

Allergic Contact Dermatitis from Formaldehyde Textile Resins

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Formaldehyde-based resins have been used to create permanent-press finishes on fabrics since the 1920s. These resins have been shown to be potent sensitizers in some patients, leading to allergic contact dermatitis. This review summarizes the history of formaldehyde textile resin use, the diagnosis and management of allergic contact dermatitis from these resins, and current regulation of formaldehyde resins in textiles.

ALLERGIC CONTACT DERMATITIS from clothing is a condition that patients have described as miserable, intractable, and debilitating. Natural cellulose or protein-based fibers (including pure cotton, linen, and silk) in their raw unfinished states rarely cause allergic contact dermatitis, but dyes, resins, and finishes can cause a variety of skin problems. Many excellent articles have reviewed allergic contact dermatitis (ACD) resulting from textile dyes.^{1–3} The goal of this review is to summarize the existing literature on ACD from the formaldehyde-releasing and formaldehyde-based textile finishes known as formaldehyde textile resins (FTRs). In addition, ACD from selected non-FTRs will be reviewed.

Formaldehyde Textile Resins

The early use of formaldehyde resins was reviewed by Storrs.⁴ Since their introduction in 1926, formaldehyde resin treatments have been applied to cellulose and rayon fibers to increase strength, prevent shrinking, and resist wrinkling (permanent press).^{5–7} Although they are marketed as easy-care, durable-press, or permanent-press finishes, a technically correct description of FTRs might be “cellulosic antishrinkage” or “cellulosic cross-linking” finishes. Blended fabrics that contain both synthetic fibers (such as rayon) and natural fibers (such as cotton, linen, or wool) are more likely to be treated with FTRs.⁸ In these fabrics, FTRs aid in the fixation of dyes and pigments in

addition to maintaining a uniformly smooth and unwrinkled appearance of the fabric after laundering.⁹ These resins have not only the ability to bind to themselves within the weave of the textile but also (in the case of cellulose-containing textiles, including cotton, rayon, and blends) the ability to bind to cellulose. Fabrics made of 100% synthetic noncellulose fibers (eg, acrylic or polyester) do not require FTR finishing because the resins are unable to cross-link synthetic fibers.

Shirts, trousers, blouses, work clothes (including uniforms), fabric linings, suits, and formal wear can be treated with these finishes, which maintain the clothes’ “just-ironed” appearance after laundering. Permanent-press finishes are also used to maintain hand-knitted, used, or crushed looks in fabrics.⁹ Tablecloths and bedsheets are often treated with permanent-press finishes because of the marked wrinkling of linen after washing.

Older FTRs

Urea formaldehyde resin was introduced in the 1930s and was one of the first FTRs to be used (Table 1). Urea formaldehyde products are readily formed in aqueous self-condensation reactions (Fig 1) producing dimethylol urea (DMU).⁹ Free formaldehyde may result from high concentrations of the starting compounds or from the production of water and formaldehyde in a condensation reaction that results in the formation of the three-dimensional methylene linkage structure.^{9,10} Similar resins were developed with melamine formaldehyde (MF) (Fig 2); these also contained high amounts of free formaldehyde.¹¹ Ethyleneurea/melamine formaldehyde (EUMF), a composite of DMU and MF, was introduced in the 1930s and also releases high amounts of formaldehyde.⁶ These compounds polymerize within the pores of cellulose or

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DECKER_X



Table 1. Major Textile Resins

<i>Date Introduced</i>	<i>Resin Chemical Name</i>	<i>Selected Trade Names*</i>	<i>Relative Formaldehyde Release[†] (ppm)</i>
Older Resins			
1930s	Dimethylol urea (urea formaldehyde) (DMU)	Kaurit S, Calaroc UFB	High
1930s	Melamine formaldehyde (MF)	Kaurit M70	High
1930s	Ethyleneurea/melamine formaldehyde (EUMF)	Fixapret AC	High
1950s	Uron formaldehyde	Dextraset 48	High
1960s	Dimethyl carbamates	NA	Medium
1960s	Dimethylol ethyleneurea (DMEU)	NA	Medium
1960s	Dimethylol methoxypropyleneurea	Fixapret PCLS	Medium
1960s	Dimethylol propyleneurea (DMPU)	Fixapret PH	Medium
1960s	Tetramethylol acetylenediurea (TMADU)	Fixapret 140	Medium
1960s	DMDHEU	Fixapret CPN	Medium (750–1,000)
Newer Resins			
1980s	DMMDHEU	Freerez PFK, Freerez CLD	Partially methylated: low (300–500); tetra/fully methylated: very low (< 300)
1980s	Modified DMDHEU, blended or reacted with glycols	Fixapret ECO, Fixapret CPF71, Permafresh EFR	Very low (< 50)
Formaldehyde-Free Resins			
1980s	Dimethylol urea/glyoxal	Permafresh Silver	None
1980s	Dimethyl dihydroxyethyleneurea (DMeDHEU)	Fixapret NF	None
1980s	1,2,3,4-Butanetetra-carboxylic acid (BTCA)	NA	None

Adapted from Hatch KL et al⁶; Schemen AJ et al⁷; Hauser P et al⁹; Fowler JF et al²⁵; Andersen KE et al³³; Omnova Solutions Inc.⁵³

DMDHEU = dimethylol dihydroxyethyleneurea; DMMDHEU = methylated DMDHEU (dimethoxymethyl dihydroxyethyleneurea); NA= not applicable.

