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Threads of Carcinogens – A Study on Cancer Causing Fabrics

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ABSTRACT
Numerous chemicals used in the textile industry are well known to cause both environmental and health issues. The majority of the scientific research on the potentially harmful health consequences of chemicals in that industry relates to human exposure during the production of textiles. However, there is substantially less information available regarding consumer exposure. In this paper, we have evaluated the most recent scientific data on human exposure to chemicals from skin-contacting clothing. The review has mostly concentrated on the correlation between early life exposure to formaldehyde and determining the probability of contracting cancer. A non-negligible presence of some chemicals in some textiles, which could pose a risk to the system, indicates human cutaneous exposure to potentially harmful substances through skin-contact textiles/clothes.

Keywords—formaldehyde, cancer, carcinogens, fabric, textile, dyes

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I. INTRODUCTION

The textile industry is in charge of spinning raw materials like cotton or wool into yarn that is subsequently used to create fabric. The development, production, manufacture, and distribution of textiles are among the procedures used to turn a raw material into a finished product. A range of fabric types, mostly belonging to the natural and synthetic categories, are used by the textile business, which manufactures and sells textiles[1]. Natural materials are those that are obtained naturally from plants and animals, as opposed to synthetic fabrics, which are created in a lab.

The entire populace uses textile items. As a result, even if some demographic groups are more vulnerable than others, all consumers are exposed to the chemicals that are connected to them. New-born’s and infants are particularly vulnerable demographic groups during these early phases since they are so important for their continued development[2].

One of the most frequently utilized compounds in the world is formaldehyde. Furniture, glues, adhesives, insulation, paper coatings, disinfectants, tobacco, cosmetics, and textiles are just a few examples of consumer goods that include them [3]. It was first used in the textile industry in the middle of the 1920s to make fabrics (such as cotton and polyester) more resistant to wrinkling while being worn and washed [4]. These days, it is also utilized for bleaching [5], crosslinking , anti-mould, and dye-fixing[6-8]. However, it is potentially poisonous, and like many other compounds that are added to fabrics, it can irritate the skin and eyes as well as produce sensitization and harmful effects when it comes into contact with the body [9].

The International Agency for Research on Cancer also states that formaldehyde causes human cancer due to adequate evidence linking it to leukaemia, Sino nasal cancer, and cancer of the nasopharynx[10,11]. The content of formaldehyde, as well as the route and timing of exposure, all affect health concerns. Due to the chemical's strong odor, inhalation poses the greatest risk, since it can aggravate asthma, irritate the eyes, nose, and throat, and induce discomfort or nausea [12,13].

Formaldehyde in clothing is linked to dermatitis, eczema, allergies, sensitization, and even enhanced cell proliferation in melanomas [13,14-16]. Clothes are in direct touch with the skin. Even though formaldehyde is harmful, it is being utilized in the textile business today, which is unfortunate. To prevent wrinkles from forming in fabrics, it is specifically employed as a reducing agent during the dyeing and finishing steps (urea-formaldehyde resin)[17].

The objective of the current inquiry was to identify the presence of formaldehyde in clothing, as well as the hazards to human health, especially those connected with "eco-friendly" labelled clothing and clothing worn by infants and young children.

II. FORMALDEHYDE

Methane, often known as formaldehyde, is a colourless gas with a distinctively strong smell. Formalin is an aqueous solution of formaldehyde that has been mixed with 10-15% methyl alcohol to prevent polymerization [18]. This common aldehyde is produced and emitted into the atmosphere while burning materials like wood, coal, charcoal, tobacco, natural gas, and kerosene. Foods like coffee (particularly instant coffee), dry bean curd, cod fish, caviar, maple syrup, and smoked ham naturally contain formaldehyde. It is a possible respiratory carcinogen, an allergy, and an irritant [19]. For those who are allergic to formaldehyde, it may result from the breakdown, conversion, and oxidation of the artificial sweetener aspartame and trigger migraines. Formaldehyde is also used widely in the textile industry as an effective way of keeping the fabric free from wrinkles.

