manufacture of textile and apparel articles, or in any component of such articles, to identify any risk to consumers caused by the use of formaldehyde in the manufacturing of such articles, or components of such articles'. We hope that quantitative formaldehyde assays in clothes will be part of that intended study.

Conclusions

The existence of ACD from formaldehyde in clothes in consumers in the US has not been demonstrated beyond doubt. In the articles reviewed (6–10), in no single case was the presence of formaldehyde

(or its quantity) demonstrated in suspected textiles. Removal of the offending clothes should have resulted in clearing of the dermatitis, but it led in two studies only to 'improvement' in a significant number of the patients. In the others, the results of allergen avoidance were not specified. The clinical picture was sometimes an integral part of the diagnosis, but we argue that the diagnostic value of the clinical pattern of textile contact dermatitis is low.

The existence of ACD from DPCF *per se*, independent of formaldehyde allergy, has not been proven. They have been implicated solely on the basis of a negative reaction to formaldehyde. We feel that there are reasons to assume that most if not all such negative reactions have been *false-negative*. In addition, it is unlikely that with modern day technology sufficient free DPCF molecules remain in the clothes after curing to either induce sensitization or elicit ACD.

At this moment, the existence of ACD from formaldehyde in clothes, although definitely *not* proven, cannot be excluded as we lack data on the elicitation threshold and the amounts of formaldehyde present in textiles. There are good suggestions, however, that clothing on the US market generally contain low and safe levels of formaldehyde.

What we most urgently need is to determine what levels of formaldehyde in textiles are capable of causing dermatitis (and consequently, which levels are safe). However, this requires a complex protocol. If it can be established that virtually all clothes contain <200 ppm formaldehyde after washing (as this usually decreases the amount of formaldehyde considerably), ACD should be extremely rare. Such investigations should take place in the USA in the near future. If the US were to adopt legislation limiting formaldehyde content in analogy to other countries such as Japan, Finland, China, Norway, France, Japan, and the Netherlands, the problem – if at all – should disappear. This should not adversely affect US apparel companies, as their trade organization already advises voluntarily limiting formaldehyde content to levels comparable to those in countries with legislation on formaldehyde in clothes and textiles.

References

1. Hovding G. Free formaldehyde in textiles. *Acta Dermatovenereologica* 1959; 39: 357–363.
2. Hatch K L, Maibach H I. Textile chemical finish dermatitis. *Contact Dermatitis* 1986; 14: 1–13.
3. Vail S L, Reinhardt R M. What do formaldehyde tests measure? *Textile Chemist Colorist* 1981; 13: 13–22.
4. Fisher A A, Kanof N B, Biondi E M. Free formaldehyde in textiles and paper. Clinical significance. *Arch Dermatol* 1962; 86: 753–756.
5. Berrens L, Young E, Jansen L H. Free formaldehyde in textiles in relation to formalin sensitivity. *Br J Dermatol* 1964; 76: 110–115.