*Multiple trade names may exist for many of the resins listed. Trade names are not available for all resins. This is not an exhaustive list.

[†]High: $> 1,000$ ppm; medium: 500–1,000 ppm; low: < 500 ppm; very low: < 300 ppm.

rayon fibers so that water molecules cannot easily permeate the fiber⁹; this improves wrinkle resistance and strength. A disadvantage to the use of these resins is their ability to absorb chlorine when exposed to bleaching agents, leading to discoloration and fabric weakening.

Cyclic ethylene and propylene derivatives were introduced in the 1950s and 1960s to address the discoloration problems of earlier resins.⁹ These products release less formaldehyde and are wash-resistant and chlorine-fast. They also have a different structure, bonding not only to themselves but also

directly to the cellulose; multifunctional cross-linking agents bind with hydroxyl groups of adjacent cellulose molecules to hinder swelling of the fiber when exposed to moisture.⁹ This group of resins includes dimethylol ethyleneurea (DMEU), dimethylol dihydroxyethyleneurea (DMDHEU), and dimethylol propyleneurea (DMPU) (Fig 3).

Newer FTRs

The Department of Health and Human Services National Toxicology Program reported that, in 1980, 30% of durable-press fabrics were finished with DMU.^{6,12} By 1990, the percentage of DMU used in durable-press fabrics had dropped to 6% largely because of concerns regarding the high release of formaldehyde.^{6,12} DMDHEU, one of the

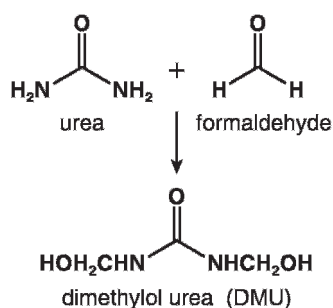


Figure 1. Formation of dimethylol urea by the addition of formaldehyde to urea.

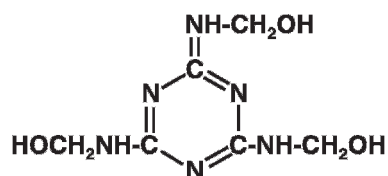


Figure 2. Melamine formaldehyde.

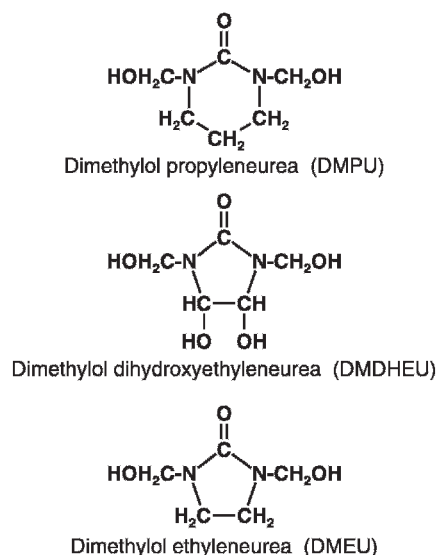


Figure 3. Cyclic ethylene and propylene textile resins.

cyclic ethylene derivatives, is the primary durable-press agent used in the United States today, as reported by an industry representative (Vinesh Genomal, marketing vice president of Cottonique, personal communication, May 2009) and the National Toxicology Program.¹² DMDHEU products cross-link with cellulose molecules, inhibiting wrinkling and shrinkage and preventing the movement of these fiber molecules during stress.⁹ DMDHEU may be modified by the addition of methyl groups, which replace the N-methylol (formaldehyde) groups, the main source of formaldehyde release⁸ (Fig 4). When DMDHEU is blended or reacted with diethylene glycol, an ultralow-formaldehyde product is produced. Generally, DMDHEU products have medium to ultralow formaldehyde release, excellent durability, low chlorine retention and reactivity, and low reactivity when ether modified (methylated).⁹ Ultralow-formaldehyde glycolated DMDHEU products have also been recently developed.

Formaldehyde-Free Resins

Dimethyl dihydroxyethyleneurea (DMeDHEU) is a textile resin that does not contain formaldehyde⁹ (Fig 5). It is formed by the reaction of N,N-dimethylurea and glyoxal.

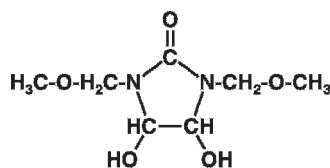


Figure 4. DMDHEU: methylated DMDHEU, or dimethoxymethyl dihydroxyethylene urea.

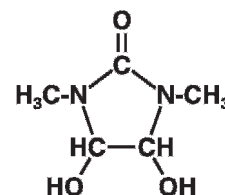


Figure 5. Dimethyl dihydroxyethyleneurea (DMeDHEU).

