GARMENT DURABILITY ANALYSIS – INFLUENCE OF TEXTILE MAINTENANCE

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ABSTRACT

Textiles used in clothing pose a large environmental burden from their initial manufacturing, maintenance and end of life. Garment production is a major problem whose environmental impacts can be easily quantified since it is a defined production process. To implement sustainable processes, it is necessary to evaluate the entire life cycle of a garment, including its maintenance and end-of-life. In this study, the maintenance phase of the garment is investigated. The garment maintenance is divided into real applied steps, and these individual steps are analysed in terms of raw material especially regarding potential/real damage to the treated garment fabric. The different maintenance steps are contextualised by the survey and results of the questionnaire used for the study. This investigated which gentle maintenance practices the respondents use in practice. The source of the analysed data is a questionnaire survey made in the Czech Republic. The result is a thorough analysis of the maintenance practices associated with garments and an analysis of ways to extend the lifetime of garments and thus reduce their environmental burden caused by excessive waste generation.

KEYWORDS

Garment; Durability; Textile maintenance.

INTRODUCTION

The textile industry is one of the largest contributors to environmental pollution. The increase in textile waste is usually perceived as the result of an increase in cheap products in a saturated market. Archetypal practices used during consumer use further contribute to this problem [1]. Textile durability is a key tool for achieving sustainability in the apparel sector. The longevity of garments is not only a matter of the textile materials used but also of the appropriate maintenance chosen and carried out.

Textile maintenance consists of stain removal (detaching), removal of impurities (washing, dry cleaning), removal of used solvent (drying, evaporation of organic solvents), minor repairs, surface alignment (ironing, mangling) and storage.

Table 1 summarizes the operations involved in garment maintenance. It gives the operation's main objective, the principle of the methods used, and the risks to the garment that can significantly reduce its service life.

The individual operations of garment maintenance are detailed below. The procedures used are:

Stain removal – detaching

One of the most common reasons for discarding garments is due to damage caused by stains and spots or their improper removal. Depending on the nature of the stain, several methods may be required to remove it. Once the chemical nature of the stain and the textile material have been correctly identified, the appropriate stain remover is selected. Often, stains can be easily removed without much difficulty or cost [2], [3].

The agents contain various oxidizing and dispersing agents as well as solvents. These agents are applied in a highly concentrated and effective form that can remove the stain or facilitate its removal in a subsequent step targeted at removing common soils. The used agents may cause local discoloration or otherwise damage the garment's fibres when applied. This can be due to an inappropriate choice of detaching agent for a given garment containing sensitive fibres or dyes [3], [4], [5]. Organic solvents are a potential risk for chemical fibres, and aqueous solutions are riskier for natural fibres [2].

Only a limited number of low-efficiency detachers are available for domestic use. Commercially available stain removers have low risk of damaging the garment. However, it is also likely that some stains

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cannot be removed with these products. Figures 1 and 2 show an example of an unremoved stain on a knitted fabric.

However, if it is not difficult to remove the stain, using normal laundry detergents and cleaning agents could ensure the removal of the stain without adding a detachment agent. Water molecules can diffuse well between the fibres and the stain using surfactants, thereby weakening the bonding forces between the stain and the fabric. Several factors influence the ability to remove stains, such as fabric characteristics, type of soiling, water quality, washing technique, detergent composition, etc. [3], [6].

Removal of impurities

Routine washing

The main purpose of the washing process is to remove dirt and microorganisms from soiled textiles to ensure hygienic safety and decontamination. The textiles undergo a washing process that includes removing dirt using special detergents, bleaching, disinfection, neutralization, and soaking [7].

The outcome of the wash depends on several factors, including the amount and type of water, temperature, length of wash cycles, chemicals used, such as detergents, and the mechanical spinner used. Dirt can be removed either by higher temperature, mechanical force, interfacial processes, or chemical degradation by enzymes or bleaching agents. Prewashing, which is a short wash before the main wash, is commonly used to effectively remove various stains and soils. Prewashing was more common in the past because laundry was dirtier, took longer to accumulate before washing, and detergents were less effective [8].

