Research Article

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

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Herein, we report on the determination of formaldehyde, pH, and heavy metals (Pb, As, Co, Cr, Ni, and Cd) in various baby apparel (cotton, polyester, nylon, elastane, and polyethylene) of different colours (light, medium, and dark) purchased from both high-end and low-end market stores. The concentrations of the heavy metals were determined by inductively coupled plasma (ICP) after wet digestion and also after extraction using artificial sweat for a selected range of skin-contact baby apparel. The relative standard deviation for the determination of all heavy metals was less than 5% except for nickel which was 10.49%. The concentrations of the heavy metals in wet digested samples were found to be in the following range: Pb (0.02–23.662 mg/kg), As (0.009–0.033 mg/kg), Co (0.001–1.053 mg/kg), Cr (0.053–6.373 mg/kg), Ni (0.039–36.715 mg/kg), and Cd (0.001–0.914 mg/kg), whereas the concentrations in artificial sweat extracted samples were in the following range: Pb (0.006–1.658 mg/kg), As (not detected), Co (0.001–1.05 mg/kg), Cr (0.112–0.371 mg/kg), Ni (0.062–0.121 mg/kg), and Cd (0.001–0.018 mg/kg). The highest concentrations of Pb, Cr, and Co after wet digestion were found in baby apparel purchased from low-end market stores, whereas for As, Ni, and Cd were from high-end market stores. All the samples had a formaldehyde concentration within the acceptable limits recommended by Oeko-Tex. Out of the thirty-four samples analysed, fifteen samples were found to have a pH higher than Oeko-Tex limits. The pH values for the samples that exceeded the Oeko-Tex limits were in the alkali region, and the highest was 11.31 which exceeded by 3.81.

1. Introduction

Textiles are always in contact with the human skin through wearable clothing, cleansing apparel, carpeting, furniture cover, and bedding just to mention a few. It is therefore paramount that these textiles and apparel do not pose a health risk to both humans and animals and cause environmental harm in case of exposure. Despite these concerns, a lot of chemicals and heavy metals are being used in the textile manufacturing processes, for instance, the dyeing process using azo dyes and metal complex dyes [1].

Azo dyes are the most commonly used group of dyes in the textile industry, and they were reported to constitute between 60 and 70% of all dyestuffs concerning textile

production [2, 3]. The chemical pollutants present in textiles are mainly dyes containing carcinogenic amines, metals, chlorine bleaching, fire retardants, halogen carriers, free formaldehyde, biocides, pentachlorophenol, and softeners [4]. It was reported that aromatic amines can be released by azo dyes through bacterial biotransformation and their exposure from consumer products bear risks for human health, particularly associated to mutagenic and carcinogenic properties of certain AAs [2].

Product safety regulations are becoming stricter; hence, more testing of toxic substances such as formaldehyde and heavy metals at lower levels is required especially in children's toys and apparel because children tend to put these items in their mouths. Formaldehyde is used to increase

wrinkle and crease resistance in textiles, and it also helps some dyes and inks to better penetrate fabrics. The raw materials used in the manufacturing of synthetic dyes should not contain compounds known to pose health risks. Formaldehyde is toxic, allergenic, and carcinogenic and can cause symptoms like headaches, burning sensation in the throat, and difficulty breathing [5]. Long-term exposure to formaldehyde can lead to cancer.

Heavy metals are also found in textile products, and their presence is partly attributed to the use of dyes especially the reactive dyes because they contain traces of heavy metals at high level. Heavy metals may pose some health risks to humans even at low concentrations in textile products since they can reach the human body through skin-contact clothes. High levels of heavy metals in textiles may also result in high metal levels in wastewater, and this has a negative impact on the environment, water quality, and microorganisms. It has been reported that the presence of some metals, for instance, in cotton leads to problems in the manufacturing, dyeing, and processing quality [6]. The continued exposure to low levels of toxic elements such as mercury (Hg), cadmium (Cd), arsenic (As), and lead (Pb) has been associated with a number of adverse effects [4, 7]. In South Africa, studies on toxic substances in clothing products are very limited; hence, this study was undertaken for the safety of consumers and also the textile industry itself.