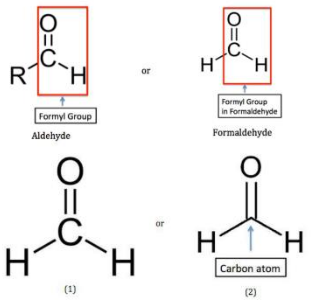

Fig. 1 The ChemicalStructure of Formaldehye

The above figure 1, represents the chemical structure of formaldehyde. The traces of this chemical has been found in the textile industry.

In experimental research by Nyamukamba et al.[20], the concentration of formaldehyde was determined using the method described in ISO 14184-1. This method provides instructions on how to use a water extraction method to measure the amount of free formaldehyde and formaldehyde extracted partially by hydrolysis. Any type of textile sample can be tested using this procedure. When determined by this approach, the procedure is designed to be used in the range of free and hydrolysed formaldehyde on the cloth between 16 mg/kg and 3 500 mg/kg. 16 mg/kg is the bottom limit. The result is recorded as "not detectable" if it falls below this threshold.

III. CHEMISTRY, LAWS AND FORMALDEHYDE CONTENT IN CLOTHINNG

The most important type of fibre for textiles is still cellulose fibres, specifically cotton [21,22]. One major drawback is wrinkling after washing, which is brought on by the cellulose fibres expanding as a result of moisture absorption. Two alternative chemical methods can be employed to address this. To prevent water molecules from easily penetrating the fibre, the original incorporates a polymerized finish into the fibre pores. This is how compounds containing urea and melamine and formaldehyde work. The most recent method involves reacting multifunctional cross-linking agents with nearby cellulose molecules' hydroxyl groups, which prevents cellulose fibre swelling. Due to the need for formaldehyde in resin production, subsequent resin degradation during storage, wear-related sweating, acid washing, or chlorine use during laundry, the majority of textile finishes produce formaldehyde.

A. Urea–formaldehyde and melamine/formaldehyde products.

The polymerization of urea and formaldehyde with a curing agent produces urea-formaldehyde (methyl urea) resins. Monomethylol urea, dimethylol urea (oxymethurea, carbamol), and methyleneurea are the intermediate intermediates. The methylolureas are condensed to low-molecular polymers in the second stage using methylene and methylene-ether linkages, which then polymerize into three-dimensional resin structures in the spaces between the textile threads. More than 1000 parts per million of free formaldehyde can be found in these resins. They are less resistant to hydrolysis, which releases formaldehyde, especially in hot and humid environments. These finishes are no longer permitted for usage on apparel in the majority of nations. It was estimated that 6% of US durable press textiles still had urea-formaldehyde treatments in 1990, though [23,24].

Melamine and formaldehyde condense to generate melamine/formaldehyde resins. The primary compounds are trimethylolmelamine and hexamethylolmelamine, which are formed when three and six molecules of formaldehyde are combined with melamine, respectively. In the spaces between the fibres, they polymerize into resins to form three-dimensional resin structures. Such resins contain some unpolymerized methylol residues that may later break down into free formaldehyde. Even while they release less formaldehyde than urea-formaldehyde finishes, these textile finish resins nonetheless contain and emit significant levels of the chemical [25]. (which may not be correct). It was estimated that 20% of US durable press textiles still had melamine/formaldehyde treatments in 1990, though [23,26].

B Cyclic urea derivatives

Concern over formaldehyde during the 1960s and 1970s led to the creation of cellulose cross-linking finishes with low levels of free formaldehyde, and eventually, totally formaldehyde-free materials. Cyclized urea derivatives are contemporary textile finish resins. These are reticulating agents made from cyclized nalkoxymethyl urea. Cellulosic textile fibres' hydroxyl (OH) groups crosslink with their N-methylol (N-CH2 -OH) groups to produce stable ether bonds. This reaction is started by acid catalysts like magnesium chloride or zinc nitrate.