Washing is commonly practiced in households and industrial laundries and is based on the use of aqueous dispersing and bleaching systems. Commonly used detergents may contain percarbonates (bleaching agents, sources of hydrogen peroxide), peroxide activators to increase the bleaching ability of percarbonates at low temperatures, pH-adjusting agents (usually alkaline in origin), detergent and emulsifying detergents, and enzymes to break down difficult-to-remove starch and protein-based impurities [3], [8].

Natural fibres, such as cotton and wool, are hydrophilic, which means they have places on their surface where water molecules bind. As a result, water remains trapped in these fibres, causing them to have a poor ability to transport and release moisture [9]. Washing cellulose-based fibres is always risky, as the fibres swell intensely during washing. The swelling of cellulose fibres causes a temporary shortening of the yarns, which usually results in shrinkage of the garment [10]. This occurrence should be expected by the user of the garment but is not usually a risk to the longevity of the garment. The second aspect of fibre swelling is the release of dyes from the fibres, which is promoted by the swelling of the polymer by water and by the opening of nano-pores in the fibre [11]. If less stable dyes are chosen, the colour of the garment may be significantly lost during washing, and the product's life may be significantly reduced. The swelling of cellulose fibres is not significantly affected by the temperature of the washing bath.

Table 1. Clothing maintenance operations.

	1. Stain removal	**2. Removal of impurities**	**3. Removal of used solvent**	**4. Minor repairs**	**5. Surface alignment**	**6. Storage**
Objective:	Elimination of visually localised impurities	Elimination of surface-deposited impurities, including odour	Remove the solvent used in the previous operation	Ensure functionality and eliminate mechanical damage to the garment	Fracture elimination, mechanical alignment of the garment	Keep the garment in usable condition
Principle:	Topical use of detergents, bleaches, solvents	Use of solvent and dispersion systems	Solvent evaporation by heat and vapour recovery	Restoration of garment	Temporarily stent clothing by exposure to temperature and humidity	Elimination of chemical, biological and mechanical influences on clothing
Risks to clothing:	Insufficient stain removal, fibre damage, localised discolouration	Insufficient impurities removal, mechanical and chemical damage to the garment, colour changes	Contamination of clothing with dirt, colour changes	Visibility of adjustments	Colour changes, thermal damage to the garment	Fracture formation, pest infestation, colour changes

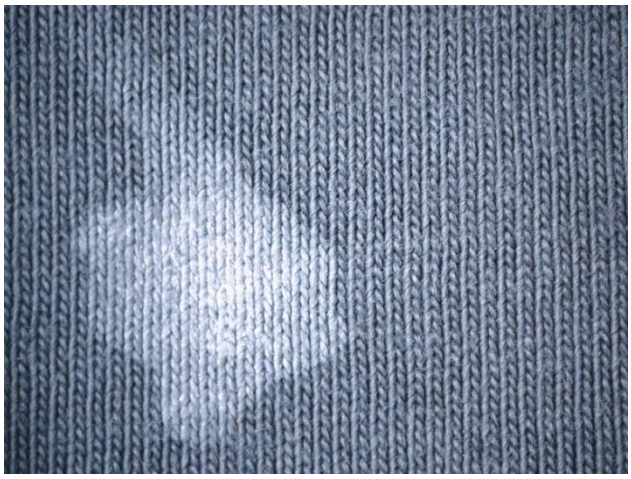

Figure 1. Paint stain on cotton knitted fabric magnified 10x.

Figure 2. Paint stain on cotton knitted fabric, magnified 35x.

For wool and other protein fibres, the potential alkalinity of the washing solution is a risk, especially at higher temperatures. Under these conditions, there is a particular risk of felting of the wool, associated with a permanent change in the appearance and dimension of the garment [12]. Also, a problem for wool fibres is the presence of some enzymes used in detergents; these are various esterases and proteases that should break down the proteins contained in the dirt on the fibre [13]. Choosing gentle washing methods, minimizing mechanical action and controlling moisture during drying can help preserve the quality and appearance of wool garments.