This study aims at investigating the levels of heavy metals and selected organic contaminants in baby apparel as they (babies) are the most affected to check if they fall within the Oeko-Tex Standard 100 limits which prohibits use of some chemical substances that are dangerous to humans [10]. Among the parameters that are controlled by Oeko-Tex, the pH, formaldehyde concentration, and extractable heavy metals were studied.

2. Experimental

2.1. Materials

2.1.1. Determination of pH. Textile processes involve the use of strong acids or alkalis which may cause irritation to skin when in contact. The pH was determined using a method developed by the International Organization for Standardization (ISO 3071:2005). About 2.0 g of the apparel samples was cut into small pieces having approximately 2 cm × 2 cm so that the test samples could be effectively wet. The handling of the samples was minimal to avoid contamination. The cut samples were put in a 250 mL volumetric flask containing 100 mL of water whose pH and temperature was 7.5°C and 27°C, respectively, and agitated to ensure that all the fabric was wet. After 2 hrs of shaking, the first extract was decanted into a 50 mL beaker and stirred with a pH electrode. The second and third extracts were decanted in separate beakers, and the pH values were measured immediately.

2.2. Determination of Heavy Metals by Extraction

2.2.1. Extraction Using Artificial Sweat Solution. The artificial sweat solution was prepared using the standard procedure reported in ISO 3160/2. In a typical experiment,

about 20 g NaCl, 17.5 g NH₄Cl, 5 g CH₃COOH, and 15 g lactic acid were dissolved in a litre of deionized water and the pH was adjusted to 4.7 using sodium hydroxide solution. About 2.0 g of the cut apparel sample was mixed with 50 mL of artificial sweat solution, shaken for 24 hrs and then filtered. The filtrate was then analysed by ICP.

2.2.2. ICP Analysis. ICP was used to determine the concentration of the heavy metals in the extracted samples. It was done using a Spectro Arcos ICP-OES instrument equipped with a side-on plasma interface. Sample inlet was done using a four-channel peristaltic pump which provides a segmented flow of the liquid samples. A 10% solution of nitric acid was used for washing between sample analyses, i.e., before the next sample could be analysed. Prior to analysis, the ICP-OES measurement conditions were optimized and the following conditions were used: plasma power, 1400 W; pump speed, 30 rpm; coolant flow, 14.00 L/min; auxiliary flow, 2.10 L/min; and nebulizer flow, 0.80 L/min.

2.2.3. Determination of Heavy Metals by Digestion. A modified version of the method by Sungur and Gulmez [9], was used to determine the concentration of heavy metals by wet digestion. In a typical experiment, about 2.0 g of apparel sample was heated at 110°C for an hour in 20 mL of 1:5 H₂O₂ (30%)/HNO₃ (70%) acid mixture. The resulting solutions were cooled and filtered. After filtration, the solutions were filled up to 50 mL with deionized water and analysed by ICP.

2.3. Determination of Formaldehyde. Formaldehyde concentration was determined using the method described in ISO 14184-1. The apparel purchased from low-end and high-end market stores were clearly identified, separated, coded, and then cut into small pieces, and about 2.5 g of each test specimen was then put in 100 mL of distilled water in a 250 mL volumetric flask. This was then shaken and heated at 40°C for an hour, and the resulting solutions were filtered. About 5 mL of each filtered solution was mixed with 5 mL of acetylacetone in a tube, and the same was done with standard formaldehyde solution. The tubes were put in water that was set at a temperature of about 40°C for an hour and then at room temperature for 30 minutes. The blank was prepared by adding acetylacetone to water and treating it the same way. The absorbances were then measured in triplicates at a wavelength of 412 nm using a UV-Vis spectrophotometer.

2.3.1. Preparation of a Standard Solution. About 1500 µg/mL stock solution was prepared by diluting 0.95 mL of 37% (m/V) formaldehyde solution with 250 mL of distilled water. Using the stock solution, 75 µg/mL of formaldehyde solution was prepared which was then used to prepare calibration solutions. The concentrations of the calibration solutions prepared were 0.15 µg/mL, 0.30 µg/mL, 0.75 µg/mL, 1.50 µg/mL, and 3.00 µg/mL.

