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Impact of Fast Fashion Industry on the Environment

Natasa PEJAK

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Author's declaration

No portion of the work references in this thesis has been submitted in support of an application for another degree or qualification of this or any other university of institutes of learning.

Natasa PEJAK

CENTRAL EUROPEAN UNIVERSITY

ABSTRACT OF THESIS submited by:

Natasa PEJAK

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Apart from food, water, and shelter, clothing is also considered necessary for everyday life. They not just keep us warm and protect us from the outside weather conditions, but they also have significant cultural, social, and emotional functions too. The clothing is our identity, through which we express ourselves and our status. Subconsciously or conscientiously, by picking our everyday outfits, we send a certain message to the world of who we are. That being said, what could possibly be wrong with clothing? What truth is hidden beneath your new modern appearance and new stylish clothing? This paper will try to reveal and examine the true cost of our trendy looks, which we aspire to. It will show the dark side of clothing production and the fast fashion phenomenon.

Keywords: concept, model, economy, fast fashion, slow fashion, industry, manufacturing, supply chain, products, clothes, apparel, life cycle, impact, environment, society, sustainability, recycling, reuse, zero-waste.

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Introduction

Fast fashion is a novel business model that has drawn recent attention due to its vast environmental and social impacts. It rests on the idea of mass production, quantity over quality, and fast replacement of clothes in a short period of time. The clothes have never been more available and cheaper than today. With its very overconsumptive nature, such a business model led to vast environmental and social problems. It is estimated that today's value of the fast fashion industry is up to 3 billion dollars globally (Ting and Stagner 2021), and it employs around 40 million people worldwide (Bick *et al.* 2018). Fast fashion is related to environmental issues such as enormous water consumption, mainly for the growth of natural fibers such as cotton, use of hazardous chemicals, discharge of toxic untreated wastewater, air pollution and GHG emissions, intense energy consumption, and extensive generation of waste, which usually ends up in the landfills. To produce clothes, the fast fashion and textile industry requires a significant amount of natural resources such as water, land, and oil (Rukhaya *et al.* 2021). It uses around 98 million tonnes of non-renewable resources per year; oil for the production of synthetic clothes, fertilizers for growing natural fibers (mostly cotton), and chemicals (Morlet *et al.* 2017); to produce 80-100 billion pieces of clothing each year (Patwary 2020). From this, we can understand that the textile industry is resource-intensive, depleting natural resources and polluting the environment to produce clothes that will be in use for a short period and end up mostly in landfills. In the last 15 years, the average use time of garments has decreased significantly. Further, every year, the global fashion industry produces around 92 million tons of waste (Napier and Sanguineti 2018), from which 87 % ends up in landfills or for incineration (Ross 2019). Such a business model is unsustainable as it relies on the take from nature, produce, use, and discharge pattern. According to the Morgan documentary The True Cost (2015), right after the oil industry, fast fashion is the second most polluting industry in the world (Ozdamar-Ertekin 2017). For example, it is one of the most intensive industries regarding chemical use. Of the total chemicals manufactured worldwide, 25% are used in the textile industry (Khandare and Govindwar 2015). Approximately 15 000 different types of chemicals are utilized during the manufacturing of clothing in various processes (Roos *et al*. 2019). Apart from consuming chemicals, fast fashion is also water-intensive, as it uses around 93 billion cubic meters of water per year (Morlet *et al.* 2017).

In the last few decades, the fast fashion industry supply chain has become a complex network, as various stages of clothes production are conducted in different countries, mostly low and middle-income countries. Closing manufacturing has shifted towards these countries because of weak environmental legislation and a cheap labor force. Actually, ,,Low and middle-income countries produce around 90% of the world's clothing" (Bick *et al.* 2018). This shift of production brought developing countries environmental problems associated with clothing production, while most of these clothes end up in the market of wealthy countries for consumption. For instance, in 2019, while the US, EU, and Japan consumed 58.1% of the world's produced clothing, China, Bangladesh, and Vietnam exported 43.8% of the world's clothing (Lu 2019). After a short period of use, the clothes that do not end up in the landfills or incineration are shipped back to developing countries as second-hand clothing for further use before it is ultimately disposed, contributing to waste problems in those countries. For example, the US exports around 450 000 tonnes of second-hand clothes each year to low- and middle-income countries (Bick *et al.* 2018). As the fast fashion model encourages buying more and more clothes and discharging behavior, developing countries face unbearable pressure.