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Legislation and Voluntary Restrictions

To lower the danger of contact dermatitis and other negative effects among their populations, some nations have imposed legislative restrictions on the amount of formaldehyde in textile products. Japan was first in 1973 (which caused formaldehyde sensitivity to dramatically decline in the years that followed) (27) and was followed by Finland (28). Additionally, China, Norway, France, Japan, and the Netherlands have legal restrictions (29, 30). Depending on the regulations, formaldehyde levels for clothing for babies and infants should typically be between 20 and 30 parts per million, for clothing in direct contact with the skin, no more than 75 to 100 parts per million, and for clothing and textiles not in direct skin contact, no more than 300 to 400 parts per million. Although formaldehyde use in textiles is not restricted in the USA, the US Congress passed the Consumer Products Safety Commission Modernization Act of 2008 in July 2008, which mandates that (within 2 years) a study be conducted on the use of formaldehyde in the production of textile and apparel articles to identify any risk to consumers.

IV. FORMALDEHYDE MEASUREMENT METHODS

Material

Table 1 provides a description of the sample materials used for the experiments. The remaining fabric remnants were repackaged in the original packaging after the samples had been reduced to size (if available). In order to reduce any potential emission loss, they were additionally coated in aluminum foil with a thickness of 30 nanometers and an aluminum composition of over 99%.

Both the 2,4-dinitrophenylhydrazine (DNPH) method and the online acetylacetone (Acac) method were used to analyze the formaldehyde levels in the air.

Online Measurement By Means Of The Acetylacetone Method

The Hantzsch dihydropyridine synthesis forms the basis of the acetylacetone technique. Formaldehyde produces 3,5-diacetyl-1,4-dihydrolutidine (DDL), acetic acid, and water as a byproduct of its reaction with acetylacetone (2,4-pentanedione) and ammonium acetate. Then, DDL is examined by 520 nm fluorescence spectrometry (Salthammer 1993). The formaldehyde monitor AL 4021 was used to do the online measurement. The DNPH approach, which is detailed below, was used to frequently validate the measurements through parallel measurements.

Within the framework of earlier comparison measurements, all formaldehyde values were in agreement with the findings of the control samples.

DNPH method

The analysis of low-molecular-weight carbonyl compounds in air samples is possible through the use of the DNPH technique. A 75 L volume is drawn over an S10-DNPH cartridge at a flow rate of 1 L/min.Through the use of HPLC-UV elution, additional analysis is carried out.

Emission chambers

1 m3 glass chambers were used for the studies involving emission and doping (ISO 16000–9 2006). Measurements of diffusion were made in a double chamber. This consists of two glass chambers that are separated by the material being studied and have a combined volume of 24 L each (see Fig.).2

Temperature, relative humidity, and air exchange can all be controlled separately in each chamber.

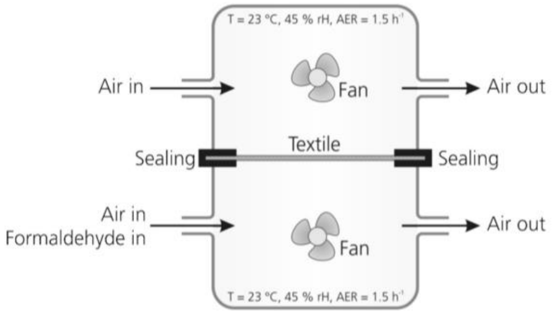


Fig. 2 Diffusion tests in the double chamber. T Temperature, rH relative humidity, AER air exchange rate.

Table 1: Information on clothing samples

Sample	Application	Material	Packaging	Country of production acc. to label
C_c	Curtain	100% cotton	Yard goods	–
C_{pe}	Curtain	100% polyester	Yard goods	–
C_{pa}	Curtain	100% polyacrylic	Yard goods	–
C_v	Curtain	100% viscose	Yard goods	–
T_c	Clothing pants	100% cotton	Original packaging	India
S_c	Clothing T-shirt	100% cotton	Original packaging	Germany
T_l	Clothing pants	100% linen	Original packaging	China
S_l	Clothing T-shirt	100% linen	Original packaging	Bangladesh
T_{pe}	Clothing pants	100% polyester	Original packaging	Germany
S_{pe}	Clothing T-shirt	100% polyester	Original packaging	–
T_{pa}	Clothing pants	100% polyamide	Original packaging	Germany
S_{pa}	Clothing T-shirt	100% polyamide	Original packaging	Indonesia
$S_{c,pe}$	Clothing shirt	55% cotton, 45% polyester	Without packaging	Bangladesh
$S_{v,e}$	Clothing shirt	96% viscose; 4% elastane	Without packaging	Bangladesh