The sample codes, description, composition, colour, and fabric type of baby apparel purchased from high-end and low-end market stores are presented in Tables 1 and 2, respectively. The various clothing fabric were made of cotton, polyester, nylon, elastane, and polyethylene, the most common being 100% cotton. The apparel type consisted of woven print, knitted print, woven pile, weft knit, woven pile-dyed, terry knit, weft knitted-dyed, and knitted. The range of samples included jeans, socks, cap, receiving blankets, vests, towels, bibs, and growlers.

3. Results and Discussion

It is important to control the pH of baby apparel which is in direct contact with the skin so as to prevent irritation and itchiness to the skin. In this study, it was found that more than 50% of the apparel from both high-end and low-end market stores was within the recommended pH level range as shown in Table 3. Out of the seventeen samples from high-end market stores, 47.06% had a pH above the recommended range, whereas 41.18% of the seventeen samples from low-end market stores had a pH above the recommended range. Sample L10 from the low-end market store had the highest pH deviation of 3.81, and it was made of 100% cotton. Generally, all the samples which were not in the recommended range were in the alkaline region and none was in the acidic region. Those fabrics which are not in the recommended range might cause contact dermatitis due to their alkali nature because a natural human skin surface pH is on average below 5, which is beneficial for its resident flora. It has been reported that changes in the skin pH play a role in the development of skin diseases such as irritant contact dermatitis, acne vulgaris, atopic dermatitis, ichthyosis, and *Candida albicans* infections [10]; hence, fabric pH control is necessary. Teijin Fibers Limited in 2011 announced that they developed a new polyester fabric that can maintain the skin's mild acidic pH level, similar to healthy skin. To the best of our knowledge, no study has been done on the determination of pH on baby clothes in South Africa even though we believe that it is an important parameter to be measured.

The apparel purchased from both high-end and low-end market shops were tested for formaldehyde concentration, and the results found are shown in Table 4. All the apparel had formaldehyde concentrations within the Oeko-Tex limits implying that they do not pose a health harm to humans due to formaldehyde. In another study, Novick et al. [11] analyzed twenty clothing items to detect the levels of formaldehyde, and they found it in only three items of which two of them had levels higher than the concentrations established by international textile regulations. Contact of the skin with formaldehyde may cause primary irritation or allergic dermatitis. According to the International Agency for Research on Cancer (IARC), formaldehyde is classified as carcinogenic to humans (Group 1) [12]. The other effects of formaldehyde include

irritation of the mucous membrane, immediate, anaphylactic reactions (Type I allergy), upper respiratory tract irritation, neurophysiologic effect, and ocular irritation [13, 14].

The concentrations of the heavy metals after wet digestion in the garments purchased from high-end and low-end market stores are shown in Tables 5 and 6, respectively. The concentrations of the heavy metals were found to be in the following range: Pb (0.02–23.662 mg/kg), As (0.009–0.033 mg/kg), Co (0.001–1.053 mg/kg), Cr (0.053–6.373 mg/kg), Ni (0.039–36.715 mg/kg), and Cd (0.001–0.914 mg/kg). The toxic effects of heavy metals on humans are well documented, and the maximum permissible values for metals in textiles are given by different regulations; in this study, comparison will be made to Oeko-Tex standards. The only elements whose limits are given by the Oeko-Tex Standard 100 regarding wet digestion extraction are Pb (<90) and Cd (<40), but as for artificial sweat extraction, all elements studied have Oeko-Tex Standard limits.