The main purpose and goal of the paper are to disclose the true environmental cost of fast fashion concept and clothes production. Thus, the paper examines the major environmental consequences of the textile and fast fashion industries. Further, the paper also includes a study of the environmental consciousness of people in Serbia about the fast fashion industry and an examination of their purchasing habits when it comes to fashionable clothes. The first chapter is about methodology, which includes a description of the survey methodology and techniques for developing a survey questionnaire. The second chapter describes obtained results. The following chapter, the literature review, begins with the history of the apparel industry and emergence of fast fashion. The first part of the chapter describes early beginnings of the textile industry (prehistoric times), followed by the industrial revolution and transformation of the textile industry, and lastly, the emergence of the fast fashion business model. The next part of the chapter includes a description of two leading and most famous fast fashion brands: Zara (Inditex) and H & M. Lastly, the literature review also covers the clothes manufacturing process and description of the main types of fibers used in the textile industry. The essential part of the thesis, the discussion, examined and analyzed major environmental consequences of the textile and fast fashion industries. The first part of the discussion is about impacts of different stages of clothes production on the environment, while the second part studies and summarizes impacts of the fast fashion industry on each segment of the environment (water, soil, air, with the part about waste generation). Finally, the thesis paper ends with recommendations which examine sustainable and circular approach applications within the fast fashion industry.

1. Methodology

In general, the common methods used for research can be divided into qualitative, quantitative, or mixed methods (Williams 2007). Every research includes a few processes such as data collection, analysis, and interpretation in order to understand a certain phenomenon (Leedy and Ormrod 2001). A method can be defined as "a particular research technique or way to gather evidence about a pehnomenon" (DeMarrais *et al*. 2004, 4). Methods are specific research tools used in research projects in order to gain a fuller understanding of the phenomenon (DeMarrais *et al*. 2004). Quantitative methods are usually used to respond to research questions requiring numerical data, while qualitative methods are used for research questions requiring textual data, and mixed approach in case of research questions requiring both numerical and textual data (Williams 2007). Quantitative research is based on a numeric and statistical approach to research design (Williams 2007). It requires a problem statement, formulation of the hypothesis, a literature review, and quantitative data analysis (Williams 2007). It involves data collection so that gathered information can be further quantified and subject to statistical analysis (Williams 2007). The researchers in quantitative research usually use mathematical models as tools for data analysis (Williams 2007). On the other hand, the qualitative method uses a holistic approach for discovering, describing, explaining, and interpreting collected data (Williams 2007). "By the qualitative research it is meant any type of research that produces findings not arrived at by statistical procedures or other means of qualification" (Strauus and Corbin 1998, 10-11). The terms "methodology" and "method" are often understood as synonyms, which is not the case. They are distinguished as two very different concepts (Harding 2013). While methodology is "purpose" (Clough and Nutbrown 2012) and "philosophy of methods" (Sapsford 2006), methods are "tools" to approach the purpose of any study (Sapsford 2006; Clough and Nutbrown 2012). Leedy and Ormrod (2001, 14) defined methodology as "the general approach the researcher takes in carrying out the research project". In other words, methodology is the way to get answers to a research question, while method is a specific tool to achieve that. This chapter will illustrate the conducted methodology and research strategy, the methods of data collection, and the obstacles and challenges faced during research.

The research for this paper was mostly based on qualitative methods, such as the literature review and the survey. The main purpose and goal of the thesis were to examine and determine the major negative environmental impacts of the fast fashion industry. For that purpose, the initial stage of research included an examination of existing related literature. The main academic open platforms used for literature research were Google Scholar, Science Direct, Emerland Insight, Springer, Science Open, and Wiley. Through these platforms, thousands of articles, books, and journals were discovered related to the fast fashion industry, however, a few dozen were selected for further research. From these, the further selection was carried out, mainly through a review of the abstract and a quick review of the main body of the articles, books, and journals, in order to establish relevant ones and discharge unnecessary ones. Finally, a few dozen were chosen as the central core, which has been used as a base, essential for further research, understanding of the topic, and writing. However, a few dozen were also selected as a complement to the core literature in order to gain a deeper understanding of the topic and, if necessary, to provide an extended explanation of the certain phenomenon. Therefore, the literature included diverse articles, journals, and books about the environmental impacts of the fast fashion industry, divided into core and additional literature.