It cross-links with cellulose in a mechanism similar to that of DMDHEU; however, because it is a less reactive compound, stronger catalysts are required. Like DMDHEU, it can also be modified by alcohols such as methanol, diethylene glycol, or 1,6-hexanediol to ether derivatives. Unfortunately, DMeDHEU is less commonly used because it is more expensive. A 1:1 mixture of DMDHEU and DMeDHEU remains popular because of its reduced formaldehyde levels and only slightly inferior physical properties to DMDHEU alone.⁹

Other nonformaldehyde resins include butanetetracarboxylic acid (BTCA) and similar polycarboxylic acids.⁹ Their costs are comparable to that of DMeDHEU, and they require an expensive catalyst that may cause discoloration when exposed to certain dyes. The products of BTCA and sodium hypophosphate provide good cross-linking properties and durability, are water soluble, and are nonirritating. Many of these nonformaldehyde resins are used in the infant and children's clothing industry.¹³

Sources of Formaldehyde

Formaldehyde may be found in both free and bound forms in fabrics treated with FTRs. Free formaldehyde in fabrics remains in solution from the original equilibrium mixture and is not incorporated into the resin. Incompletely reacted resin and pendant N-methyl groups may also release gaseous formaldehyde. Resins require heat curing at temperatures of 150° to 170°C for a specific time to evaporate off all formaldehyde.⁹ Outsourced manufacturing has made quality control in this area a specific concern for the industry because some low-cost producers use lower-than-prescribed temperature settings and shorter curing times (Vinesh Genomal, personal communication, May 2009). The cured resin itself may also be a source of formaldehyde because it may degrade under certain use or storage conditions, including elevated temperatures, high humidity levels,^{14,15} presence of acids,¹⁶ and washing with bleaching agents.^{17,18} Finally, because cellulose readily binds with formaldehyde, high levels of formaldehyde have been found in formaldehyde-free fabrics that have been stored with FTR-treated fabrics.⁵

Formaldehyde Textile Resin Dermatitis

Cutaneous intolerance to FTR can include irritant and allergic contact dermatitis, exacerbation of atopic dermatitis, urticaria, and phototoxic eruptions.¹⁷ Erythroderma, petechial eruptions,^{19,20} generalized pruritis,⁷ and lichen amyloidosis²¹ have also been reported. The results of key studies of patients tested with FTRs are summarized in Table 2.

History

Among the first cases of ACD from formaldehyde in textiles were those reported by Marcussen of Denmark from 1934 to 1958. Of 249 cases of “unquestionable formaldehyde eczema,” Marcussen reported that 26 (10.4%) fulfilled five key diagnostic criteria for formaldehyde dermatitis caused by clothing (Table 3).²² Marcussen observed a significant rise in textile contact dermatitis from 1950 to 1958 in concordance with an increase in textiles treated with DMU or MF.²² Of those patients who had textile dermatitis, one-third were suspected to have been sensitized by formaldehyde-containing antiperspirants.

From 1953 to 1961, Cronin saw an increase in the number of cases of textile-related dermatitis due to formaldehyde in Britain.²³ Over those 9 years, 69 patients with positive reactions to formaldehyde were seen, as well as 30 patients with textile dermatitis. Patients suspected of having textile dermatitis were patch-tested with formaldehyde, DMU, MF, and material from suspected garments. Although tests of the garment samples indicated the presence of formaldehyde, only 4 (20%) of 20 patients had positive reactions to the fabric itself.

In 1965, O’Quinn and Kennedy were the first US dermatologists to report contact dermatitis from formaldehyde in clothing.²⁴ In 1992, Fowler and colleagues evaluated a group of 1,022 eczematous patients from Kentucky and New York and found that 17 (1.7%) had formaldehyde resin allergy.²⁵ Severe disease was seen in the older patients (age ≥ 55 years); 3 of 4 patients had generalized erythroderma. The authors suggested that imported textiles may have contributed to these cases of FTR allergy.

Prevalence

The prevalence of ACD from FTRs is unknown. In the 1990s, 1.2 to 2.3% of eczematous patients were estimated to have FTR dermatitis.^{6,25} A 2002 study by Lazarov and colleagues reported a frequency of 4.2% in symptomatic

Israeli patients referred for patch testing to textile allergens.²⁶ Several experts have opined that allergy to formaldehyde resins is underdiagnosed.^{25,27} It is also likely that a surveillance bias exists as patch testing with specific resins is performed only on individuals suspected of having textile allergy.²⁷

Risk Factors

Risk factors for ACD from FTRs may include gender, race, and prior sensitization to formaldehyde. Although recent reports have shown the genders to be equally afflicted,²⁵ earlier studies indicated a female-to-male prevalence of 3:1¹⁴ and 5:1.²³ Postulated reasons for female predominance included higher exposures to crease-resistant garments (especially blouses and dresses), greater frequency of wear, and fashion (tight clothes worn in close contact with the skin).⁵ It has been suggested that men may be more likely than women to be affected as a result of occupational sensitization to formaldehyde.^{23,27} One study proposed that Caucasians may be at a higher risk of allergy to FTRs than black or Hispanic patients.²⁵