V. EARLY-LIIFE EXPOSURE TO FORMALDEHYDE THROUGH CLOTHING

Numerous substances, some of them potentially dangerous, are found in clothing. Recently, there has been an increase in demand for environmentally friendly clothing, which uses organic cotton. Environmentally friendly fabric manufacture does not, however, forgo the use of harmful materials like formaldehyde, a proven human carcinogen. The objective of the current experiment was to find out whether formaldehyde was present in conventional and eco-friendly apparel worn by expectant mothers, infants, and toddlers on the Catalan (Spain) market. By comparing the reduction of formaldehyde in washed and unwashed clothing, the potential impacts of washing were also examined.

20% of samples had formaldehyde identified, with a mean level of 8.96 mg/kg. Surprisingly, the levels of formaldehyde in eco-friendly clothing were greater than in conventional clothing (10.4 vs. 8.23 mg/kg). These variations, however, were only statistically significant (p 0.05) for pregnant women's bras (11.6 vs. 7.46 mg/kg) and underwear (27.1 vs. 6.38 mg/kg). Three vulnerable demographic groups—pregnant women, infants, and toddlers—had their dermal exposure and health concerns evaluated. In general, infants were exposed to higher levels of radiation (up to 1.11 103 mg/kg/day) than other age groups (2.58 104 and 4.50 103 mg/kg/day for toddlers and pregnant women, respectively).

Based on the mean concentration of each garment, dermal exposure to formaldehyde was evaluated for the same population categories, including expectant mothers, newborns, and children between the ages of 12 and 36 months. The total exposure, taking into account that people wear multiple articles of clothing at once, and the individual exposure, taking into account each textile category, are summarised in Table 2. The category with the highest exposure was determined to be baby socks (5.13 104 mg/kg/day), followed by pants/leggings/jeans (3.30 104 mg/kg/day). In general, infants had a 2-fold higher overall exposure (1.11 103 mg/kg/day) than toddlers (4.50 104 mg/kg/day), whereas pregnant women had the lowest exposure to formaldehyde.

Table 2: Dermal exposure (mg/kg/day) to formaldehyde through clothing.

		Dermal Exposure per Item	Total Exposure (Non-Cancer Risk)
Pregnant women	T-shirts	5.23×10^{-5}	2.58×10^{-4}
	Jeans/leggings	1.48×10^{-4}	
	Bras	1.54×10^{-5}	
	Panties	4.23×10^{-5}	
Babies (<12 months old)	Pyjamas	3.07×10^{-4}	1.11×10^{-3}
	Bodysuits	2.92×10^{-4}	
	Socks	5.13×10^{-4}	
Toddlers (12–36 months old)	Pyjamas	2.68×10^{-4}	4.50×10^{-4} * 1.44×10^{-4} **
	Underwear	2.99×10^{-5}	
	Dresses	1.14×10^{-4}	
	T-shirts	8.96×10^{-5}	
	Trousers	3.30×10^{-4}	

* Dressed with underwear, T-shirt and trousers. ** Dressed with underwear and dress.

The most frequent side effects of brief skin contact with formaldehyde are likely dermatitis or local allergic responses. The amount of formaldehyde present in garments was used in the current investigation to assess the risk of sensitization. All of the garments had formaldehyde extraction levels that were at least ten times lower than NOAEC (0.005% w/w), with 0.1% serving as the threshold at which evidence of sensitization could be seen.

The dermal exposure and RfD estimates of the hazardous quotient (HQ) revealed that it was significantly lower than the limit value of unity. It is obvious that formaldehyde in garments does not currently pose a risk to the general public for non-cancer risks. Contrarily, the cancer risks for expectant mothers ranged from 1.38 107 to 9.49 107, for infants from 4.61 107 to 2.76 107, and for toddlers from 8.13 107 to 2.97 106. All values fall below the Spanish cutoff level of 105.

VI. EFFECT OF FORMALDEHYDE

When formaldehyde is present in the air, certain people may feel unpleasant symptoms like watery eyes, burning sensations in the eyes, nose, and throat, coughing, wheezing, nausea, and skin irritation at levels above 0.1 ppm.Some people react significantly to the same amount of formaldehyde while others do not.