Both Pb and Cd concentrations in the baby apparel were below the recommended limits by Oeko-Tex meaning that the baby apparel under study will not pose a health risk due to Pb or Cd. The highest concentrations of Pb (23.662 mg/kg), Co (1.053 mg/kg), and Cr (6.373 mg/kg) were found in apparel purchased from low-end market stores, whereas the highest concentrations of As (0.033 mg/kg), Ni (36.715 mg/kg), and Cd (0.914 mg/kg) were found in apparel from high-end market stores. Arsenic had the least concentration in most fabrics from both high-end and low-end market stores. The abundance of metal concentrations follows the order: Ni > Pb > Cr > Cd > Co > As for high-end market apparel and Ni > Pb > Cr > Co > Cd > As for low-end market stores. In almost all fabrics, nickel was the most abundant element. Although nickel is an essential trace element for human and animal health, large quantities of nickel in the body can result in birth defects, asthma, respiratory failure, and chronic bronchitis. It can also cause cancer on different sites within the bodies of animals [15]. High Ni concentrations and long-term exposure to humans can lead to liver, heart damage, and skin irritation as reported in the literature [16].

Sample T7 which was a blue-dyed facecloth made of 100% cotton had the least amounts of most elements, i.e., Pb, Co, Cr, and Ni. On the contrary, T9, a white vest made of 100% cotton had the highest concentrations of all the detected elements (Pb, Cr, Ni, and Cd) implying that this is the worst apparel among all the sample apparel from the high-end market stores. The chromium that was found in the apparel may originate from the dye which did not fully get incorporated into the fibre, and this chromium may affect babies during perspiration. This skin exposure can be a dangerous route of absorption, promoting dermatitis [17]. Chromium (VI) is used in certain textile processes, and it is highly toxic even at low concentrations. High levels of Cr have been reported to cause a reduction in the percentage of body fat, resulting into weight loss in humans [18]. There are some clinical and laboratory evidences which indicate that hexavalent chromium, Cr(VI), is responsible for most of the toxic actions [19].

TABLE 1: Sample code, description, colour, composition, and apparel type from a high-end market store.

Code	Description	Colour	Dye/print	Made in	Composition	Woven/knit
T1	Blanket	White	Print	SA	100% Cot	Woven
T2	Blanket	Navy	Print	SA	100% Cot	Woven
T3	Blanket	Blue/navy	Print	NS	100% PET	Knit
T4	Fleece	White	—	China	100% PET	Knit
T5	Nappy	White	—	SA	100% Cot	Woven-pile
T6	Towel	Blue	Dye	China	100% Cot	Woven-pile
T7	Facecloth	Blue	Dye	China	100% Cot	Woven-pile
T8	Facecloth	White	—	SA	100% Cot	Woven-pile
T9	Vest	White	—	SA	100% Cot	Knit
T10	Cap	White	—	SA	100% Cot	Knit
T11	Cap	Blue	Dye	SA	100% Cot	Knit
T12	Socks	White	—	China	80% Cot, 18% PA, 2% EL	Knit-terry
T13	Socks	Blue	Dye	SA	80% Cot, 18% PA, 2% EL	Knit-terry
T14	Grower	White	—	NS	100% Cot	Knit
T15	Grower	Yellow	Dye	SA	100% Cot	Knit
T16	Grower	Navy blue	Dye	China	100% Cot	Knit
T17	Jeans	Navy blue	Dye	Bangladesh	75% Cot, 23% PET, 2% EL	Woven

Cot: Cotton; PA: Nylon; PET: Polyester; EL: Elastane, SA: South Africa, NS: not specified.

TABLE 2: Sample code, description, composition and apparel type from a low end market store.

Code	Description	Colour	Made in	Composition	Fabric type
L1	Face towel	White	Pakistan	100% Cot	Woven pile
L2	Facecloth	Blue	Pakistan	100% Cot	Woven pile
L3	Bib	Blue & white		100% Cot	Knitted
L4	Bib	White & powder blue	China	98% PET, 2% PE	Knitted
L5	Bib	White & sky blue	China	98% PET, 2% PE	Knitted
L6	Nappy	White		100% Cot	Woven pile
L7	Bath towel	Powder blue	Pakistan	100% Cot	Woven pile
L8	Blanket	White	SA	100% PET	Woven pile
L9	Blanket	Brown	China	100% PET	Woven
L10	Receiver	White	Pakistan	100% Cot	Woven print
L11	Grower	White	SA	100% Cot	Woven pile
L12	Grower	White	China	100% Cot	Woven
L13	Grower	Yellow		100% Cot	Woven
L14	Romper	Navy	China	100% PET	Woven pile
L15	Socks	White	SA	93% PET, 5% EL, 2% PA	Knitted
L16	Socks	Blue	NS	93% PET, 5% EL, 2% PA	Knitted
L17	Jean	Navy	SA	73% Cot, 25% PET, 2% EL	Woven

Cot: cotton; PA: nylon; PET: polyester; PE: polyethylene; EL: elastane.