In many early reports in the midcentury, ACD from FTRs was felt to have been the result of a prior sensitization to formaldehyde.¹¹ The initial sensitization may have resulted from formaldehyde in consumer products such as antiperspirants, cosmetics, or preservatives.^{22,23} In a 2004 study of 892 patients, Carlson and colleagues found that 7.2% of patients suspected of having a textile allergy had positive reactions to formaldehyde (10% of men and 5% of women tested). It was speculated that many of the men were sensitive to formaldehyde because of occupational exposure in the local automotive industry and that they later had cross-reactions with FTRs.²⁷

Clinical Presentation

In contrast to the often acute and explosive dermatitis seen with allergy to textile dyes, allergy to FTRs commonly results in a more subacute and chronic dermatitis.²⁵ The affected areas are typically sites where the garments fit snugly, with no involvement in areas beneath undergarments. Dermatitis of the anterior and posterior axillary folds (but sparing the vault) is typical. Men often have increased irritation around the neck, where tight-fitting collared shirts are in contact with the skin. Dermatitis from pants treated with FTRs often manifests on the anterior and inner thighs and popliteal fossae. Bedsheets and furniture fabrics may also be a source of textile

Table 2. Major Studies of Patch Testing with Formaldehyde Textile Resins

<i>Study</i>	<i>Allergens Tested</i>	<i>No. of Patients</i>	<i>Patients Reacting Positively</i>
Marcussen ²² Denmark, 1959	Formaldehyde 4% aq	249	10.4% (26/249)
	Personal clothing	249	10.4% (26/249)
Hovding ¹⁴ Norway, 1961	Formaldehyde 4% aq	2,110	6.5% (137/2,110)
		M: 982	M: 3.56% (35/982)
		F: 1,128	F: 9.04% (102/1,128)
Cronin ²³ England, 1963	Formaldehyde 2% aq	30	96.6% (29/30)
	DMU 10% paraffin and MF 10% paraffin	26	73% (19/26) reactive to one or both resin
	Personal clothing	20	20% (4/20)
Malten ²⁹ Netherlands, 1964	DMU 50% aq	27	48% (13/27)
	MF 50% aq	27	11% (3/27)
	MF 70% acetone	27	33% (9/27)
	Formaldehyde 5% aq	27	18.5% (5/27)
Andersen ³³ Denmark, 1982	Formaldehyde 2% aq	15	100% (15/15)
	DMU 10% pet	10	80% (8/10)
	DMDHEU 10% pet	10	30% (3/10)
	EUMF 10% pet	5	60% (3/5)
	DMMPU 10% pet	5	20% (1/5)
	DMPU 10% pet	5	60% (3/5)
Fowler ²⁵ United States, 1992	Formaldehyde 1% aq	17	70.6% (12/17)
	DMDHEU 4.5% aq	17	29.4% (5/17)
	DMPU 5% aq	17	64.7% (11/17)
	TMADU 5% aq	17	47.1% (8/17)
	EUMF 10% pet	17	82.3% (14/17)
	DMU 10% pet	17	58.8% (10/17)
	MF 7% pet	17	64.7% (11/17)
Scherman ⁷ United States, 1998	Formaldehyde 1% aq	10	100% (10/10)
	DMDHEU 4.5% aq	10	100% (10/10)
	DMPU 5% aq	10	40% (4/10)
	TMADU 5% aq	10	80% (8/10)
	EUMF 5% pet	10	60% (6/10)
	DMU 10% pet	10	50% (5/10)
	MF 5% pet	10	70% (7/10)
	DMMDHEU		
	Freerez PKF 5% aq	10	10% (1/10)
	Freerez CLD 5% aq	10	20% (2/10)
	Modified DMDHEU:		
	Fixapret ECO 5% aq	10	10% (1/10)
	Permafresh EFR 5% aq	10	20% (2/10)
	DMeDHEU 5% aq	10	20% (2/10)
Lazarov ²⁶ Israel, 2002	DMDHEU 4.5% aq	286	0.7% (2/286)
	DMPU 5% aq	286	2.1% (6/286)
	TMADU 5% aq	286	2.1% (6/286)
	EUMF 5% pet	286	3.1% (9/286)
	DMU 10% pet	286	2.4% (7/286)
	MF 7% pet	286	2.4% (7/286)
Metzler-Brenckle ³⁴ United States, 2002	Formaldehyde 1% aq	24	67% (16/24)
	EUMF 5% pet		
	NACDG allergen	23	48% (11/23)
	Chemotechnique allergen	24	46% (11/24)
	DMDHEU 4.5% aq	24	67% (16/24)

Table 2. Continued.