Less is known about the potential long-term health implications of formaldehyde exposure, despite the fact that the short-term health impacts are well-established.Researchers discovered in 1980 that rats exposed to formaldehyde could develop nasal cancer. This finding raises the prospect that exposure to formaldehyde could result in cancer in humans. Formaldehyde was labeled a probable human carcinogen by the U.S. Environmental Protection Agency (EPA) in 1987 when exposure levels were unusually high or sustained.

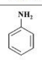
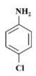
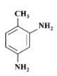
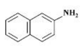
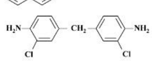
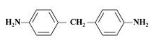
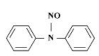
Since then, research on humans has shown a connection between formaldehyde exposure and various malignancies. Formaldehyde is categorized as a human carcinogen by the International Agency for Research on Cancer (IARC).In 2011, the National Toxicology Program, an interagency program of the Department of Health and Human Services 12th Report on Carcinogens listed formaldehyde as a recognized human carcinogen.

VII. AMINES

Chemical compounds known as aromatic amines typically have one or more aromatic rings with one or more amino substituents in their molecular structure. The simplest one is aniline, whereas the most complex ones have conjugated aromatic or heterocyclic rings structures, as well as many substituents.

Table 3 describes some amines that are encountered[32]:

Table 3: Amines

Name/CAS number	Chemical structure	Major origins	Potential impact
Aniline		Manufacture of isocyanates, rubber, dyes, explosives, pesticides, pharmaceuticals. Oil refining. Tobacco smoke. Forest fires.	VOC with ozone-forming potential; Toxic to aquatic life; Possibly carcinogenic and genotoxic
4-Chloroaniline		Manufacture of dyes, pesticides, various chemicals	Toxic to humans Carcinogenic and genotoxic
Toluene 2,4-diamine		Manufacture of toluene diisocyanate (for elastomers), dyes, resins, fungicides	VOC Toxic to humans and aquatic life Possibly carcinogenic and genotox
2-Naphthylamine		Manufacture of dyes	Toxic to humans Carcinogenic
4,4′-Methylenebis(2-chloroaniline)		Manufacture of polyurethanes	VOC Toxic to humans and aquatic life Possibly carcinogenic and genotox
4,4′-Methylenedianiline		Manufacture of polyurethanes, dyes, epoxy resins	VOC. Recalcitrant adsorption onto particulate matte Toxic to humans and aquatic life Possibly carcinogenic and genotox
N-Nitrosodiphenylamine		Manufacture of dyes, pharmaceuticals, rubber	Harmful to humans Possibly carcinogetic

The dye production business was the first to raise issues with human exposure to carcinogenic aromatic amines as early as the late eighteenth century [33]. Therefore, the focus of studies on the toxicity and carcinogenicity of aromatic amines as well as initiatives to enhance occupational health was primarily on intermediates used in dye manufacture, and then on amines used in other sectors of the chemical manufacturing industry. More recently, it has been thought that the likelihood of manufactured azo dyes decomposing into their constituent amines while being used poses a health risk. Although the International Agency for Research on Cancer only lists 8 dyes in Group 2B, a few of which are azo dyes, and only benzidine-based dyes in Group 2A, it has been shown that azo bond reduction can result in aromatic amines under a variety of ecological conditions, including those found in mammal digestive tracts [34]. Therefore, the reduction products of azo dyes have received the majority of the attention regarding any potential risks associated with their use. As of September 2003, all EC member states must implement the 19th amendment to Directive 76/769/EEC (Directive 2002/61/EC, Table 4), which has established at the European level the need for attention to the unique situation of azo dyes used in the production of textiles. Directive 2002/61/EC is the first harmonised international strategy for the control of aromatic amine emissions specifically resulting from the dyeing of textiles with azo dyes. It follows the earlier initiative of the German Consumer Goods Ordinance and the subsequent regulations appearing in several member states.

