Design and Production of Textile Fabrics Waste from Sudanese Garment Factories

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INFORMATIONs	ABSTRACT

The textile and apparel industry is one of the most significant industrial sectors in the world, however, it generates a large number of textiles and apparel waste before and after consumers' using. This study is conducted on the reusing and recycling of garment fabric waste in Sudanese garment factories and aimed to identify the causes of this waste and try to increase their economy, by collecting and reusing this waste to produce useful products. The problem was identified and working on solving it after observing the amount of fabric waste accumulated in the Sudanese garment factories, various tailors stores, and other tailors in the markets. Many several methods were used to reach these objectives, including observation and interviews with workers in this field, then conducted a questionnaire for them to help in the primary data collection. After collecting waste from different sources it was sorted and classified into subcategories, then many tests were done to obtained fabric pieces with a good quality. In the last step many designs were done by making a several patterns matched to the size and type of fabric, and the final products are (children's clothes, bags, bedsheets, and other textiles), these products were presented to people who specialize in textile and garment industry to know their opinions about them and if it will benefit the society. From the results of this study, we found that the different garments that were produced from waste fabrics showed to have a great satisfaction among consumers.

KEYWORDS

1. INTRODUCTION

Clothing (also known as apparel and garment) is one of the most critical human necessities and an indispensable component of human society throughout its history [1], they uses clothes to protect themselves from the external environment and preserve the necessary condition, also to express their identity, wealth, power, etc... The garment industry is one of the most critical sectors globally as it benefits the labor employed and the utilization of available resources [2]. It is an industry that goes through several stages to obtain the final product, starting from the design and samples section, pattern section, inspection section, cutting of fabrics section, preparation process, and the operation and finishing of the garments [3]**.**

Therefore, the amount of waste generated in the garment industry's various stages (especially the cutting department), is considered waste in the factory [4, 5]**.** This waste is a central problem for the factory, and they are disposed of by burning, and many harmful gases were appearance as a result of this process [6]**.** These factories have other ways to dispose of this waste as they are sold

and used for other purposes such as; cleaning, washing the cars, manufacturing ropes and other products [7]. The problems of this waste in the garment factories and small workshops, various fashion houses, and even tailors in the market. Some workshops dispose of this waste in the same way as factories. Sometimes, sell it to other people, as mentioned above, throws or burns it, which damages the landscape and affects the surrounding environment [8]. Some of the components of waste have good value and can be recycled once correctly recovered, and the good management of waste can be reduced the undesirable impacts on the environment and society [8].

Many researchers are focusing their studies on the garment industry, they calculate the percentage of garment waste in this industry and work on reusing and recycling it. They found that the textile industry is one of the most critical sectors globally, which is indispensable industry and most countries are developing and relying on it to increase their economy [8, 9]. The garment industry continues to flourish and grow with the increasing population and demand for clothing [9]. Thus, the increase in the garment industry, there will be an increase in the waste that results from this industry and has become a disaster in human life due to its harmful effects on people, as well as on the animal and the environment in genera [9, 10]. Reusing and recycling waste are important ways to get rid of textile waste, and the whole world is moving towards developing new ways and reaching zero waste, many countries approved reused textile waste after collection and sorting it, some of waste can be treated and reused again, for example, old clothes can be donated or resold it, and other waste, can converted into fibers by specialized machines, then weaved again to make it fabric [10].

The United States Environmental Protection Agency EPA analysis in (2006) showed that 4 million tons of garment waste were going to landfills every year (Corporation & Curran), however, nearly 45% of garment waste was recyclable. For this, many entities attempted to collect recyclable textile and garment waste before they ended up in landfills [11]. There are many textile waste recycling companies that recycle more than 100,000 tons of textile waste every year, and according to a Chinese study,

3.5 million tons were recycled and reused in 2017 [12]. Additionally, the study indicated that in France, a legal decree was issued for textile and clothing factories on the French market to take responsibility for the recycling or proper disposal of textile waste [13]. [14, 15] Stated that Sweden textile garment waste collected in boxes and bags , and then was sent to incineration with other municipal waste collected, where heat recovered from the incineration process can replace energy sources.

Many researchers have examined the employment and exploitation of the remains of fabrics produced by the garment factories [15, 16]. Thus, the most important findings of these studies are that it is necessary to take advantage of the remains of fabrics in the factories. Some studies worked on applying the art of patching, which gives many beautiful products. Another study indicated benefiting from fabric residues in factories and using them to develop students' abilities to manufacture clothes [17]. A study conducted in 2007 aimed to create a small factory for recycling textile waste to opens jobs for many workers [18]. The fabric remains can be used to make new products such as home furnishings and ground furniture and then sell it again [19].