Study	Allergens Tested	No. of Patients	Patients Reacting Positively
Lazarov ⁵⁴ Israel, 2004	DMPU 5% aq	24	96% (23/24)
	TMADU 5% aq	23	91% (21/23)
	DMU 10% pet	24	67% (16/24)
	MF 7% pet	24	75% (18/24)
	MF 7% pet	82	20.7% (17/82)
	DMU 10% pet	82	18.3% (15/82)
	EUMF 5% pet	82	20.7% (17/82)
	DMDHEU 4.5% aq	82	9.8% (8/82)
	Modified DMDHEU 5.0% aq	82	17.1% (14/82)
	DMeDHEU 5% aq	82	13.4% (11/82)
Carlson ²⁷ United States, 2004	Formaldehyde 1% aq	852	7.2% (61/852)
	EUMF 5% pet	852	2% (17/852)
	DMDHEU 4.5% aq	398	2.3% (9/398)

aq = aqueous; DMDHEU = dimethylol dihydroxyethyleneurea; DMeDHEU = dimethyl dihydroxyethyleneurea; DMMDHEU = methylated DMDHEU (dimethoxymethyl dihydroxyethyleneurea); DMMPU = dimethylol methoxypropyleneurea; DMPU = dimethylol propyleneurea; DMU = dimethylol urea (urea formaldehyde); EUMF = ethyleneurea/melamine formaldehyde; F = female; M = male; MF = melamine formaldehyde; NACDG = North American Contact Dermatitis Group; pet = petrolatum; TMADU = tetramethylol acetylenediurea.

dermatitis, causing a pattern of dermatitis on the back, posterior legs, and even the face. Pressure, friction, warmth, and perspiration all potentiate ACD from textiles.^{17,28}

Patients with occupational ACD from FTRs present differently, are generally younger, and are more likely to have hand involvement.^{25,27} The dermatitis typically flares during periods of uninterrupted work and improves on weekends or holidays.¹⁸ An interesting case of occupational ACD due to FTRs was reported by Donovan and Skotnicki-Grant in 2006.²⁸ A 49-year-old female pediatrician presented with generalized pruritus that began at the end of the severe acute respiratory syndrome (SARS) epidemic in Toronto, Canada, in 2003. She routinely wore hospital scrubs and also wore an N95 disposable surgical mask and a disposable paper gown for protection against SARS. She developed a pruritic eruption involving the face, neck, flexures, trunk, and legs that worsened while she was

on overnight call. Patch testing revealed positive reactions to MF, DMU, EUMF, quaternium-15, and 1% formaldehyde. The presence of formaldehyde in the patient's N95 mask and scrubs was later confirmed. This case is an example of formaldehyde textile dermatitis from both woven (scrubs) and nonwoven (disposable N95 mask) textile products.

Diagnosis

Diagnosis of ACD from FTRs is based on history, examination, and patch testing with suspected allergens and fabrics.^{14,22} Patients with textile resin ACD may be allergic to the formaldehyde released from the resin or to the resin itself,^{7,23,29} and textile-allergic patients may have reactions to numerous resins.²⁵ The presence of formaldehyde-releasing preservatives in many personal products may also confuse the diagnosis of dermatitis due to FTRs.

Patch testing for textile-finish dermatitis has changed significantly over the past 70 years as the profile of resins used by the industry has changed; however, no "gold standard" currently exists for diagnosis. One cornerstone of the earliest screening method was testing with 2% or 4% aqueous formaldehyde^{14,22}; another was patch-testing with the patient's clothing. In 1964, Berrens and colleagues advised that patch testing with clothing samples was of little benefit.³⁰ Their formaldehyde-sensitive patients who were tested with 600 suspect clothing samples universally had negative results unless there was a hypersensitivity to another allergen (such as fabric dye) in the samples. Schorr

Table 3. Key Diagnostic Criteria for Allergic Contact Dermatitis from Formaldehyde Textile Resins

1. Characteristic location of the eruption, corresponding with contact with clothing
2. Positive patch-test reaction to formaldehyde
3. Patch test positive to suspected fabric
4. Demonstration of free formaldehyde in the suspected fabric
5. Negative reaction to other potential clothing allergens (eg, rubber, nickel, dyes)

Adapted from Hovding G¹⁴; Marcussen PV²²; Berrens L et al.³⁰

and colleagues later stated, “a false-negative patch-test response to the formaldehyde-containing clothing...does not necessarily rule out clothing dermatitis due to formaldehyde.”³¹ Patch testing with personal clothing involves soaking 2 cm squares of fabric separately in 5 cc of water, ethanol 70%, and acetone for 30 minutes. The squares are then removed, and patch testing is performed with the aqueous and alcoholic extracts. The acetone extract (1 cc) is diluted 1:3 in water for patch testing. In addition, a 1 cm piece of clothing moistened with water is applied directly to the skin and occluded for 48 hours.³² If the response is negative at 48 hours, the fabric pieces can be remoistened and re-applied to the same site for a full 96 hours of occlusion.