Damage to synthetic polymer fibres is almost impossible at recommended washing temperatures. The recommended washing temperature is practically always below the fibre polymer's glass transition temperature, thus ensuring not only the fabric's mechanical stability but also the dye's stability during washing.

Wet cleaning

Wet cleaning is one of the methods of professional garment maintenance normally carried out by dry cleaners. This optimized washing procedure uses the basic principles and technologies of conventional washing. The risks to garments are comparable to conventional laundering [5].

Dry cleaning

It is one of the methods of professional garment maintenance and is typically carried out in dry cleaners. In contrast to washing and wet cleaning, non-aqueous solvents such as perchloroethylene and some liquid hydrocarbons are used [14]. Dry cleaning is gentler on the natural fibres and the dyes in them. The use of inappropriate solvents is a risk factor for synthetic materials. There is practically no risk when using standard textile fibres and standard dry-cleaning solvents [5]. The problem tends to be the design components of garments made of low-resistant polymers.

Removal of used solvent

Clothes are dried in different ways. They are usually dried using a combination of air or hot air, resulting in the evaporation of moisture and then removing it with a stream of air. Different forms of drying racks and lines are used, both indoors and outdoors. Drying chambers and separate drying rooms, such as drying cabins with or without heating, and, finally, tumble dryers, are also used. On average, about 32% of households in Europe use tumble dryers [8].

Air drying

Air drying is the most energy-efficient method, as it uses ambient air temperature as the energy source to evaporate water, which also removes evaporated moisture. Drying in direct sunlight is the fastest but also the most problematic regarding garment life. Direct sunlight generates active oxidising agents in wet textiles, which are particularly damaging to the fabric's colour. In addition, direct sunlight also damages the polymer, but this process is relatively slow [15], [16]. An example of the change in colour of the fabric is shown in Figure 3.

Drying in the tumble dryer

Drying in a tumble dryer is quick but less gentle on fabrics compared to air drying. The mechanical action in the dryer can cause slight abrasion between garments, gradually damaging them. Loose fibres tend to get caught in the tumble dryer filter. While this reduces the fabric’s weight over time due to fibre loss, it also helps to remove microfiber deposits accumulated during washing. [17] Research shows that all fibre types release significant amounts of microfibres when washed, but cellulose-based fabrics release more microfibres than polyester with the same fabric structure. The physicochemical properties of fibres and yarns play an important role in forming microfibres. Fabrics with higher abrasion resistance, low pilling and higher yarn breaking strength have a lower tendency to form tufts and/or release microfibres when subjected to the mechanical

Figure 3. Colour change of cotton knitted fabric due to light and humidity (unexposed on top, exposed knitted fabric on bottom), magnified 12x.

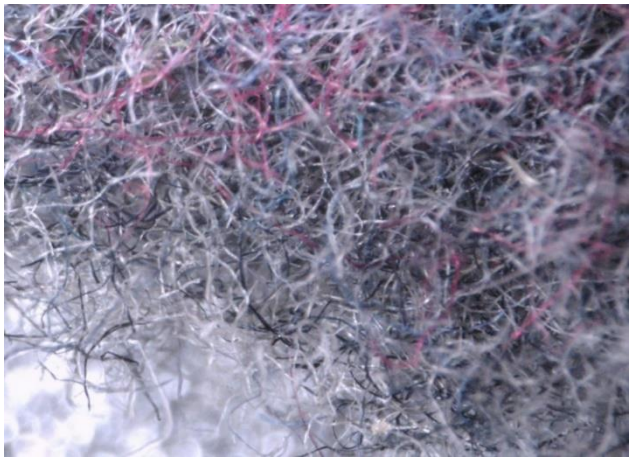

Figure 4. Fibrous microplastics caught on the tumble dryer filter magnified 100x.

action of washing [18]. A sample of the fibrous microplastics released during drying of the fabric is shown in Figure 4. The advantage of the tumble dryer is that there is no risk of photochemical decomposition of dyes, however, too high drying temperatures and mechanical movement can cause mechanical deformation of the fabric.