Sudan is one of the largest countries in Africa, and its population growth is considerable, with an average growth rate of 2% per person per year. The industrial sector in Sudan is vast, therefore, waste is generated in these factories every day and causes many problems for these factories' environment. However, it is not disposed of properly due to the absence of certified systems to dispose of this waste [20, 21]. The textile industry is one of the old industries in Sudan because it is rich in its raw resources, but this industry suffer from a large amount of waste during garment manufacturing, this waste is thrown into the surrounding environment or burned it, but these methods harms humans and the environment, so some factories avoid this harmful impact by selling waste to other benefiters [22]. This problem is not just in the factories but extends to various workshops and sewing shops in the country; this causes a catastrophic environment that the designated authorities [23].

Based on all above studies, it was found that most countries are interested in the recycling of textile garment wastes of both types before and after consumption, where the pre-consumption is the waste produced in the manufacture of garments [24], while the waste after consumption is represented in old clothes. Waste before the consumption, including a new cloth, was not used and did not enter the designs of ready-made fabrics. It can be used to make new products such as clothes for children and furniture and others, the waste after consumption can be repaired so that the clothes are sorted and cleaned and used as second-hand clothes and sold again at a lower price and usually exported to the least developed countries [25, 26]. Some of the second-hand clothes that cannot be sold again are either converted to other products by taking advantage of the fabric's correct parts or converted to fibers by melting, re-spinning, and weaving again. Each of these methods has its characteristics and vary depending on the available waste [27, 28]. Notwithstanding all these studies, which showed the importance and how to get rid of textile garment waste and showed the environmental burden, however, most of these studies focus only on aspects of consumption and reuse of waste. Still, it did not consider reaching zero waste, which means the formation of zero residues of fabrics during clothing manufacturing.

The main purpose of this research is to identify the reasons for the large quantities of textile waste in garment factories in Sudan and effort to reduce it by increasing their awareness, after that collecting these waste and reuse it to obtain valuable products. The other objective of this research is to increase community awareness of the importance of textile garment waste recycling in Sudan and the impact it on the environment, and the possibility of created jobs opportunities for many people to raise their income by creating special workshops to reusing textile waste..

2. MATERIALS AND METHODS:

### 2.1 Materials:

As a material, the garment waste was collected from different zones because of the number of textile wastes produced from numerous sources. The materials used in this research are fabric waste produced from various processes in the garment industry and classified as waste. These wastes were obtained by collecting them from different sources, which are such as:

1. Garment factories are the primary source of fabrics waste and have been collected from many Sudan garment factories.
2. Garment workshops are also an essential source of textile fabric waste, and the amount of destruction depends on the operator's production.
3. Garment sewing shops and tailors in the markets, and sometimes this waste contained some foreign matter such as dirt and dust.

2.2 Tools and Equipment:

The tools and equipment used in this research are; needles and pins and pincushion(s), scissors, measure tape, iron and water sprayer, thimble and threaded, threads, rulers, pattern weights, seam ripper and tweezers, frixion pens, chalk, lint roller, sewing gauge and binder clips, masking tape, "professional" tools to add seam allowances (lol), glue stick and ponytail holders, chopsticks, rotary cutter and cutting mat, and tracing wheel used in design and manufacturing of fabric waste of garment-making processes as shown in figure (1).
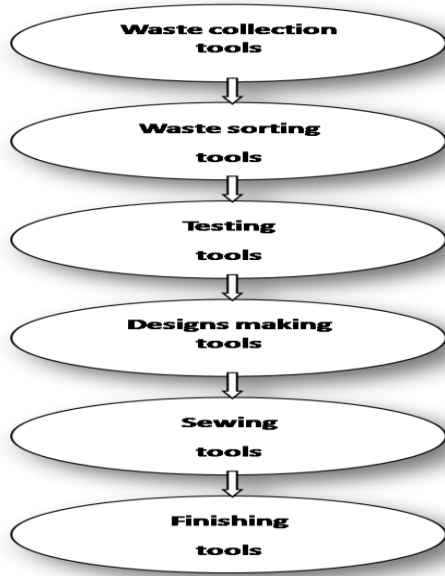
Figure(1): Tools used in reusing waste