Clothes that are in direct contact with the skin are usually exposed to perspiration, which may cause metal extraction from textiles and absorption to skin [17]. Sport activities such as marathon would be of special concern when studying clothing for adults, as the sweaty athlete remains in contact with the clothes. The concentrations of heavy metals in all examined textile apparel after extraction using artificial sweat (Table 7) were lower than those for wet digestion. The low leaching rates of heavy metals in artificial sweat extract is an indication of the quality of the textile products. The determination of the amounts of these heavy metals that might pass into the human body from textile products as a result of sweating is very significant.

The concentrations extracted using artificial sweat in selected skin-contact apparel were in the following range: Pb (0.006–1.658 mg/kg), As (not detected), Co (0.001–1.05 mg/kg),

Cr (0.112–0.371 mg/kg), Ni (0.062–0.121 mg/kg), and Cd (0.001–0.018 mg/kg), as shown in Table 7. The levels of the heavy metals followed the order Pb > Co > Cr > Ni > Cd which is different from the order found in wet digestion extraction due to the variance in solubility of the heavy metals in different extraction media. T5 and L14 are the only skin-contact samples whose Pb concentrations were higher than the limits recommended by Oeko-Tex. The concentration range of Pb in this study was higher than that found by Rovira et al. [4], which were in the range 0.03–0.32 mg/kg in skin-contact clothing samples. These apparel whose lead concentrations are higher than the limits recommended by Oeko-Tex may pose a health risk to babies who wear them because lead is a neurotoxin, it affects the human brain as well as the reproductive system. There are certain kinds of neurological damage caused by lead that cannot be reversed.

TABLE 3: pH of fabrics from store A and store B and the Oeko-Tex recommended values.

Sample code	pH	Sample code	pH	Recommended
T1	7.71	L1	7.25	4.0–7.5
T2	7.42	L2	7.60	4.0–7.5
T3	5.46	L3	7.65	4.0–7.5
T4	5.56	L4	5.09	4.0–7.5
T5	8.34	L5	7.55	4.0–7.5
T6	8.49	L6	8.30	4.0–7.5
T7	7.63	L7	7.04	4.0–7.5
T8	6.19	L8	5.49	4.0–7.5
T9	8.89	L9	6.87	4.0–7.5
T10	8.35	L10	11.31	4.0–7.5
T11	7.66	L11	6.77	4.0–7.5
T12	7.79	L12	7.42	4.0–7.5
T13	6.45	L13	9.29	4.0–7.5
T14	6.25	L14	6.78	4.0–7.5
T15	6.86	L15	8.64	4.0–7.5
T16	6.14	L16	6.00	4.0–7.5
T17	7.44	L17	7.48	4.0–7.5

TABLE 4: Formaldehyde concentration in apparel purchased from high-end and low-end market stores, and the Oeko-Tex recommended values.

Sample	Formaldehyde conc. (mg/kg)	Sample	Formaldehyde conc. (mg/kg)	Recommended
T1	0.090	L1	0.044	<16 mg/kg
T2	0.047	L2	0.041	<16 mg/kg
T3	0.037	L3	0.074	<16 mg/kg
T4	0.036	L4	0.048	<16 mg/kg
T5	0.058	L5	0.041	<16 mg/kg
T6	0.040	L6	0.040	<16 mg/kg
T7	0.040	L7	0.040	<16 mg/kg
T8	0.049	L8	0.038	<16 mg/kg
T9	0.049	L9	0.037	<16 mg/kg
T10	0.044	L10	0.070	<16 mg/kg
T11	0.042	L11	0.039	<16 mg/kg
T12	0.041	L12	0.040	<16 mg/kg
T13	0.041	L13	0.039	<16 mg/kg
T14	0.042	L14	0.037	<16 mg/kg
T15	0.045	L15	0.040	<16 mg/kg
T16	0.043	L16	0.036	<16 mg/kg
T17	0.047	L17	0.053	<16 mg/kg

In children, lead affects reading and reasoning abilities and in some instances, it is linked to hearing loss, speech delay, balance difficulties, violent tendencies, clumsiness, agitation, and/or decreased activity and somnolence [20].