Table 4: Aromatic amines listed in some hazardous substances emission inventories and restriction of use regulations, complemented with their status in the carcinogenic substances list of the International Agency for Research on Cancer[35-39]

CAS number	Name	TRI (USA)[a]	Pollution Inventory (UK)[b]	Directive 76/769/EEC[c]	Directive 2002/61/EC[d]	IARC Classification[e]
92-67-1	4-Aminobiphenyl	carcinogen	–[f]	carcinogens: cat. 1	√[g]	Group 1
62-53-3	Aniline	toxic	√	–	–	Group 3
90-04-0	*o*-Anisidine	carcinogen	–	carcinogens: cat. 2	√	Group 2B
134-29-2	*o*-Anisidine hydrochloride	carcinogen	–	–	–	–
104-94-9	*p*-Anisidine	toxic	–	–	–	Group 3
92-87-5	Benzidine	carcinogen	–	carcinogens: cat. 1	√	Group 1
106-47-8	*p*-Chloroaniline	carcinogen	–	carcinogens: cat. 2	√	Group 2B
95-69-2	*p*-Chloro-o-toluidine	carcinogen	–	–	√	Group 2A
120-71-8	*p*-Cresidine	carcinogen	–	–	√	Group 2B
615-05-4	2,4-Diaminoanisole	carcinogen	–	–	√	Group 2B
39156-41-7	2,4-Diaminoanisole sulfate	carcinogen	–	–	–	–
101-80-4	4,4′-Diaminodiphenyl ether	carcinogen	–	–	√	Group 2B
2687-25-4	2,3-Diaminotoluene	–	√	–	–	–
95-80-7	2,4-Diaminotoluene	carcinogen	√	carcinogens: cat. 2	√	Group 2B
823-40-5	2,6-Diaminotoluene	–	√	–	–	–
496-72-0	3,4-Diaminotoluene	–	√	–	–	–
25376-45-8	Diaminotoluene (mixed isomers)	carcinogen	–	–	–	–
99-30-9	2,6-Dichloro-4-nitroaniline	toxic	–	–	–	–
91-94-1	3,3′-Dichlorobenzidine	carcinogen	–	carcinogens: cat. 2	√	Group 2B
612-83-9	3,3′-Dichlorobenzidine dihydrochloride	carcinogen	–	carcinogens: cat. 2	–	–
64969-34-2	3,3′-Dichlorobenzidine sulfate	carcinogen	–	carcinogens: cat. 2	–	–
119-90-4	3,3′-Dimethoxybenzidine	carcinogen	–	carcinogens: cat. 2	√	Group 2B
20325-40-0	3,3′-Dimethoxybenzidine dihydrochloride	carcinogen	–	carcinogens: cat. 2	–	–
111984-09-9	3,3′-Dimethoxybenzidine hydrochloride	carcinogen	–	carcinogens: cat. 2	–	–
838-88-0	3,3′-Dimethyl-4,4′-diaminodiphenylmethane	–	–	carcinogens: cat. 2	√	Group 2B
121-69-7	*N,N*-Dimethylaniline	toxic	–	–	–	Group 3
119-93-7	3,3′-Dimethylbenzidine	carcinogen	–	carcinogens: cat. 2	√	Group 2B
612-82-8	3,3′-Dimethylbenzidine dihydrochloride	carcinogen	–	carcinogens: cat. 2	–	–
41766-75-0	3,3′-Dimethylbenzidine dihydrofluoride	carcinogen	–	carcinogens: cat. 2	–	–
122-39-4	Diphenylamine	toxic	–	–	–	–
101-14-4	4,4′-Methylenebis (2-chloroaniline)	carcinogen	√	carcinogens: cat. 2	√	Group 2A
101-61-1	4,4′-Methylenebis (*N,N*-dimethyl)benzenamine	carcinogen	–	–	–	Group 3
101-77-9	4,4′-Methylenedianiline	carcinogen	√	carcinogens: cat. 2	√	Group 2B
134-32-7	1-Naphthylamine	carcinogen	–	–	–	Group 3
91-59-8	2-Naphthylamine	carcinogen	–	carcinogens: cat. 1	√	Group 1
100-01-6	*p*-Nitroaniline	toxic	–	–	–	–
99-59-2	5-Nitro-o-anisidine	toxic	–	–	–	Group 3
99-55-8	5-Nitro-o-toluidine	toxic	–	–	√	Group 3
55-18-5	*N*-Nitrosodiethylamine	carcinogen	–	–	–	–
86-30-6	*N*-Nitrosodiphenylamine	toxic	–	–	–	Group 3
156-10-5	*p*-Nitrosodiphenylamine	toxic	–	–	–	Group 3
95-54-5	1,2-Phenylenediamine	toxic	–	–	–	–
108-45-2	1,3-Phenylenediamine	toxic	–	–	–	Group 3
615-28-1	1,2-Phenylenediamine dihydrochloride	toxic	–	–	–	–
624-18-0	1,4-Phenylenediamine dihydrochloride	toxic	–	–	–	–
106-50-3	*p*-Phenylenediamine	toxic	–	–	–	Group 3
139-65-1	4,4′-Thiodianiline	carcinogen	–	–	√	Group 2B
636-21-5	*o*-Toluidine hydrochloride	carcinogen	–	–	–	–
95-53-4	*o*-Toluidine	carcinogen	–	carcinogens: cat. 2	√	Group 2A