3.3 The Method:

The methodology was followed to suit the objectives of this study as flow: The study conducts experiments to make new products from the textile waste collected from different sources, then sorting and classifying these wastes, and working to some tests, then producing new products and it can be divided into the steps as follows:

1. Collection.
2. Sorting.
3. Classification.
4. Testing and the tests conducted in this research are:
   - The test of drape and fabric recovering characteristics (ASTM D 4032–94).
   - The test of color fastness for washing (ASTM D2096 - 11(2019) e1).
   - The test of color fastness for friction (ASTM D 3412-07).
   - The test of flammability (ASTM D1230 – 17).
   - The test of the fabric strength of tearing (ASTM D1424 - 09(2019).
5. Patterns designs.
1. Fabrics Assembly (Sewing).
2. Clothing (Finishing).

1. Patternmaking:

After completing the necessary tests on all fabric samples and then obtaining suitable quality fabrics to produce new products 'patterns were designed based on final products, and the quality of the final products directly depends on the quality of these designs and methods that were done correctly and conform to the types of these fabrics and their small sizes. Therefore, the patterns design was divided into different types of clothing, and each one contains many scenarios, these clothing are:

1.1 The patterns design of garment:

In sewing and fashion design, a pattern is a template from which a garment's parts were traced onto fabric before being cut out and assembled. Patterns are usually made of paper and are sometimes made of sturdier materials like paperboard or cardboard if they need to be more robust to withstand repeated use. Making or cutting patterns was sometimes condensed to one-word Patternmaking, but it can also be written pattern making or pattern cutting. Therefore, for this study, patterns are designed to design several children's clothes, including dresses, shirts, and shorts. The design was done through the (adobe illustrator cc 2018) program. The sizes were taken based on specific dimensions, some of them were taken from the basic size table of children's clothes, and some were taken from children's body measurements, as shown in Figure (2). Many designs were done to produce children's garments.
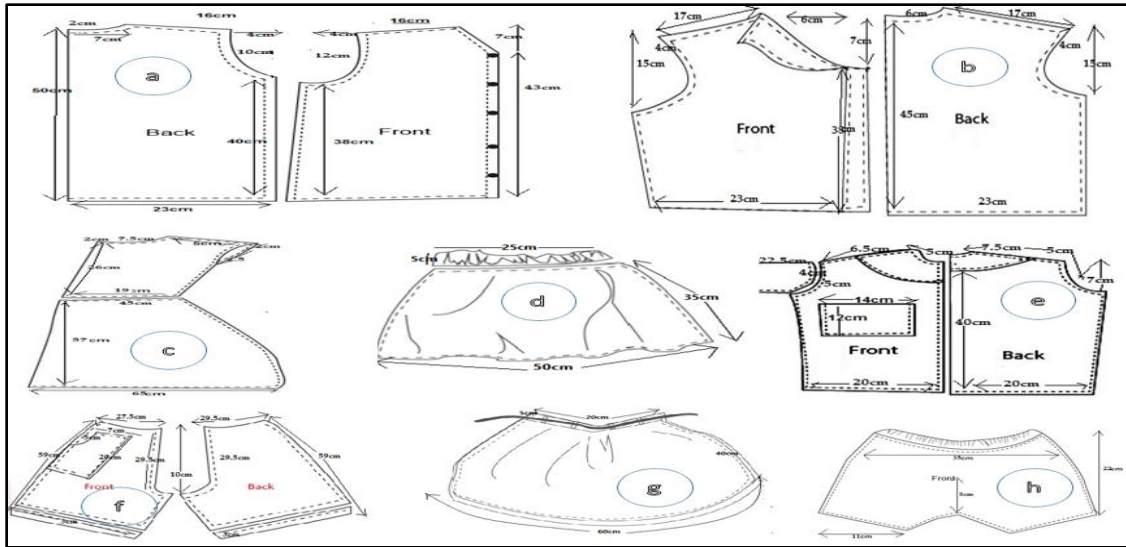
Figure (2): The patterns of children clothes; (a) T-shirt, (b) T-shirt, (c) Dress, (d) Skirt for Girl, (e) T-shirt, (f) Children's Short, (g) Skirt for Girl, and (h) Children's short.