Minor repairs

Repair is essential as it can reduce garment consumption and textile waste, thereby improving the sustainability of garments throughout their life cycle and enhancing the circular economy [19]. Most of the time, clothes are mechanically damaged during use, and this damage is one of the main reasons why clothes are discarded from the wardrobe. However, some mechanical damage is repairable with relatively little effort. The most common is the reattachment of separated garment parts, the addition of lost buttons, etc. [20]. Examples of minor mechanical damages of garments are shown in Figures 5 and 6. Minor repairs indicate that the wearer values their garment; they generally do not require advanced skills, but willingness is crucial. Each minor repair significantly contributes to prolonging the garment's life.

Various surveys indicate that while certain segments of society are starting to acknowledge the environmental and social advantages of garment repair, this perspective diverges from mainstream thinking. The prevailing attitude leans towards discarding damaged garments rather than repairing them [1].

There are many barriers that complicate garment repair. Among these are financial costs and lack of time and skills. The study also highlights that social and psychological reasons play a big role in repair. Traditionally, the imperfection of textile materials is strongly associated with a lack of finances, and wearing visibly worn or damaged clothing plays a significant role in characterising social conditions. However, the increasing visibility of repairs challenges traditional, outdated views of clothing repair. Designing visible repair patterns that are modern, stylish, accessible and can be deemed personalised offers the potential for a wider extension of repair techniques, making them personal, meaningful and socially acceptable to wear in the workplace [20].

Surface alignment

Ironing

Ironing is based on the application of high temperature, pressure and moisture to the garment material. The mechanism of action varies from fibre to fibre, but the result is similar for all garment fibres. Temperature has a significant effect on the ironing result for synthetic fibres, while moisture has a greater effect on natural fibres. Particularly for synthetic polymer fibres, a sufficiently high temperature is necessary but must not exceed a critical temperature close to the melting or decomposition temperature of the fibres. Significantly exceeding the ironing temperature leads to the destruction of the fibre structure in the case of fusible fibres and carbonisation or colour changes in the case of non-fusible fibres. If a synthetic fibre fabric (typically polyester) is dyed with a disperse dye for a non-standard short period of time, the dye is localised just below the surface of the fibres. The temperature effect of ironing causes a redistribution of the dye in proportion to the intensity of ironing, leading to irremovable and easily visible colour changes [21].

Mangling

The same principles used for mangling are also used for ironing. Due to the different geometry of the process, there is less risk of fibre damage and colour variations on the textile. Mangling is a process of smoothing clothing instead of ironing it after it has been dried. This is done by passing it between heavy rollers, which may be heated [22].

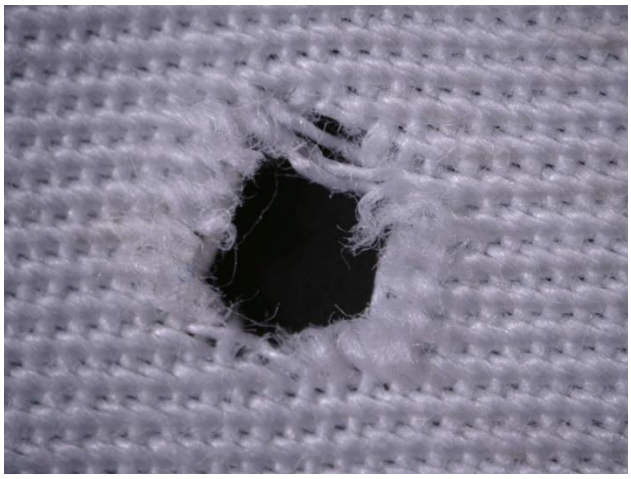

Figure 5. Mechanically damaged cotton fabric - perforations, suitable for repair, enlarged 25x.

