

Detection of Heavy Metals and Formaldehyde in Fabric Rolls used for Manufacturing Adult Clothing

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Abstract :

Textile fabrics are treated with toxic heavy metals (e.g., lead, nickel, chromium, etc.) and chemicals like formaldehyde to impart certain desired fabric properties. If not removed from fabrics after application, they have been reported to cause diseases and discomfort. Because of these, it is important that the concentrations of heavy metals, formaldehyde, and pH levels in fabrics must meet the recommended limits. This study focuses on the determination and detection of metals and chemicals found in fabric rolls used to make clothing in South Africa. Heavy metal results showed that all fabrics contained heavy metals, except for brown polycotton fabric. The heavy metals concentrations in dark-blue polycotton fabric were higher than prescribed Oeko-Tex limits except for copper metal. White cotton, black polyester, and navy-blue wool fabrics exceeded the recommended limit for nickel. Chromium was found only in dark-blue polycotton and navy-blue wool fabric and its concentration exceeded the recommended limit only in dark-blue polycotton fabric whereas for navy-blue wool fabric it was below the limit. All fabrics contained formaldehyde, and its concentration was below the recommended limit. The pH of white cotton and black polyester fabrics was within the recommended range of 4 - 7.5 while that of dark-blue polycotton, brown polycotton, and dark-blue wool fabrics was above the limit.

Keywords: detection, Fabrics, formaldehyde, heavy metals, recommended limits

Citation: Lebo Maduna, Pardon Nyamukamba, Asis Patnaik, "Detection of Heavy Metals and Formaldehyde in Fabric Rolls used for Manufacturing Adult Clothing", *Journal of the Textile Association*, **86/3**(Sept-Oct,25), 259-263, <https://www.doi.org/10.63665/>

Article History : Received : 19-08-2025, Revised: 21-09-2025, Accepted: 25-09-2025

1. Introduction

The rapid growth of the textile industry has led to environmental and health concerns due to toxic chemicals being used in the processing and finishing of textile products. In some countries, the textile industry accounts for the largest share of the economy. Health and environmental concerns are being raised as some of the chemicals are toxic and not easily degraded. Some of the toxic chemicals are formaldehyde, pentachlorophenol, halogens like chlorine, and heavy metals such as cadmium (Cd), zinc (Zn), copper (Cu), lead (Pb), mercury (Hg), iron (Fe), argon (Ar), cobalt (Co) and chromium (Cr). In humans, they can accumulate in the body as they are not easily degraded. High levels of chemicals in the body have been associated with lung, liver, brain, and kidney diseases [1, 2]. Accumulation in the environment contaminates the soil and water and as such the health of plants and aquatic animals is negatively affected. Manufacturing processes are the main source of heavy metals. Because of the toxicity of heavy metals, some countries have adopted stringent measures to limit the amounts that can be released into the environment [1].

Heavy metals and chemicals like formaldehyde are used in textile processes for dyeing and printing as well as to impart antimicrobial, water repellences, flame retardancy, and

crease-resistant properties. In fibres like cotton, the main source of toxic chemicals is attributed to the chemicals used to treat the fibres. Human beings can acquire these chemicals through direct skin contact, ingestion, and inhalation. Direct skin fabric contact increases the risk of exposure because the body is in constant direct contact with clothes [2, 3]. Sweating also increases the risk of absorbing the chemical residues remaining in finished clothing through direct contact with the skin. The wearer can develop skin infections. Some authors reported that the presence of metals in branded and non-branded clothes for both children and adults was lower, and as such was considered safe [2, 4]. Identifying the source of toxic heavy metals and chemicals in the supply chain is not easy because not all companies involved in the supply chain keep records about the heavy metals or chemicals used in their manufacturing processes. The rapid changes being driven by fashion trends further complicate the identification of sources. Furthermore, materials used in the industry are sourced from or finished in different parts of the world [3].