1.2 The patterns design of some bags and wallets:

Bags and wallet patterns were designed through the (adobe illustrator cc 2018) program, based on matching the different types and sizes of waste fabric, and then add some accessories to it after implementation as shown in Figure (3) the various bags and wallet patterns.
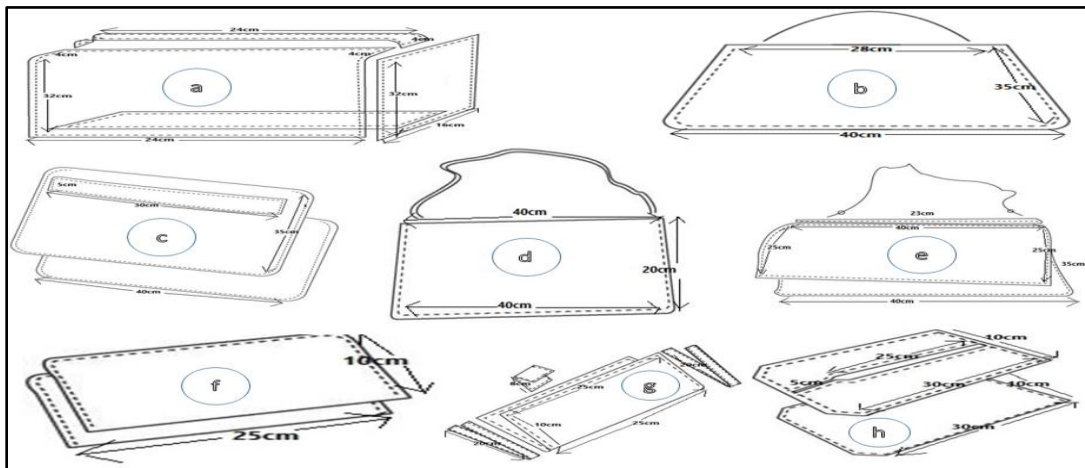

Figure (3): The patterns of bags and wallets; (a) for making a bag, (b) for making a handbag, (c) for making a handbag, (d) for making a women handbag, (e) for making a women handbag, (f) for making a wallet, (g) for making a wallet, and (h) for making a wallet.

1.3 The patterns design of bed sheets and decorative garments:

From the remaining garments, it was found that some pieces of fabrics can be used as a bedsheet and decorative for furniture, proportion to their size and type of material, so we designed many patterns to produce many bed sheets and decorative pieces. Here are many patterns designed through the (adobe illustrator cc 2018) program shown in Figures (4).
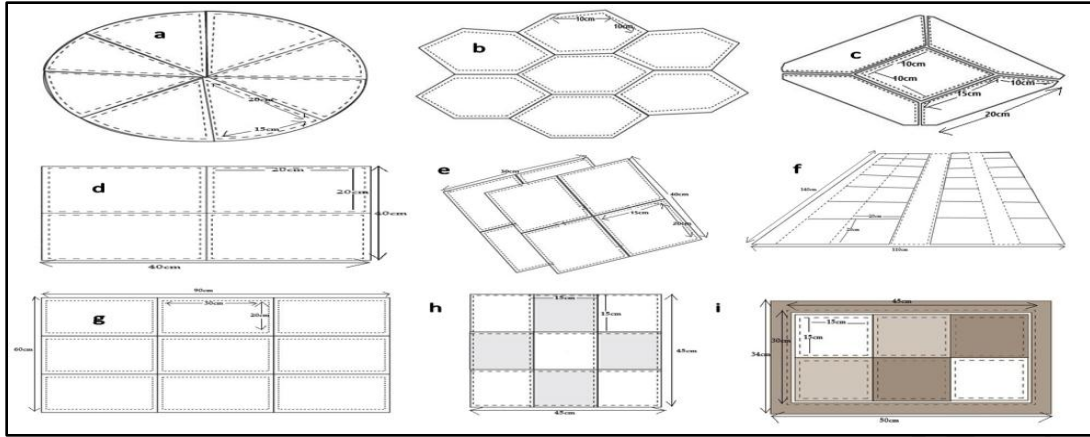
Figure (4)**:** The patterns of bed sheets and decorative garments; (a) for making a table's decorative, (b) for making a table's decorative, (c) for making a table's decorative, (d) for making a bed's decorative, (e) for making a table's decorative, (f) for making a bedsheet, (g) for making a table's decorative, and (h) for making a table's decorative, (i) for making a table's decorative