Figure 6. Mechanically damaged cotton fabric - loose pocket, suitable for repair, enlarged 15x.

Storage

Textiles are not usually exposed to intensive processes from their surroundings during storage, but rather to low-intensity, long-term processes. However, the result can be the destruction of the garment. The problem in storage is usually moisture, which promotes hydrolysis reactions and thus damages the fibres, such as in the case of polyamide. Moisture also promotes the activity of insects, moulds and bacteria, which can degrade textiles, although it is more common for hard-to-remove odours or coloured stains to appear on textiles [23]. Another problem is direct sunlight, which, when exposed for long periods, can significantly damage the exposed areas both at the polymer level and at the level of the fabric's colour. Clothing should be stored in a dark area with low humidity and adequate temperature to avoid the aforementioned problems.

EXPERIMENT

A questionnaire-based method was chosen to collect data on reasons for which clothes were discarded from the wardrobe and, simultaneously, to collect data on the users' behaviour towards the clothes at the time of their discarding. The questionnaire was created using Google Forms and distributed to the public. Considering the topic of the questionnaire, an increased proportion of respondents from the circle of those interested in fashion and clothing can be expected. Given the creation of the questionnaire in a university setting, an increased proportion of student respondents can also be expected. The questionnaire presented here is in English; a questionnaire in the Czech language was used to collect data for this study. The respondents are, therefore, mainly from the Czech Republic. For this research, responses were collected from a total of 498 respondents.

The collection of responses using this questionnaire took place from 15.2 to 17.4 2024.

Asked questions:

1. Which of these maintenance practices do you use to make your clothing last longer? (you can select more than one option).
   - · Proper storage (dry, dark, clean environment...)
   - · Gentle washing (following care label instructions)
   - · Removing stains with special agents
   - · Minor textile repairs (preventing knitwear from pilling, patching holes...)
   - · I don't dry textiles in direct sunlight

2. How often do you repair or alter clothing instead of discarding it due to minor damage or wear and tear?
   - · Often (once a week)
   - · Occasionally (once a month)
   - · Rarely (once a year)
   - · Never

RESUTLS AND DISCUSSION

Evaluation of questionnaire data:

Many respondents were women (81%), with the remainder (19%) being men (Figure 1). No other gender was indicated by the respondent. The higher percentage of women is related to the higher percentage of women in our university (Faculty of Textile Engineering TU Liberec) and the expected higher percentage of women interested in clothing and fashion.

The age distribution of respondents is relatively even, encompassing the entire range of adults (18+), though a few respondents under 18 also participated. The higher proportion of individuals in the 19 to 26-year-old category can be attributed to the significant number of respondents from our university. Refer to Figure 8.

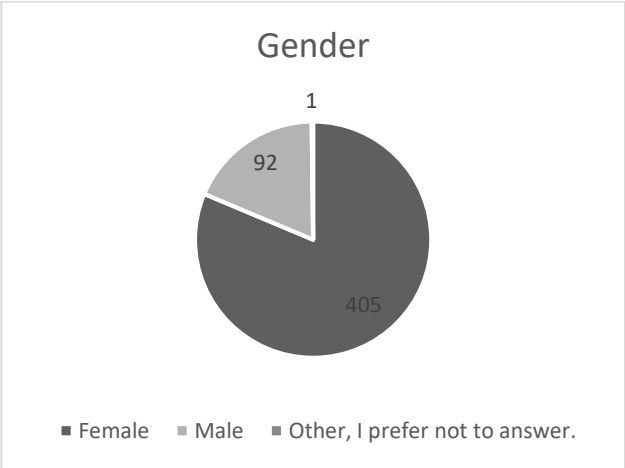

Figure 7. Gender of respondents.