Patch tests with aqueous formaldehyde have been shown to be highly sensitive (but not specific) for the detection of ACD from FTRs. Based on the results of 1956 study, Cronin recommended patch testing with 2% aqueous formaldehyde.²³ In 1982, Andersen and Hamann found that 2% formaldehyde and urea formaldehyde were the most common allergens for patients sensitive to FTRs.³³ In contrast, in 1992, Fowler and colleagues found that, among 17 patients with contact dermatitis due to FTRs, 5 (29.5%) were patch test negative to 1% aqueous formaldehyde.²⁵ In that study, EUMF 10% in petrolatum was the best screening agent, identifying 14 (82.4%) of 17 patients.

In 1998, Scheman and colleagues reported that glycolated DMDHEU was better at detecting allergy to FTRs⁷; it was also the predominant resin in use at that time. Reactions to the newer low-formaldehyde resins were found to be less common and of less intensity than reactions to the older resins.

In 2002, Metzler-Brenckle and Rietschel reported 188 patients who had suspected textile ACD and who were patch-tested with commercially available resin allergens and formaldehyde.³⁴ For the 24 patients with FTR allergy, DMPU was clearly the best screening agent (a 96% positive rate), followed by TMADU (91%). Neither agent is currently available through allergen suppliers, and neither is used widely by industry at present.³⁴ For the detection of FTR allergy, DMDHEU was found to be the best of the available choices in commercial use today. Currently commercially available textile resin allergens are listed in Table 4.

Other Textile Allergens

In addition to the FTRs, numerous other substances that may contribute to ACD are applied to textiles; it is

Table 4. Commercial Textile Resin Allergens Currently Available

<i>Supplier</i>	<i>Resin</i>
Chemotechnique Diagnostics	Dimethylol dihydroxyethyleneurea (DMDHEU) 4.5% aq
	Urea formaldehyde (DMU) 10% pet
	Melamine formaldehyde (MF) 7% pet
	Ethyleneurea/melamine formaldehyde (EUMF) 5.0% pet
	Dimethyl dihydroxyethyleneurea (DMeDHEU) 4.5% aq
AllergEAZE	Modified DMDHEU 5.0% aq
	DMDHEU 4.5% aq
	EUMF 5% pet

Adapted from Metzler-Brenckle L et al³⁴; Chemotechnique Diagnostics⁵⁵; AllergEAZE.⁵⁸

aq = aqueous; pet = petrolatum.

important to consider testing with these biocides, fire retardants, softeners, water repellants, and antistatic agents, among others.

Biocides inhibit mildew growth and are commonly applied to fabrics that are intended for outdoor use. These compounds include tributyltin oxide, zinc naphthenate, quaternary ammonium compounds, and neomycin. A small epidemic of dermatitis localized to the back, buttocks, and the posterior aspect of thighs and arms of patients in Finland in 2006 and later in England was attributed to dimethyl fumarate (DMF).³⁵ This compound was found in the upholstery of several chairs and sofas manufactured in China and presumably was used as a biocide and mold-preventative agent in the finishing phase of production. Two similar cases were described in Spain in 2009.³⁶ According to both the Finnish and Spanish reports, patch testing with 0.001% aqueous DMF was sufficient to cause a positive reaction. Additional reports of DMF in Chinese boots and shoes causing a blistering dermatitis of the soles have surfaced (D. Sasseville, personal communication, May 2009).

In 2007, a sewing machine operator in Finland patch-tested positively for 2-N-octyl-4-isothiazolin-3-one (OIT),³⁷ a preservative and antimicrobial agent designed for latex and oil paints³⁸ but also used in fabrics, adhesives, wood preservatives, and metalworking fluids.³⁹ This patient had vesicular dermatitis of the palm and fingers of the left hand, which came into contact with mattresses in her work. Patch testing with OIT and with two mattress samples containing the largest amounts of OIT (40 ppm and 50 ppm) yielded positive reactions, and occupational ACD from OIT in mattress textiles was diagnosed.³⁷

Spin finishes are solutions of waxes, surfactants, and biocides that are applied to newly extruded nylon threads to reduce friction and static. Several spin finishes have been implicated in textile-related ACD. Batta and colleagues reported a case of occupational ACD from N,N-methylene-bis-5-methyl-oxazolidine in a nylon spin finish.⁴⁰ Podmore also implicated 2-bromo-2-nitropropane-1,3-diol and methylchloroisothiazolinone and methylisothiazolinone in ACD from spin finishes.⁴¹

An interesting outbreak of dermatitis occurred in 1988 among 19 people employed at two dressmaking mills in England.⁴² The problem affected the workers' hands and periorcular areas and consisted of erythema, pruritus, and scaling that worsened during the week and improved on weekends. The clothing at these mills was treated with Evafanol-AS-1 (Nikka Chemical Industry Co., Ltd., Tokyo, Japan), an anti-pill resin to which 11 of the 19 affected patients were patch test positive. The principle component of this resin is 1,6-diisocyanatohexane, also called hexamethylene diisocyanate (HDI). When 6 of the symptomatic patients were tested with HDI, all had positive reactions (the remaining 13 could not be tested). ACD from isocyanates has not commonly been reported; in this case, however, HDI

was a potent sensitizer for those working for this clothing manufacturer, sensitizing up to 10% of the work force.⁴²