The main health risk associated with heavy metals and chemicals contained in fabrics is skin irritation due to constant human skin and fabric contact. The amount that can be leached from the fabric due to sweating varies as different individuals have different sweating rates. Lead can cause birth defects, behavioural problems, liver problems, high blood pressure, neurological degeneration, and bone

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deformities. Exposure to high levels of nickel can lead to skin irritation, liver and heart problems. Cadmium can cause respiratory and metabolic problems. Arsenic can accumulate in the liver and is indicated to cause metabolic problems. Chromium has been reported as a carcinogenic, and it is reported to destroy body fat [5, 7]. Cobalt causes skin eczema and lung infection. Formaldehyde is a chemical used to treat textile fabrics is carcinogenic and also causes reproductive, developmental, and skin problems [8, 9]. It also can cause skin irritation. Formaldehyde is used in textile finishing to improve fabric resistance to shrinkage and loss of shape. Not all countries have recommended limits for the presence of metals and chemicals in textile products. In Japan, for formaldehyde, the maximum limits for children under the age of 2 years are 16 µg/g and 75 µg/g depending on the type of textile product. In Finland, it is 30 µg/g and 100 µg/g which are higher than that of Japan [10, 11]. The pH of clothing is another factor that should be taken into consideration when testing the fabrics as it causes skin irritation. The human skin pH is about 5 and the pH of clothing must be closer to a pH of 5 to avoid skin irritation [6].

It is recommended that new clothing should be washed before use because clothing does come with labels indicating the toxic metals or chemicals they contain. Buying from sellers who adhere to the recommended minimum limits of chemicals in clothing is also important to minimise risk [12]. One such method that can be used to determine if clothing is safe for humans about the presence of metals or chemicals in clothing is the Oeko-Tex Standard 100 [13].

Other sources for heavy metal release are laundry and environmental weathering. During laundering dark colour garments, there are bleeding of these colours resulting in the release of the heavy metal to the wastewater sources. It not only contaminates water sources, also it contaminates soil and subsequently affecting aquatic and soil ecosystems [14]. Due to the environmental weathering effect like ultraviolet rays (UV) rays from sun, temperature, humidity, rain, dew, discarded clothing's are sources of heavy metal release into the environment. The fabric structure breakdown due to the prolonged environmental exposure resulting in the heavy metal release into the environment. This heavy metal may have adsorbed into the fabrics during the usage phase or added to the fabrics as a finishing or coatings during the manufacturing stages. Apart from the water and soil pollutions, heavy metals can change the soil ecosystems affecting microbial growth which are important to maintaining a good soil condition [15]. Furthermore, increase in the toxicity levels of heavy metals due to the environmental exposure can lead to an adverse effect on the environment and ecosystem [16].

Some of the potential solutions to reduce release of formaldehyde from the fabrics is to wash the new garment with detergents before use and then air drying [17, 18]. Using

hot water during washing also assisted in removing residual formaldehyde from the garments. Similarly, alternative bio-based phenol-formaldehyde resins with low-emission can be used to reduce the release of formaldehyde from the fabrics [19]. Furthermore, enzyme treatment can break the harmful formaldehyde by converting into water and CO₂ [20].

When the concentrations of toxic metals and chemicals are above the recommended limits, clothing is regarded as unsafe [6]. The recommended limits for children are lower than that for adults as children's immune system is not yet as fully developed. Children are at a higher risk because they crawl on the floor and put textile products in their mouths. Human skin and fabric contact is considered the main direct route that humans acquire heavy metals and determining the amount of these metals in clothing is important in reducing the risk of acquiring them. This study focuses on the determination and detection of metals and chemicals found in fabric rolls used to make clothing in South Africa. Pb, Cd, Cr, Ni, and as pose a health risk to humans and the environment due to their toxicity. The aim is to determine the concentration of the contaminants to ensure that they are within Oeko-Tex standard 100 acceptable limits. As a result, the pH levels, formaldehyde levels, and extractable heavy metals were examined.

2. Materials and Methods

2.1 Materials

The fabric rolls, viz. dark-blue polycotton fabric, brown polycotton fabric, navy-blue wool fabric, white cotton fabric, and black polyester fabric were procured from the local fabric suppliers. Furthermore, these suppliers are scouring fabrics from manufacturers/finishers mainly from Asian countries, it is difficult to trace the actual source of materials. Sodium chloride (NaCl), ammonium chloride (NH₄Cl), acetic acid (CH₃COOH), lactic acid, ammonium acetate, and acetylacetone were purchased from Sigma Aldrich, South Africa.