1.4   The patterns design of other designs:

Many patterns were designed to produce many products depending on the fabric's size, type, and color. Therefore, this group came in various designs, including patterns for the production of facemasks, caps, seat scarves,and bow ties. Below are many patterns designed by (adobe illustrator cc 2018), shown in Figures (•).
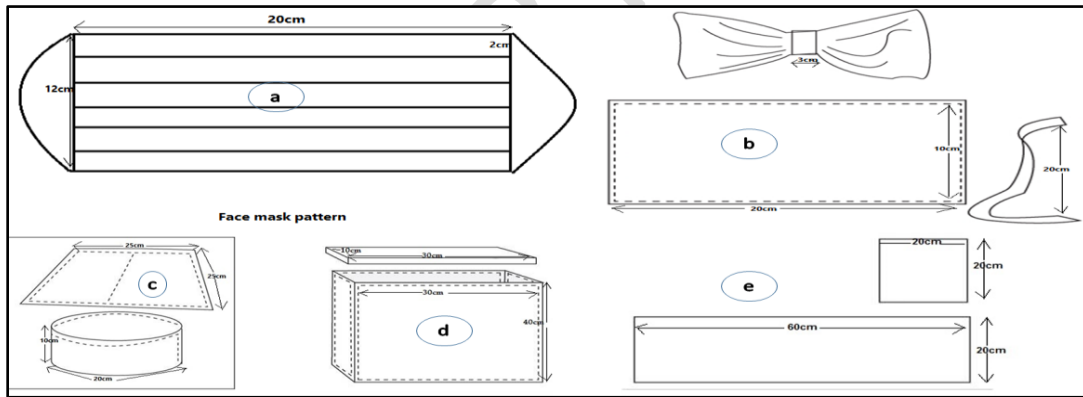

Figure (2)**:** The patterns of other designs; (a) for making a face Mask, (b) for making a bow tie decorative, (c) for making a cup, (d) for making a candy box, (e) for making a seat

4. RESULTS AND DISCUSSION

In the results, we first determined how the Sudanese garment factories deal with recycling clothing and the number of recycled garments in these factories. The study focuses on how the reuse and recycling of clothing and textiles can increase overall. After that, obstacles for reuse and recycling are identified. Finally, the subjective evaluation test of the designed garment was presented; thus, all the results were mentioned as follows:

4.1 The amount of garment waste produced in Sudanese factories:

From Table No. (1), the quantity of fabric introduced at the beginning of the garment production process in the various Sudanese garment factories was identified (constant

amount of materials). After that, the amount of fabric waste was calculated in different stages of garment production.

Then the percentage of fabric waste was calculated separately.

Table (1): The percentage amount of garments waste in different production stages.

Factory Number	The Input of Cloth in KG	Waste Production in kg					The Percentage of Waste
		Checking Stage	Cutting Stage	Sewing Stage	Preparation Stage	Total Waste	
A1	1000	0.1	0.8	0.2	0.1	1.2	0.12%
A2	1000	0.5	1	0.4	0.1	3	0.3%
A3	1000	0	3	1.2	0	7.2	0.72%
A4	1000	0	16	8	0	24	2.4%
A5	1000	0.05	0.5	0	0.001	0.551	0.0551%
A6	1000	0	2	1.4	0	3.4	0.34%
A7	1000	0	4	0	0	4	0.4%
A8	1000	0	17.5	2.5	0	20	2%

Table No. (1): The amount of fabric waste varies from one stage to another in garment production. From the results, we notice that factory number A4 and the factory number A8 have the most significant percentage of waste compared to other factories, and this is due to their lack of implementation of the excellent testing protocol for the raw fabric materials from the beginning and the inaccuracy of their patterns designs.

4.2 Fabrics waste Samples classification:

The classification stage for all the collected samples comes after the sorting process is completed. The classification of fabrics depends on the nature of the materials used to manufacture their fibers. They are classified according to the type of fabric or the textile structure in them. The following figures show the classification in terms of the kind of fabric and the fabric structure for (200) samples, see Figures (٦) and (٧):

1.   Samples classification according to the fabrics types:
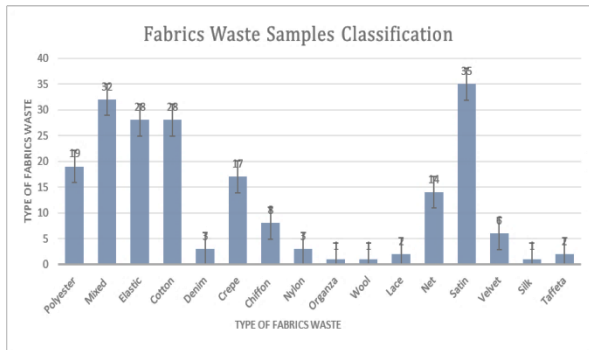
Figure (6): Classification by types of fabric