L8 is the only sample that had a cobalt concentration higher than the Oeko-Tex limits, but it exceeded slightly. Cobalt may cause skin problems such as eczema if it leaches from the apparel and gets in contact with skin. Cases of severe hand eczema after using a cobalt-containing gel were reported by Chave and Warin [21], and the eczema disappeared when the product was discontinued. Cobalt is a skin sensitizer which may lead to contact dermatitis either allergic or irritant, and the latter is the most frequent [4].

No elements except Cd were detected in T12 which was made of 80% cotton, 18% polyester, and 2% elastane.

Arsenic was not detected in all samples extracted using artificial sweat. Cobalt was only detected in a few samples. Cd is the only element that was found in all samples but only at very low concentrations when compared to other elements. Cr and Ni are the only elements that were found not to exceed the Oeko-Tex limits in all the samples that were under study. The use of artificial sweat gives an indication of the levels of the heavy metals in baby skin-contact clothes although the composition of sweat varies between individuals and also in the same individual, depending on body region, age, season, climate, diet, presence of infection, and activity level [22]. Because the sweat varies between individuals, it also means that the amount of heavy metals that will leach will vary from person to person resulting in different side effects in individuals.

TABLE 5: Heavy metal concentrations (mg/kg) in various textile apparel purchased from high-end market stores after wet digestion.

Heavy metal	SD	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	Min.	Max.
Pb	0.049	0.027	2.745	2.170	0.024	1.891	8.953	0.020	0.131	16.738	0.267	0.169	0.029	0.043	0.035	0.379	0.379	0.225	0.020	16.738
As	0.046	0.033	n.d	n.d	n.d	n.d	n.d	0.008	n.d	n.d	0.006	0.025	n.d	0.009	0.012	0.014	0.012	0.011	0.009	0.033
Co	0.041	0.003	0.158	n.d	0.004	n.d	n.d	0.001	0.002	n.d	0.010	0.004	0.032	0.007	0.003	0.005	0.001	0.005	0.001	0.158
Cr	0.033	n.d	2.683	2.305	0.133	2.658	3.249	0.053	0.067	3.263	0.139	0.175	0.835	0.432	0.278	0.230	0.189	0.365	0.053	3.263
Ni	0.100	n.d	26.315	28.098	0.115	26.215	31.972	0.039	0.066	36.715	0.081	0.072	0.259	0.141	0.120	0.101	0.068	0.093	0.039	36.715
Cd	0.009	0.001	0.280	0.284	0.002	0.247	0.760	0.002	0.012	0.914	0.007	0.017	0.425	0.004	0.003	0.008	0.014	0.018	0.001	0.914

n.d: not detected.

TABLE 6: Heavy metal concentrations (mg/kg) in various textile apparel purchased from low-end market stores after wet digestion.

Heavy metal	SD	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	L16	L17	Min.	Max.
Pb	0.049	0.058	0.057	10.866	0.067	0.057	23.147	3.093	3.481	0.168	0.298	14.680	1.381	0.051	1.928	23.662	23.778	4.472	0.057	23.662
As	0.046	0.001	0.009	n.d	0.017	n.d	0.006	0.006	0.010	0.001	0.009	n.d	n.d	0.010	0.001	0.001	0.013	n.d	0.001	0.017
Co	0.041	0.023	0.002	0.090	0.017	0.001	n.d	n.d	1.053	n.d	n.d	n.d	n.d	<0.001	n.d	0.013	0.027	0.007	0.001	1.053
Cr	0.033	0.187	0.245	6.373	0.147	0.160	3.307	2.823	2.295	4.069	2.277	3.237	2.448	0.166	2.207	3.181	2.895	3.200	0.160	6.373
Ni	0.100	0.077	0.083	32.660	0.051	0.054	37.671	29.633	29.378	29.901	27.289	33.85	29.383	0.072	28.524	33.201	31.095	27.708	0.051	33.85
Cd	0.009	0.003	0.004	0.737	0.004	0.005	0.734	0.216	0.310	0.225	0.263	0.764	0.237	0.003	0.295	0.881	0.817	0.338	0.003	0.881