2.2 Determination of heavy metals using artificial sweat solution

The determination of heavy metal method was performed according to ISO 3160/2. Weigh about 20g NaCl, 17g NH₄Cl, 5g CH₃COOH, and 15g lactic acid and dissolved in 1 litre of distilled water. The pH was adjusted to 4.7 using NaOH solution. Small pieces of dark-blue polycotton fabric (2 cm × 2 cm) were randomly cut. About 2g triplicate of the cut fabric specimens were weighed and each one was mixed with 50 mL of artificial sweat solution. The mixture was mechanically shaken for 24 hours and then filtered. The filtrate was analyzed using the ICP-MS (Inductively coupled plasma mass spectrometry) instrument equipped with a plasma interface. A 10% nitric acid was used for washing samples, before starting next sample analysis. Prior to analysis, the following conditions were used: power of plasma, 1400 W; speed of pump, 30 rpm; coolant flow,

14.00 L/min; auxiliary flow, 2.10 L/min; and nebulizer flow, 0.80 L/min. The same procedure was followed for other types of fabrics.

2.3 Determination of formaldehyde (free and hydrolysed formaldehyde)

Three dark-blue polycotton fabric specimens weighing about 2g were cut. The specimens were cut into smaller pieces with dimensions 0.5cm x 0.5cm and then put into three separate 250 mL volumetric flasks containing 50 mL distilled water. Flasks were shaken and put in an incubator for 24 hours at $49 \pm 1^\circ\text{C}$ and after they were allowed to cool to room temperature. Each extract was filtered, and 5 mL of the filtrate was pipetted into a clean test tube followed by adding 5 ml acetylacetone reagent. A blank was prepared by adding 5 ml of acetylacetone reagent into 5 ml of distilled water. Test tubes were placed in water for 24 hours at 40°C and then allowed to cool for further analysis. Formaldehyde measurements were carried out by measuring the absorbance at 412 nm using Optizen Pop UV spectrophotometer. The same procedure was followed for other types of fabrics. The standard solution was prepared by pipetting 0.95 ml of formaldehyde solution (37% m/v) into a 250 mL volumetric flask and filling it to the mark with distilled water. The solution was labelled A. A 2.5 mL solution A was pipetted into a 50 ml volumetric flask and it was filled with distilled water. The obtained solution was labelled B.

2.4 Determination of pH

Three dark-blue polycotton fabric specimens weighing about 2g were cut. The specimens were cut into smaller pieces with dimensions 0.5cm x 0.5cm and then put into three separate 250 mL volumetric flasks, containing 100 mL distilled water and shaken for 2 hours using an orbital shaker. Prior to using the distilled water, the distilled water pH was adjusted to be in the range of 4.7 - 7.5 by boiling and cooling it to room temperature. The extract was filtered and the filtrate pH was measured. The three pH values from the three beakers were used to calculate the average pH. The same procedure was followed for other types of fabrics.

3. Results and Discussion

3.1 Heavy metals

Table 1 shows that the brown polycotton fabric was the only fabric with no heavy metals detected in it, whereas in other fabric types, heavy metals were detected. Dark-blue polycotton fabric contained all metals, with concentrations in the range of 2.263 mg/kg to 4.899 mg/kg. The resultant concentrations were higher than the prescribed Oeko-Tex limits of less than 0.1 and 0.2 mg/kg for the metals except for copper which had a concentration of 3.735 mg/kg which was less than the recommended limit of less than 25 mg/kg. Nickel was detected in all fabrics except in brown polycotton fabric and its concentration exceeded the recommended limit of less than 1.0 mg/kg. Chromium was detected only in dark-blue polycotton and dark-blue wool fabrics and its concentration of 4.899 mg/kg in dark-blue polycotton fabric was higher than the recommended limit of less than 1.0 mg/kg. In contrast, the dark-blue wool fabric concentration of 0.052 mg/kg was less than the limit of 1.0 mg/kg. No lead, copper, arsenic, cobalt, and cadmium were detected in all fabrics. These results show the use of these fabrics poses a risk to humans. Brown polycotton fabric was the only exception with no heavy metal detected in it.