Management of Formaldehyde Textile Resin Allergy

Educating patients is critical to the management of FTR allergy. Once an FTR has been identified as the source of a patient's ACD, avoidance of that resin (through alternate clothing and bedding sources) is imperative because even intermittent exposure can result in persistent dermatitis.²⁷ Patients should be counseled to choose 100% silk, polyester, acrylic, and nylon garments. Linen and denim may also be acceptable choices if they are soft and wrinkle easily. Any garments with labels that say "easy care," "permanent press," or "wrinkle free" should be avoided. Most important, patience and persistence should be encouraged. Table 5 lists some manufacturers that monitor the FTRs in their products.

Some experts also recommend avoidance of formaldehyde-releasing preservatives in personal products. Lists of formaldehyde-free products are available from several sources,⁴³ including the Contact Allergen Replacement Database (CARD).⁴⁴

Table 5. Clothing Retailers That Monitor Formaldehyde Textile Resins in Their Products*

<i>Retailer*</i>	<i>Customer Service Contact Information</i>	<i>Web Site</i>
Bamboosa	(800) 673-8461	www.bamboosa.com
Continental Clothing	(323) 460-7300	www.continental-usa.com
Cottonique	(888) 902-6886	www.cottonique.com
Cottonfield USA	(888) 954-1551	www.cottonfieldusa.com
Cuddl Duds	(800) 627-9261	www.cuddlduds.com
Eddie Bauer	(800) 426-8020	www.eddiebauer.com
GAP Incorporated Brands		
Banana Republic	(888) 277-8953	http://bananarepublic.gap.com
GAP	(800) 427-7895	www.gap.com
Old Navy	(800) 653-6289	http://oldnavy.gap.com
Halo Innovations	(952) 259-1500	www.haloinnovations.com
Hannah Andersson	(800) 222-0544	www.hannaandersson.com
Levi Strauss	(800) 872-5384	www.levistrauss.com
Liz Claiborne	E-mail: consumer_relations@liz.com	www.lizclaiborne.com
L.L. Bean	(800) 441-5713	www.llbean.com
Pottery Barn Kids	(800) 993-4923	www.potterybarnkids.com
PinUp Pets	(718) 544-1525	http://pinuppets.com
Sprout	(310) 717-3152	www.sproutkidscllothing.com
TS Designs	(336) 229-6426	http://tsdesigns.com
Victoria's Secret	(800) 411-5116	www.victoriassecret.com

Adapted from Carlson RM et al²⁷; Scheman A et al.⁴³

*Not all products sold by these companies are free of formaldehyde textile resins or adhere to the Oeko-Tex Standard 100 or the Japanese Law 112 standard. Contact the company to be sure if a specific item uses textile finish chemicals. This list is not exhaustive.

Table 6. Methods of Detecting Formaldehyde in Textiles

<i>Method</i>	<i>Temperature</i>	<i>Fabric Exposed to Acid?</i>	<i>Supernatant Exposed to Acid?</i>	<i>Quantitative Method?</i>
Chromotropic acid	100°C	No	Yes	Yes, with spectrophotometry
Schiff reagent	> 66°C	Yes	Yes	Yes, with spectrophotometry
Modified chromotropic acid	25°C	No	Yes	Yes, with spectrophotometry
Merck test	> 66°C	Yes	Yes	Semiquantitative; comparison of test-strip color to standardized color chart
Japanese Law 112 ⁴⁷	40°C	No	No	Yes, with spectrophotometry

Adapted from Hovding G⁵; Schemen AJ et al⁷; Berrens L et al.³⁰

Detection of Formaldehyde in Fabrics

Tests for detecting formaldehyde in textiles are summarized in Table 6. As early as 1959, Hovding used chromotropic acid to quantify both the free formaldehyde and total formaldehyde (the free molecule plus the molecule that has reacted with the resin and cellulose) content in 256 samples of cellulose-based textiles (including rayon, rayon blends, and cotton) with a modification of a method described by Roff.^{5,45} Of these samples, 227 (89%) were found to contain formaldehyde. The highest quantities of formaldehyde were found in those samples that had been stored in a warehouse for the longest time. Rayon samples had the highest content of free formaldehyde and the highest resin content.

In 1964, Berrens and colleagues examined 600 pieces of clothing from Dutch patients with formaldehyde textile dermatitis.³⁰ The free formaldehyde content of the fabrics was determined with a modified chromotropic acid test. Mean values for the formaldehyde content of the fabric samples ranged from 270 ppm to 750 ppm.