2.   Samples classification according to the structure of the fabric:
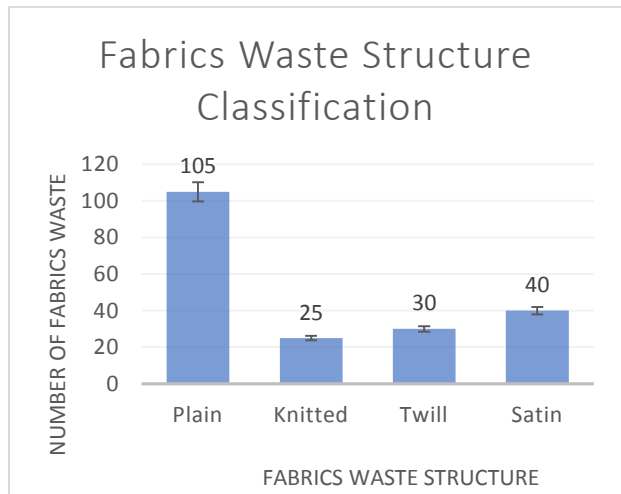

Figure (7): Classification by fabrics structure

From Figure No. (6) and Figure No. (7), we have clearly shown that the most significant difference in the remaining fabrics waste of different fabrics from one garment to another, and these variations depend on the consumer's behavior when choosing fabrics types, so we found that

satin fabrics are the most fabrics waste among the different fabrics.

4.3 Garment Fabrics Waste Characteristics Test:

After taking the statistics from the sources and conducting the classification on all the samples, the test of Garment Fabrics Waste Characteristics is done, and to perform the test in a good way, it must be in a standard atmosphere with humidity (65 ± 2%) and temperature (20 ± 2 m). The tests

After collecting the fabric waste from different factories, some tests were conducted to know the quality of different fabrics, as shown in Table No. (2). The characteristics of fabrics drape and recovering were performed according to (ASTM D2594) standards. Found that 13 samples had a weakly drape, 16 had a high drape, and 21 had an average drape property. Based on the relationship between the characteristics of fabrics drape and recovering, the samples with low drape had a high recovering rate, and conversely, for the samples with higher drape.

To find out the fabrics' fastness to color for washing and friction. The test of color fastness for washing and friction was conducted as shown in Table No. (2). These tests were performed according to (ISO 105-C01-9), (AATCC 61), (AATCC 8), and (ISO 105×12) standards. We found that 22 pieces have excellent dye stability and got a score of 5 on the greyscale, and (18) samples have less dye stability and earned a degree (4.5) in the greyscale.

4.4 The Results of Designs Executed:

After previous processes were completed and then monitoring the results of each of them, and a fabric with good quality was obtained and classified. Therefore, it can be ready to produce new products not less important than the products designed from the new fabrics. However, they were classified as waste because they did not enter the specific product's design; at this stage, new products were produced. The success of these products depends on preparing designs and patterns, which are mentioned previously. Accordingly, the designed products were divided into groups, and each group contained many clothes to clarify and solidify the idea. These groups were:

carried out in this research were determined according to specific criteria, following the test method according to the specifications mentioned in the textile testing standards, including the American Chemical and Dyeing Fabrics Association (AATCC), the International Standards organization (ISO), and American Society for Testing and Materials (ASTM).Therefore, all these results are shown in Table (2) below.

Thus we found that most of the waste fabrics have excellent stability for colorfastness. Therefore, the test of flammability was conducted based on (ASTM D6413) standards. When the piece of waste fabrics is exposed to the fire's flame, and observing the fabric's behavior when it was burned. Frome Table No. (2), we found that 28 was samples melted, these means it is synthetic fibers, 14 samples burning to carbon column means that it is a mixed fiber (cotton/polyester), the rest of the samples, which are (8), the result of combustion were (ash), it means that they are made of cotton fibers. Also, fabric tearing strength was conducted according to (ISO 13937-1) and (ASTM D1424) standards. From Table No (2), we found that 25 samples have a ratio of the strength of tearing ranged between (4000 - 6000), and 25 samples have the strength of tearing ranged between (1000 - 3900). Thus, we found that the percentage of tearing strength between samples is different due to the difference in the type of fabrics and textile structure used in their design.