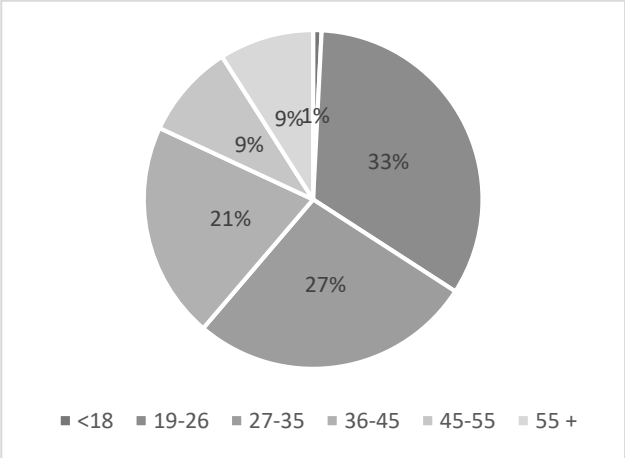

Figure 8. Age distribution of respondents (only 1% of respondents below 18 years).

This question received 1328 responses. The following is a multiple-choice question. The least preferable method is drying in direct sunlight. Only 20.5% of respondents chose this option. The theory of drying textiles in direct sunlight should spread more widely among the public. It is scientifically proven that progressive tendering of fibres occurs on exposure to sunlight for long periods, and serious losses in strength can occur, particularly with lightweight fabrics. The different fibres lose strength at different rates and range from sensitive silk to resistant polyacrylonitrile fibres, which withstand sunlight for long periods.[24].

On the other hand, the procedure followed the most is proper washing and following the procedure on the label. A total of 73.1% of respondents followed this procedure.

A significant number of respondents (68.3%) reported that they store textiles correctly. Factors such as a dry, dark and clean environment ensure that textiles are protected and maintained in optimal conditions, contributing to their long-term durability and quality. Such a clean environment is crucial not only for private households but also for industrial storage facilities or museums.

Many respondents prolong the life of their garments with minor and relatively simple repairs (61.8%). 43% of respondents choose to remove stains using special detaching products. The percentage of responses is summarized in Figure 9.

These responses suggest that consumers very often take care of their garments, thus prolonging their life. A related question focuses on how often users repair or alter their clothes instead of discarding them due to minor damage or worn-out items. Only 8% of respondents answered that they do not tend to maintain their garments in this way.