The assessment of consumers' exposure to chemicals in textiles is just as crucial as hazard characterization. The following equation determines the internal exposure Dint ((µg/kg BW/day)[40]:

$$D_{int} = \frac{A_{skin} \times \mathrm{m}_{prod} \times c_{subts} \times f_{use} \times F_{migr} \times F_{pen}}{BW}$$

Where F_{mgr} (µg/µg) is the proportion of the substances that will be released while wearing, and F_{pen} (µg/µg) is the proportion that penetrates the skin. The exposed skin area A_{skin} (cm^2) , the area density of the textile m_{prod} (g/cm^2), the amount of chemical in the textile c_{subst} (µg/g), the wearing frequency f_{use} (1/day), and the body weight BW (kg) are also required.

VIII. PERCUTANEOUS ABSORBTION OF DYES

The evaluation of internal exposure continues with the consideration of percutaneous absorption. molecules that effectively pass through one type of skin and then other layers can then enter the bloodstream and become available to the body's systems. This process is mirrored in in vitro systems by its appearance in the receptor fluid, such as Franz diffusion cells.

After topically applying the 14C-labeled tri-azo dye Direct Black 38 (DB38; 782 g/mol) or the tetra-azo dye Direct Black 19 (DB19; 840 g/mol), Aldrich et al. [42] investigated the excretion of radioactivity in Fischer-344 rats and New Zealand rabbits. The following specific activities were used to obtain the dosing parameters: In an alkaline sodium carbonate buffer, the dyes were dissolved at concentrations of 3330 g/mL (DB38) and 17,000 g/mL. (DB19). On shaved dorsal skin, dye solutions of 27, 3, or 8 L/cm2 were applied, producing surface dosages of 89 g/cm2 DB38 and 44 g/cm2 (rat) or 131 g/cm2 (rabbit) DB19. Application areas were shielded using a barrier assembly without occlusion, and color solutions were dried using a hair dryer. During the six days that the dye was on the skin, urine and feces samples were taken every day.

At least during the first few days, the cumulative excretion of radioactivity (represented as dye equivalents) increased virtually linearly in both the urine and the feces. With the exception of rabbits with DB19, where fecal discharge was only noticed on day 1. (Fig. 3). Since the cumulative excretion profiles are linear, it follows that there is a steady-state flow of dye equivalents via the skin and animals. The total excretion of DB38 through both routes amounts to percutaneous fluxes of 0.0008 g/cm2 per hour in rats and 0.0304 g/cm2 per hour in rabbits. For DB19, values of 0.0001 (for rats) and 0.0004 g/cm2 /h (for rabbits) were achieved, which are noticeably lower levels. The azo linkages of the dyes were broken by the skin microbiota (and presumably also by skin enzymes), releasing 14C-labeled cleavage products, according to the scientists' interpretation of the excreted radioactivity. Additionally, the increased excretion in DB38-treated rabbits compared to rats may be due to variations in the skin's permeability and microbiota.