Table 2 - Fabric formaldehyde concentrations and the Oeko-Tex recommended limits

Samples	Formaldehyde concentration (mg/kg)	Recommended concentration (mg/kg)
Dark-blue polycotton	0.242	<16
Brown polycotton	0.199	<16
Dark-blue wool	0.061	<16
White cotton	0.064	<16
Black polyester	0.012	<16

Table 1 - Fabric metal concentrations and the Oeko-Tex recommended limits

Samples	Metal concentrations (mg/kg)								
	Pb 217	Pb220	Cu 213	Cu 327	As 193	Co238	Cr267	Ni221	Cd214
Dark-blue polycotton	2.263	3.464	4.616	2.853	4.593	2.869	3.213	4.899	4.229
Brown polycotton									
Navy-blue wool	-	-	-	-	-	-	0.052	2.464	-
White cotton	-	-	-	-	-	-		2.856	-
Black Polyester	-	-	-	-	-	-	-	2.746	-
Oeko-Tex acceptable limits	<0.2 ^a and <1.0 ^b	<0.2 ^a and <1.0 ^b	<25.0 ^a and <50.0 ^b	<25.0 ^a and <50.0 ^b	<0.2 ^a and <1.0 ^b	<1.0 ^a and <4.0 ^b	<1.0 ^a and <1.0 ^b	<1.0 ^a and <2.0 ^b	<0.1

^a children ^b adults

3.3 pH

Since the skin is in direct contact with the fabric, it is important that the fabric pH must be closer to the skin pH of about 5. Excessive low and high pH is reported to skin irritability and itching. Oeko-Tex recommends the pH to be within the range of 4 - 7.5 as seen in Table 3. The results show that only white cotton and black polyester fabric's pH was within the recommended range of 4 - 7.5, whereas that of dark-blue polycotton, brown polycotton, and dark-blue wool fabrics was above the upper limit of 7.5. These pH results showed that even though the brown polycotton fabric had no toxic heavy metals that were detected in it and met the Oeko-Tex limit concentrations for formaldehyde, however, its pH of 7.96 makes it unsuitable for garment construction.

Table 3 - Fabric pH and the Oeko-Tex recommended limits

Samples	Formaldehyde concentration (mg/kg)	Recommended concentration (mg/kg)
Dark-blue polycotton	0.242	<16
Brown polycotton	0.199	<16
Dark-blue wool	0.061	<16
White cotton	0.064	<16
Black polyester	0.012	<16

References:

- [1] Reddy S & Osborne W J, Heavy metal determination and aquatic toxicity evaluation of textile dyes and effluents using *Artemia salina*, *Biocatalysis and agricultural biotechnology*, 25 (2020) 101574
- [2] Rovira J, Nadal M, Schuhmacher M & Domingo J L, Human exposure to trace elements through the skin by direct contact with clothing: Risk assessment, *Environmental Research*, 140 (2015) 308-316
- [3] Fransson K & Molander S, Handling chemical risk information in international textile supply chains, *Journal of Environmental Planning and Management*, 56 (2013) 345-361
- [4] Yousef S, Tatariants M, Tichonovas M, Sarwar Z, Jonuskiene I & Kliucininkas L, A new strategy for using textile waste as a sustainable source of recovered cotton, *Resources, Conservation & Recycling*, 145 (2019) 359-369
- [5] Duong A, Steinmaus C, Mchale C M, Vaughan C P & Zhang L, Reproductive and developmental toxicity of formaldehyde: A systematic review, *Mutation Research*, 728 (2011) 118-138
- [6] Nyamukamba P, Bantom C, Mququ Z, Ngcobo T & Isaacs S, Determination of the levels of heavy metals and formaldehyde in baby clothes in South Africa: A case study of stores in the greater Cape Town region, *Journal of Spectroscopy*, 11 (2020) 1
- [7] Paithankar J G, Saini S, Dwivedi S, Sharma A & Chowdhuri D K, Heavy metal associated health hazards: An interplay of oxidative stress and signal transduction, *Chemosphere* 262 (2021) 128350
- [8] Renu K, Chakraborty R, Myakala H, Koti R, Famurewa A C, Madhyastha H M, Vellingiri B, George A & Gopalakri A, Molecular mechanism of heavy metals (Lead, Chromium, Arsenic, Mercury, Nickel and Cadmium) - Induced hepatotoxicity: A review, *Chemosphere* 271 (2021) 129735
- [9] Xu Z, Yuan Z, Zhang D, Huang Y, Chen W, Sun Z & Zhou Y, Cr(VI) removal with rapid and superior performance utilizing cost-efficient waste-polyester-textile-based mesoporous carbon: Behavior and mechanism, *Journal of Molecular Liquids* 278 (2019) 496-504
- [10] Kawakami Y, Maruo Y Y, Nakagawa T & Saito H, A screening method for detecting formaldehyde emitted from textile products, *Measurement* 62 (2015) 41-46
- [11] Priha E, Are textile formaldehyde regulations reasonable? Experiences from the Finnish textile and clothing industries, *Regulatory Toxicology and Pharmacology* 22 (1995) 243-249
- [12] Kiracofe E A & Zirwas M J, Formaldehyde in textiles—what dermatologists need to know about the relationship to contact dermatitis: A review of the US government accountability office's report to congressional committees, *Journal of the American Academy of Dermatology* 62 (2012) 313-314
- [13] Oeko-Tex Standard 100: The original safety standard, Oeko-Tex, 2024