6. Carlson R M, Smith M C, Nedorost ST. Diagnosis and treatment of dermatitis due to formaldehyde resins in clothing. *Dermatitis* 2004; 15: 169–175.
7. Sherertz E F. Clothing dermatitis: practical aspects for the clinician. *Am J Contact Dermatitis* 1992; 3: 55–64.
8. Fowler J F Jr, Skinner S M, Belsito DV. Allergic contact dermatitis from formaldehyde resins in permanent press clothing: an underdiagnosed cause of generalized dermatitis. *J Am Acad Dermatol* 1992; 27: 962–968.
9. Metzler-Brenckle L, Rietschel R L. Patch testing for permanent-press allergic contact dermatitis. *Contact Dermatitis* 2002; 46: 33–37.
10. Scheman A J, Carroll P A, Brown K H, Osburn AH. Formaldehyde-related textile allergy: an update. *Contact Dermatitis* 1998; 38: 332–336.
11. Cohen D, Hatch KL, Maibach H, Pratt M. Clothes make the (wo)man: diagnosis and management of clothing dermatitis. *Am J Contact Dermatitis* 2001; 12: 229–231.
12. Pratt M D, Belsito D V, DeLeo V A et al. North American Contact Dermatitis Group patch-test results, 2001–2002 study period. *Dermatitis* 2004; 15: 176–183.
13. Marks J G Jr, Belsito D V, DeLeo V A et al. North American Contact Dermatitis Group patch-test results, 1998 to 2000. *Am J Contact Dermatitis* 2003; 14: 59–62.
14. Marks J G Jr, Belsito D V, DeLeo V A et al. North American Contact Dermatitis Group patch-test results, 1996–1998. *Arch Dermatol* 2000; 136: 272–273.
15. Marks J G Jr, Belsito DV, DeLeo VA et al. North American Contact Dermatitis Group patch test results for the detection of delayed-type hypersensitivity to topical allergens. *J Am Acad Dermatol* 1998; 38: 911–918.
16. Davis M D P, Scaif L A, Yiannias J A et al. Changing trends and allergens in the patch test standard series. *Arch Dermatol* 2008; 144: 67–72.
17. Andersen K E, Hamann K. Cost benefit of patch testing with textile finish resins. *Contact Dermatitis* 1982; 8: 64–67.
18. Aalto-Korte K, Jolanki K, Estlander T. Formaldehyde-negative allergic contact dermatitis from melamine-formaldehyde resin. *Contact Dermatitis* 2003; 49: 194–196.
19. Tratner A, Johansen J D, Menné T. Formaldehyde concentration in diagnostic patch testing: comparison of 1% with 2%. *Contact Dermatitis* 1998; 38: 9–13.
20. Pontén A, Dubnika I, Gruvberger B, Isaksson M, Bruze M. Detection of contact allergy to formaldehyde. *Contact Dermatitis* 2008; 58(Suppl. 1): 26.
21. Cooke T F, Weigmann L. The chemistry of formaldehyde release from durable-press fabrics. *Text Chem Col* 1982; 14: 25–28.
22. http://www.performancechemicals.basf.com/ev-wcms-in/internet/en_GB/portal/show-content_tc/function:evproducts:/list/basic/4906?rootid=4905 (Fixapret, Kaurit) (last accessed November 27, 2008).
23. www.omnova.com (Permafresh) (last accessed November 27, 2008).
24. Peterson H, Pai P S. Reagents for low-formaldehyde finishing of textiles. *Textile Res J* 1981; 51: 282–302.
25. Hatch K L, Maibach H I. Textile dermatitis: an update. (I). Resins, additives and fibers. *Contact Dermatitis* 1995; 32: 319–326.
26. Rietschel R L, Fowler J F Jr. *Fisher's Contact Dermatitis*, 6th edition, Hamilton, BC Decker Inc, 2008: 346.
27. Peters K-P, Heese A. Formaldehyd und Formaldehydharze. Ihre Bedeutung bei Textilallergien. *Allergologie* 1997; 20: 239–245.
28. Lazarov A. Textile dermatitis in patients with contact sensitization in Israel: a 4-year prospective study. *JEADV* 2004; 18: 531–537.
29. Lazarov A, Cordoba M. Purpuric contact dermatitis in patients with allergic reaction to textile dyes and resins. *JEADV* 2000; 14: 101–105.
30. Schorr W F, Keran E, Plotka E. Formaldehyde allergy. The quantitative analysis of American clothing for free formaldehyde and its relevance in clinical practice. *Arch Dermatol* 1974; 110: 73–76.
31. Zachariae C, Hall B, Cottin M et al. Experimental elicitation of contact allergy from a diazolidinyl urea-preserved cream in relation to anatomical region, exposure time and concentration. *Contact Dermatitis* 2005; 53: 268–277.
32. Jordan W P Jr, Sherman W T, King S E. Threshold responses in formaldehyde-sensitive subjects. *J Am Acad Dermatol* 1979; 1: 44–48.
33. Cooke, T F, Weigmann H D. The chemistry of formaldehyde release from durable press fabrics. *Textile Chemist and Colorist* 1982; 14: 100–106.
34. Sugai T, Yamamoto S. Decrease in the incidence of contact sensitivity to formaldehyde. *Contact Dermatitis* 1980; 6: 154.
35. Priha E. Are textile formaldehyde regulations reasonable? Experiences from the Finnish textile and clothing industries. *Regulatory Toxicol Pharm* 1995; 22: 243–249.
36. <https://www.apparelfootwear.org/Resources/RestrictedSubstances.asp> (accessed November 27, 2008).
37. Mathews T G, Daffron C R, Merchant E R. Formaldehyde release from durable-press apparel textiles. Final project report to the U.S. Consumer Product Safety Commission. Washington, D.C., 1985.
38. <http://www.accc.gov.au/content/index.phtml/itemId/801314/fromItemId/2332> (accessed November 27, 2008).
39. Donovan J, Skotnicki-Grant S. Allergic contact dermatitis from formaldehyde textile resins in surgical uniforms and nonwoven textile masks. *Dermatitis* 2006; 18: 40–44.

Address:
 Anton C. de Groot
 Schipslootweg 5
 8351 HV Wapserveen
 The Netherlands
 Tel: +31521320332
 e-mail: antondegroot@planet.nl