Both the chromotropic acid and Schiff reagent techniques generate formaldehyde from heated fabric samples.^{5,7} The Schiff reagent method also exposes the fabric samples to acid. Because high heat and acid exposure may cause depolymerization of the textile resin, both of these methods not only measure free formaldehyde but may also measure formaldehyde bound in the resin, thereby potentially overestimating the overall formaldehyde content of the tested fabric.^{4,23} Because the modified chromotropic acid method tests fabrics at room temperature,³⁰ it may provide a more accurate measure of free formaldehyde. Scheman and colleagues described a no-longer available test that involved both heating the test fabric and exposing it to acid.⁷ Color was generated and compared with a standardized color chart to estimate formaldehyde content. A similar test kit is currently available from EMD Chemicals (EM Quant

Formaldehyde Test, EMD Chemicals Inc, Gibbstown, NJ).⁴⁶

The Law for the Control of Household Goods Containing Harmful Substances, known as Japanese Law 112 of 1973, describes a specific method of quantifying formaldehyde in textiles⁴⁷ that was internationally standardized as ISO 14184.⁴⁸ In this method, the fabrics are heated only to 40°C and are not exposed to acidic reagents. Chromatography of samples with known formaldehyde content is used to create a curve with which the formaldehyde content of test samples is compared.

Standards and Regulations

Although there are no formaldehyde restrictions or standards for textile items produced or sold in the United States, many other countries have instituted the regulations summarized in Table 7. The 2008 US Consumer Product Safety Commission Modernization Act (H.R. 4040) contains a provision for the Consumer Product Safety Commission (CPSC) to conduct a study of the use of formaldehyde in textiles and apparel,⁴⁹ to begin on August 14, 2010. Industry groups, including the American Apparel & Footwear Association, the National Cotton Council, the National Council of Textile Organizations, the National Retail Federation, the National Textile Association, and the Retail Industry Leaders Association, while supportive of the study, have expressed concern that it may lead to further regulation or action by the CPSC.⁵⁰

In addition to nation-specific standards, the International Oeko-Tex Association in 1992 developed the Oeko-Tex Standard 100,⁵¹ a voluntary standard placing limitations on formaldehyde content in textiles. In 2009, the American Apparel & Footwear Association published the Restricted Substances List, suggesting that its members adhere to these same Oeko-Tex Standard 100 textile formaldehyde parameters.⁵²

Table 7. International Textile Formaldehyde Regulations

Country	Regulation	Textile Formaldehyde Limit
Germany	Gefahrstoffverordnung (Hazardous Substances Ordinance) Annex III, No. 9, 26.10.1993	Textiles that normally come into contact with the skin and release > 1,500 mg/kg formaldehyde must bear the label "Contains formaldehyde. Washing this garment is recommended prior to first time use in order to avoid irritation of the skin."
France	Official Gazette of the French Republic, Notification 97/0141/F	Regulations apply to products that are intended to come into contact with human skin (including textiles, leather, shoes, etc) Textiles for babies: 20 mg/kg Textiles in direct skin contact: 100 mg/kg Textiles not in direct skin contact: 400 mg/kg
Netherlands	The Dutch (Commodities Act) Regulations on Formaldehyde in Textiles (July 2000)	Textiles in direct skin contact must be labeled "Wash before first use" if they contain > 120 mg/kg formaldehyde, and the product must not contain > 120 mg/kg formaldehyde after washing.
Austria	Formaldehydverordnung, BGBl Nr. 194/1990	Textiles that contain $\geq$ 1,500 mg/kg must be labeled.
Finland	Decree on Maximum Amounts of Formaldehyde in Certain Textiles Products (Decree 210/1988)	Textiles for babies aged < 2 yr: 30 mg/kg Textiles in direct skin contact: 100 mg/kg Textiles not in direct skin contact: 300 mg/kg
Norway	Regulations Governing the Use of a Number of Chemicals in Textiles (April 1999)	Textiles for babies aged < 2 yr: 30 mg/kg Textiles in direct skin contact: 100 mg/kg Textiles not in direct skin contact: 300 mg/kg
China	Limits of Formaldehyde Content in Textiles GB18401-2001	Textiles for infants and babies: $\leq$ 20 mg/kg Textiles in direct skin contact: $\leq$ 75 mg/kg Textiles not in direct skin contact: $\leq$ 300 mg/kg
Japan	Harmful Substance-Containing Household Products Control Law No.112	Textiles for infants: not detectable to 15 ppm Textiles in direct skin contact: 75 ppm
Multiple	International Oeko-Tex Association, Oeko-Tex Standard 100	Textiles for infants (40–36 mo): not detectable Textiles in direct skin contact: $\leq$ 75 mg/kg Textiles not in direct skin contact: $\leq$ 300 mg/kg

Adapted from Hong Kong Standards and Testing Centre⁵⁶; Rietschel RL et al⁵⁷; International Oeko-Tex Association.⁵¹

Summary

Although allergic contact dermatitis from formaldehyde textile resins is rare, it is an important condition and one for which the index of suspicion must be high. While essential to diagnosis, proper patch testing is difficult because no gold standard for screening exists, and patients may show significant cross-reactivity not only among the various FTRs but also to other products that contain or release formaldehyde. The key to treatment is educating patients. The patch-testing community needs to maintain a dialogue with textile manufacturers for continued understanding of industry trends and also must advocate clear labeling and adherence to safety standards in the clothing industry.

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