n.d: not detected, SD: standard deviation. Oeko-Tex standard 100 limit values: Pb < 75; Cd < 40.

TABLE 7: Heavy metal concentrations (mg/kg) in various textile apparel after extraction with artificial sweat.

Shop A samples	Pb	As	Co	Cr	Ni	Cd
L3	0.075	n.d	0.090	0.260	0.082	0.004
L6	0.089	n.d	n.d	0.165	0.062	0.006
L7	0.056	n.d	n.d	0.184	0.066	0.004
L8	0.045	n.d	1.05	0.262	0.121	0.004
L9	0.167	n.d	n.d	0.265	0.072	0.004
L10	0.150	n.d	n.d	0.331	0.116	0.018
L11	0.091	n.d	n.d	0.195	0.092	0.005
L12	0.022	n.d	n.d	0.202	0.073	0.003
L14	1.658	n.d	n.d	0.185	0.097	0.003
L15	0.038	n.d	0.013	0.178	0.097	0.003
L16	0.018	n.d	0.004	0.182	0.082	0.023
L17	0.047	n.d	0.005	0.371	0.115	0.003
T2	0.006	n.d	n.d	n.d	n.d	0.001
T3	0.028	n.d	n.d	n.d	n.d	0.001
T5	1.492	n.d	n.d	0.125	0.072	0.004
T6	0.057	n.d	n.d	0.112	0.095	0.004
T9	0.093	n.d	n.d	0.140	0.102	0.005
T12	n.d	n.d	n.d	n.d	n.d	0.002
Minimum	0.006	—	0.001	0.112	0.062	0.001
Maximum	1.658	—	1.05	0.371	0.121	0.018

Oeko-Tex standard 100 limit values: Pb < 0.2; As < 0.2; Co < 1.0; Cr < 1.0; Ni < 0.1; Cd < 0.1.

4. Conclusion

The determination of the extractable amounts of heavy metals in baby apparel was of great importance because it reflected the possible impact on human health. These days, it is very important to prove that there is little or no formaldehyde in all finished textile materials to avoid posing risks to humans. This study showed that the formaldehyde concentration fall within the Oeko-Tex 100 implying that the garments do not pose a health risk to humans due to the presence of formaldehyde. About 44.12% of the analysed apparel had a pH above the recommended range implying that South African textile samples should be analysed more often with respect to pH before making clothes. The heavy metal concentrations in all baby apparel after extraction using artificial sweat extract were lower than those for wet digestion. Arsenic is the only metal that was not detected in all apparel after extraction using artificial sweat. Only one sample (L8) had a cobalt concentration (1.05 mg/kg) higher than the Oeko-Tex limits (1.0 mg/kg), but it exceeded slightly. Pb concentrations were higher than the limits recommended by Oeko-Tex (Pb < 0.2 mg/kg) in only two samples (T5 = 1.492 mg/kg) and L14 (1.658 mg/kg). Cr and Ni are the only elements that were found not to exceed the Oeko-Tex limits in all the samples that were under study. Generally more samples purchased from low-end market stores had metal concentrations that were higher than the Oeko-Tex limits when compared with the apparel purchased from high-end market stores. The highest concentrations of all the metals detected were found in apparel purchased from low-end market stores. Although the composition of sweat varies between individuals, the results of this study using artificial sweat gave an indication of the levels of the heavy metals in baby skin-contact clothes in Cape Town, South

Africa. The results of this study might be useful to evaluate potential human risk when exposed to heavy metals from textile materials.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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