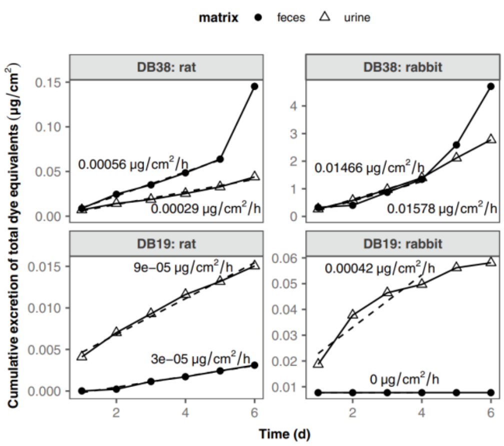


Fig. 3 After dermal application of 89 g/cm2 Disperse Black 38 (DB38) or of 44 g/cm2 (rat) and 131 g/cm2 (rabbit) Disperse Black 19, the cumulative excretion of total dye equivalents in faeces and urine of Fischer-344 rats and New Zealand rabbits was measured (DB19). The periods of constant excretion are shown by regression lines (dashed lines), and the accompanying values show the excretion rates. Please

take note of the various y-axis scales. Information from Aldrich et al

IX. THE RISK OF AMINES

Migration values pertain to a specific dye-fabric system because they are influenced by numerous parameters. However, for new, unwashed fabrics that were dyed utilizing the cutting-edge technique, the research reported here demonstrated maximum migration values of 0.5-1% of the dye load (maximum 0.83 g/ cm2). If any data are missing, these can be used as default values. Although maximum migrations of up to 11.9 g/cm2 (5.4%) were recorded for textiles with poor color fastness, higher migration rates cannot be completely ruled out. Depending on the experimental design and dye characteristics, the reported cutaneous absorption of textile dyes varies significantly among studies.

The maximal percutaneous flow of 0.2 g/cm2/h was discovered with a surfactant substance as the solvent and a high surface dose of 200 g/cm2, despite the fact that numerous trials revealed no absorption through human skin. With sweat solution and a dose that was realistically applied (4.2 g/cm2), the greatest flow through human skin was 0.09 g/cm2/h.

X. CONCLUSION

Formaldehyde was discovered in 20% of the samples that were examined, with amounts ranging from 12.8 mg/kg to 55.7 mg/kg. Formaldehyde levels in every textile sample were under the EU recommendations (75 mg/kg). In comparison to printed clothing (7.07 mg/kg), the levels in colored apparel (10.2 mg/kg) were greater. Regardless of the fabric used to produce the clothes, cotton clothing exhibited higher formaldehyde concentrations than synthetic clothing (7.51 mg/kg vs. 6.66 mg/kg). It's fascinating to observe that eco-friendly apparel contained formaldehyde. In some instances (such as toddler gowns and T-shirts, pregnant women's undergarments, etc.), even higher levels than in traditional clothing Even so, skin contact with formaldehyde through clothes was not substantial, estimated to be about 10-times lower than formaldehyde inhalation, which is the most pertinent exposure route to this toxin. Additionally, the risks were below the safety limits for both carcinogenic and non-carcinogenic effects. Washing all textile products before use is a straightforward but highly efficient method of lowering these risks. In addition to formaldehyde, clothing may also contain other harmful chemicals. Therefore, future health risk analyses should take into account individual susceptibility when evaluating a scenario with multiple exposures and multiple chemicals.

Migration values pertain to a specific dye-fabric system because they are influenced by numerous parameters. However, for new, unwashed fabrics that were dyed utilizing the cutting-edge technique, the research reported here demonstrated maximum migration values of 0.5-1% of the dye load (maximum 0.83 g/ cm2,). If any data are missing, these can be used as default values. Although maximum migrations of up to 11.9 g/cm2 (5.4%) were recorded for textiles with poor color fastness, higher migration rates cannot be completely ruled out. Depending on the experimental design and dye characteristics, the reported cutaneous absorption of textile dyes varies significantly among studies. The highest percutaneous flux of 0.2 g/cm2/h was discovered using a surfactant substance as a solvent and a high surface dose of 200 g/cm2, despite the fact that numerous trials revealed negligible absorption through human skin. With sweat solution and a dose that was realistically applied (4.2 g/cm2), the greatest flow through human skin was 0.09 g/cm2/h.

Clothes and fabric remain in direct contact with our skin. As a result the exposure to the chemicals and carcinogens in it are high. The clothes must contain minimal amount of these chemicals. Organic clothes must be really organic.

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