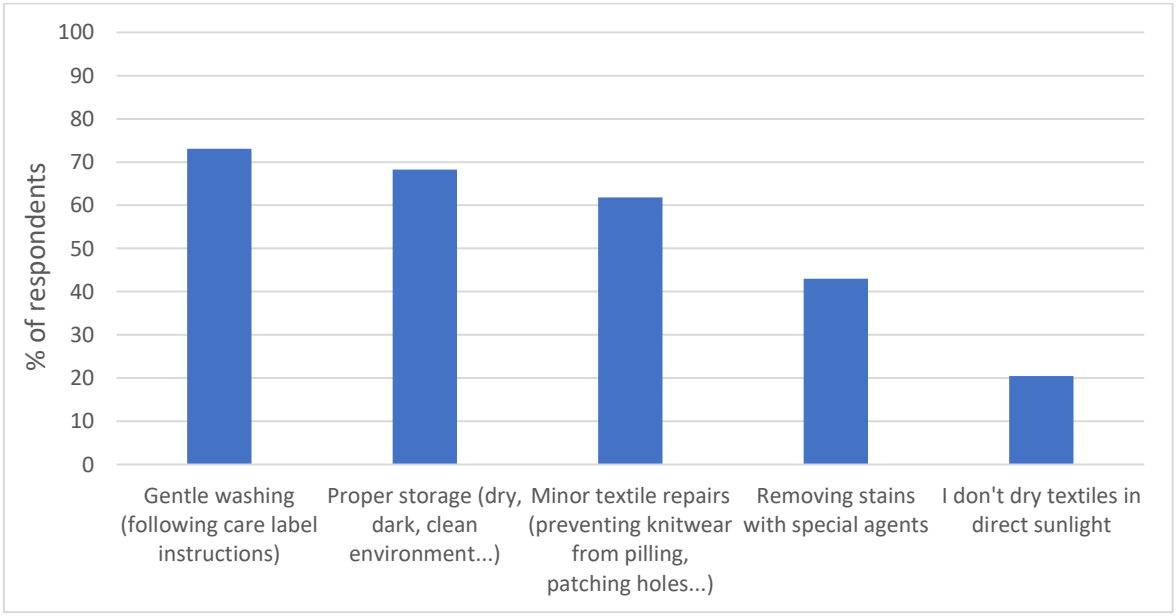

Figure 9. Percentage of respondents using this method of garment maintenance.

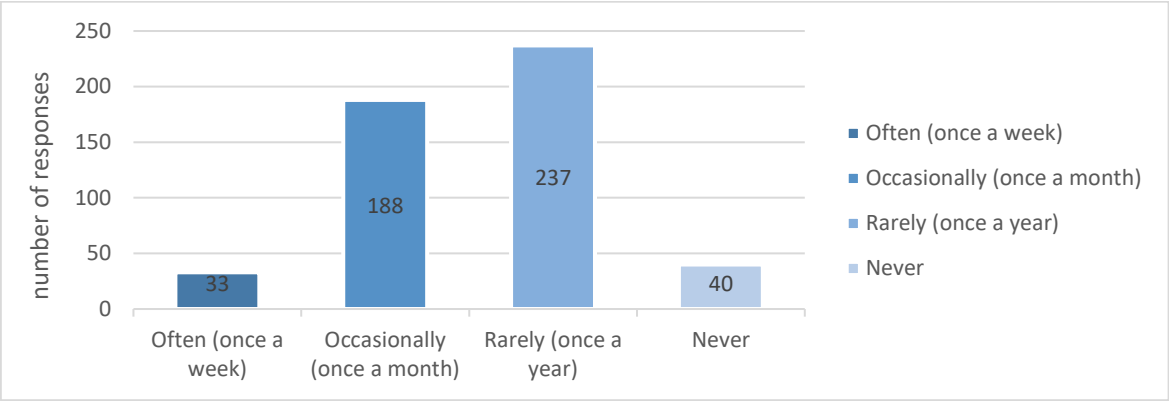

Figure 10. Frequency of small repairs and alterations to respondents' clothing.

When comparing clothing repairs by gender, it is found that 35% of men and 68% of women prefer to have their clothes repaired. 498 respondents answered the question on the frequency of minor clothing repairs. The questionnaire results show that 33 people in this group regularly repair their clothes once a week, indicating that they take considerable care of their clothes. 188 people choose to repair their clothes monthly, indicating a regular effort to maintain the quality of their wardrobe. A further 237 respondents choose to have their garments repaired once a year, which may indicate their intention to save the cost of new garments while maintaining their favourite items. Conversely, 40 people admitted that they never repaired their garments, which may reflect their preference for buying new pieces over repairing old ones. Frequency of small repairs is summarised in Figure 10.

CONCLUSION

In this study, the life cycle of garment maintenance was analysed to identify and quantify garment maintenance risks. The different stages of garment maintenance and the associated degradation of garments were discussed. Improperly selected maintenance or improperly performed garment maintenance mainly leads to changes in garment colour but can also lead to permanent damage to the fibre structure of the garment. Damage to the garment is a common reason for removing it from the wardrobe and thus ending its life. Damaged garments are usually not suitable for reuse, and it can, therefore, be said that any damage to a garment leads to a significant shortening of the garment's life. Much of the damage to garments is caused by incorrect maintenance, and therefore, garment maintenance needs to be popularised. At the same time, garments that require easy and risk-free maintenance need to be industrially produced. A questionnaire survey was conducted to verify consumer awareness of garment maintenance methods and risks. The questionnaire survey results are satisfactory; most respondents employ suitable methods for garment maintenance and understand the risks associated with improper care on garment durability.

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