Both white cotton and black polyester meet the recommended pH limit as well as for formaldehyde, however, their concentrations for heavy metal limits (see Table 1) were higher than the recommended limits making them not good candidates for fabrics that will be in direct contact with the skin. The pH of dark-blue polycotton, brown polycotton and dark-blue higher than the recommended limit and it will cause skin itching and irritation.

4. Conclusion

Heavy metals were found in all fabrics except in brown polycotton fabric. In dark-blue fabric, the concentrations of all metals were higher except for copper and as such, this fabric poses a significant risk if used as a garment material. The concentrations of formaldehyde in all fabrics were found to be below the recommended Oeko-Tex limits and pose less risk to human beings. The pH had mixed results with some within and outside the recommended range limit. This study showed there is a need to test all fabric rolls for pH, formaldehyde, and heavy metals as there was no fabric that met the recommended limits if the heavy metal formaldehyde and pH tests are to be used to recommend if the fabric is safe to be used to make clothing. The results show the need to test the fabric rolls before use to ensure that the toxic substances are fairly below the recommended limits as the fabric rolls do not come with such information.

- [14] Xiong M, Cui D, Cheng Y, Ma Z, Liu C, Yan C, Li L & Xiang P, Heavy metals in infant clothing: Assessing dermal exposure risks and pathways for sustainable textile policies, *Toxics* 13 (2025) 622
- [15] Angon P B, Islam MS, K C Shreejana, Das A, Anjum N, Poudel A & Suchi S A, Sources, effects and present perspectives of heavy metals contamination: Soil, plants and human food chain, *Heliyon* 26 (2024) e28357
- [16] Zuo C, Li Y, Chen Y, Jiang J, Qiu W & Chen Q. Leaching of heavy metals from polyester microplastic fibers and the potential risks in simulated real-world scenarios, *Journal of Hazardous Materials*, 461 (2024) 132639
- [17] Herrero M, González N, Rovira J, Marquès M, Domingo J L & Nadal M, Early-life exposure to formaldehyde through clothing, *Toxics*, 10 (2022) 361
- [18] Pathak P S & Hegde MG, Formaldehyde usage in fashion industry: Environmental and health implications. *Journal of the Textile Association*, 85 (2025) 528-534
- [19] Sarika P R, Nancarrow, P, Khansaheb A & Ibrahim T, Bio-based alternatives to phenol and formaldehyde for the production of resins, *Polymers*, 12 (2020) 2237
- [20] Zhai, Z, Li Y, Li Z, Wang J, Li Y & Zhang Y H P J, Enzymatic cleanup of formaldehyde in aqueous solutions, *ChemSusChem*, 18 (2025) e202402711
- [21] Huang C, Zhang N, Wang Q, Wang P, Yu Y & Zhou M, Development of hydrophilic anti-crease finishing method for cotton fabric using alpha-lipoic acid without causing strength loss and formaldehyde release problem, *Progress in Organic Coatings* 151 (2021) 106042
- [22] Wang F, Fang K, Liu X, Zhang S & Qiao X, A review on the status of formaldehyde-free anti-wrinkle cross-linking agents for cotton fabrics: Mechanisms and applications, *Industrial Crops and Products* 200 (2023) 116831
- [23] Camargo M M, Taye E A, Roether J A, Redda D T & Boccaccini A, A Review on natural fiber-reinforced geopolymer and cement-based composites, *Materials* 13 (2020) 4603
- [24] Mohsin M, Farooq U, Raza Z A, Ahsan M, Afzal A & Nasir A, Performance enhancement of wool fabric with environmentally-friendly bio-cross-linker, *Journal of Cleaner Production* 68 (2014) 130-134



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