1. Children's clothes.
2. Bags and wallets clothes.
3. Bedspreads and decorative textiles clothes.
4. Other designs clothes.

1. Children's Clothes:

This group includes many clothes, including children's clothes, and some other clothes. Children's clothes are designed according to the custom size chart for children's clothes, and the other clothes are designed according to sizes taken from many people. The clothing collection contains the following designs, see Figure No. (٨):

Table (2): Garment Fabrics Waste Characteristics Test Results

Sample No	Fabric Drape and Recovering Characteristics			Color Fastness for Washing		Color Fastness for Friction		Flamm-ability	Strength of Tearing (MPa)
	Angle	Drop-off	Recovering	Spotting Degree	Color Fastness Degree	Spotting Degree	Color Fastness Degree		
1	180^0	Week	High	5	5	5	5	Melt	2000
2	170^0	Week	High	5	5	5	5	Ash	4800
3	55^0	High	Week	5	5	5	5	Melt	5100
4	45^0	High	Week	4.5	4.5	4.5	4.5	Melt	3000
5	70^0	Average	Average	5	5	5	5	Carbon	4000
6	65^0	Average	Average	5	5	5	5	Ash	1300
7	45^0	High	Week	5	5	5	5	Carbon	2800
8	80^0	Average	Average	4.5	4.5	4.5	4.5	Melt	5400
9	50^0	High	Week	4.5	4.5	4.5	4.5	Melt	4500
10	180^0	Week	High	5	5	5	5	Ash	6000
11	60^0	Average	Average	4.5	4.5	4.5	4.5	Melt	3700
12	65^0	Average	Average	5	5	5	5	Melt	5100
13	70^0	Average	Average	4.5	4.5	4.5	4.5	Melt	4200
14	35^0	High	Week	5	5	5	5	Melt	4400
15	35^0	High	Week	5	5	5	5	Carbon	3700
16	65^0	Average	Average	4.5	4.5	4.5	4.5	Melt	2400
17	45^0	High	Week	5	5	5	5	Melt	4600
18	70^0	Average	Average	4.5	4.5	4.5	4.5	Melt	2700
19	65^0	Average	Average	5	5	5	5	Carbon	2800
20	70^0	Average	Average	4.5	4.5	4.5	4.5	Carbon	4300
21	45^0	High	Week	5	5	5	5	Melt	3800
22	180^0	Week	High	5	5	5	5	Melt	4100
23	180^0	Week	High	5	5	5	5	Melt	6200
24	75^0	Average	Average	4.5	4.5	4.5	4.5	Carbon	2700
25	180^0	Week	High	5	5	5	5	Melt	4900
26	75^0	Average	Average	4.5	4.5	4.5	4.5	Melt	5100
27	180^0	Week	High	5	5	5	5	Carbon	3900
28	75^0	Average	Average	4.5	4.5	4.5	4.5	Melt	3400
29	180^0	Week	High	4.5	4.5	4.5	4.5	Ash	4600
30	180^0	Week	High	5	5	5	5	Ash	3700
31	75^0	Average	Average	5	5	5	5	Carbon	4900
32	180^0	Week	High	4.5	4.5	4.5	4.5	Ash	5100
33	70^0	Average	Average	5	5	5	5	Melt	3800
34	45^0	High	Week	4.5	4.5	4.5	4.5	Melt	3400
35	60^0	Average	Average	5	5	5	5	Carbon	4600
36	180^0	Week	High	5	5	5	5	Melt	3700
37	90^0	Average	Average	4.5	4.5	4.5	4.5	Melt	4900
38	180^0	Week	High	5	5	5	5	Ash	3200
39	65^0	Average	Average	5	5	5	5	Carbon	2100
40	35^0	High	Week	5	5	5	5	Melt	3000
41	40^0	High	Week	4.5	4.5	4.5	4.5	Melt	2100
42	45^0	High	Week	0	5	0	5	Carbon	4900
43	60^0	Average	Average	4.5	4.5	4.5	4.5	Melt	4100
44	70^0	Average	Average	5	5	5	5	Melt	6000
45	180^0	Week	High	5	5	5	5	Carbon	3100
46	45^0	High	Week	5	5	5	5	Melt	2000
47	55^0	High	Week	4.5	4.5	4.5	4.5	Carbon	6000
48	60^0	Average	Average	5	5	5	5	Melt	3000
49	35^0	High	Week	5	5	5	5	Carbon	3800
50	45^0	High	Week	5	5	5	5	Ash	5400
Average				4.72	4.82	4.72	4.82		3966

Figure (8): Children's clothes

2. Bags and Wallets Clothes:

It was found that there are many fabric residues of high durability that can be used to make bags. In this way, many types of bags and wallets for women and men were designed in different sizes, and this group contains the following designs, see Figure No. (٩):
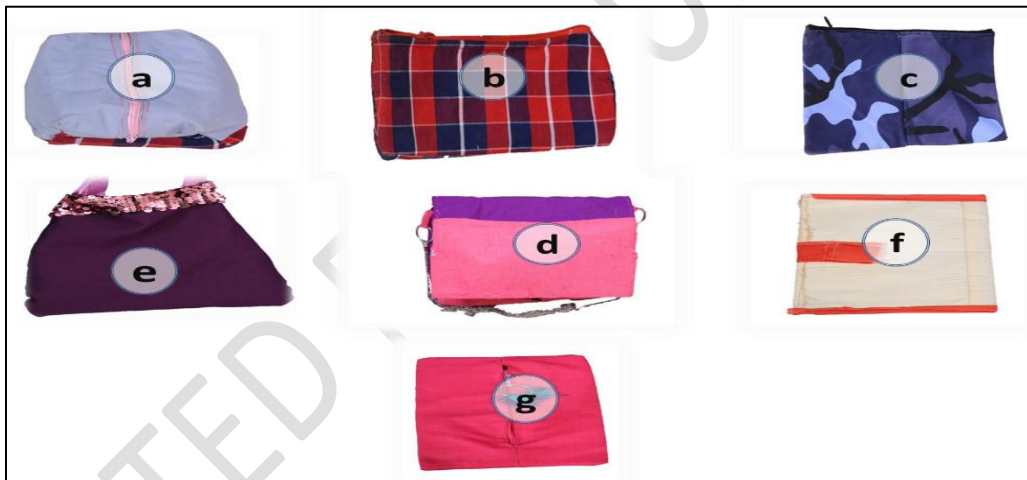

Figure (3): Bags and wallets Clothes

3. Bedspreads and Decorative Textiles Clothes:

As we found the remains of suitable durability fabrics and were used in the design of bags, there are remains of fabrics with bedsheets' characteristics. Their sizes were suitable for the design of bedspreads and textiles that are used in decoration, and the design of the bedsheets started from small sizes until the design of a bedsheet; this group contains the following designs, see figures No. (١٠):

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Figure (4): Bedspreads and decorative textiles clothes

5. Other Designs Clothes:

This group contains many designs that do not fall under any of the previous groups. Each design is to produce a specific product depending on the type of fabric, its size, and color; this group includes designs such as capes, scarves, and bow ties. The face mask is also designed using pieces of non-woven fabric and then sterilized so that it is suitable for use more than once, with the possibility of re-sterilization. See Figure No. (١١).

Figure (5): Other designs

5. CONCLUSION

Reusing is discovering another use for a present garment, or in the case of textiles, it infrequently also signifies converting (waste) into reusable materials. Garment fabric reusing generally involves finding the additional user or use by devoting a brand new stage for its life starting. The significance of this scientific research on the reusing and recycling of textile waste, because it was conducted on several Sudanese garment factories. This research's essential objective is to reduce textile fabrics waste production in Sudanese garment factories and increase awareness of the importance of reusing and recycling to make new products of this waste. In this recent study, the primary data was collected from Sudanese garment factories, and identified the types of the waste in garment factories, workshops, and various tailors each separately and inquired about how they dispose of the waste, and statistically analyzed. A sorting process was conducted for all fabric samples and classified according to

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the type of materials and structure used in their design. Therefore, some tests had to be done to know their quality and usability again, so the result was fabrics of relatively good quality fabrics and thus can benefit from it, here appeared the step of producing new products from this waste, several designs were produced the products designed were divided into groups (clothing - bags - furniture - and others), and to know the quality of these products had to be evaluated by the consumer. Through all the results from this study, we found that the different garments that were produced from waste fabrics showed to have a great satisfaction among consumers.

6. **Recommendations:**

1. Increasing awareness of the harmful effects of textile waste.

2. Increasing awareness of the importance of reusing and recycling textile waste.

3. Establish special units for recycling waste in the garment factories.

4. Putting a special container in the tailor's shops in the markets to put the fabric waste and collect it by those who interested in reusing and recycling.

5. Developing cutting techniques in the phase of fabric cutting.

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