However, the focus of the paper was not only to understand the diverse negative environmental impacts of the fast fashion industry but also to grasp human behavior, habits, and attitudes towards the fast fashion industry and clothes. For that purpose, the survey was required as a tool for conducting the desired research. The selection of a research approach depends on many factors, such as the purpose of the research, the type of research questions, and the availability of resources (Ponto 2015). Even though survey research seems as a recent method, examples of early surveys date back more than 2,000 years (DeMarrais *et al*. 2004). For instance, the collection of data on epidemics and vital statistics in Europe in the 1600s as well as census and population surveys in the 1700s and 1800s are considered the forerunners of the modern survey method (DeMarrais *et al*. 2004). In the late 1800s, a landmark study by Charles Booth on social conditions in London is recognized as the first large-scale social survey (DeMarrais *et al*. 2004). By the end of the 1920s, survey research had become the domain of social scientists and today is used in many social sciences disciplines as a method to obtain valuable data (DeMarrais *et al*. 2004). However, using a survey as a method for gathering data is not as simple as it may seem, rather, it is a complex process which involves several stages and careful planning. Good survey research requires extensive planning and attention to detail throughout the entire process (DeMarrais *et al*. 2004). It begins with a theoretical and conceptual framework and ends with the analysis and interpretation of results (DeMarrais *et al*. 2004). Survey research is defined as “the collection of information from a sample of individuals through their responses to questions” (Check and Schutt 2012, 160). It is a highly efficient way to gather information about entities in a number of settings for various purposes (Ruel *et al.* 2015). “Survey research can use quantitative research strategies (e.g., using questionnaires with numerically rated items), qualitative research strategies (e.g., using open-ended questions), or both strategies (i.e., mixed methods)” (Ponto 2015, 168). It is a systematic collection of information from or about people in order to describe, compare, or explain their opinions, knowledge, attitudes, and behavior (Fink 2003). The survey quantitatively describes specific aspects of a given population (Glasow 2005). Survey findings can be later generalized and used for the description of attributes of the population on a larger scale. The survey process involves development of a questionnaire as a tool for data collection from respondents. Therefore, a questionnaire is a part of the survey process and a survey instrument. Gathered information from surveys is typically used for descriptive purposes or for examining relationships between variables (DeMarrais *et al*. 2004). Surveys can examine, understand, and predict human behavior, or preferential characteristics, attitudes, opinions, and beliefs.

Designing a questionnaire for survey research is a complex multistage process which involves much more than simply developing questions (Ruel *et al.* 2015). It is a crucial and most time-consuming aspect of the survey study (DeMarrais *et al*. 2004). In this step, it is very important to consider the principles of questionnaire construction (Ruel *et al.* 2015). Prior to designing a survey, the primary research question, the target population, and available sources must be considered (Ruel *et al.* 2015). "A survey study begins like any other, with the formulation of a clearly stated purpose, delineation of a set of research questions, and identification of the target population(s)" (DeMarrais *et al*. 2004, 290). The questionnaire must have a defined purpose which is related to the objectives of the research (Roopa and Rani 2012). "Once the objectives of the survey are determined, the design of the survey must be chosen. In doing so, it is essential to keep the study objectives in mind so that data will address those objectives" (Weisberg *et al*. 1996, 32). Setting goals and objectives of the survey study also determine the target population and questions (Kuter 2001). If the goals and objectives are not clear, also the result of the survey will remain uncertain (Kuter 2001). Apart from this, deciding who the responders will be, how many are needed, and how they are going to be selected is an essential step (DeMarrais *et al*. 2004). Errors are usually introduced into the study during questionnaire planning and construction due to failure to appropriately match content to target population, survey administration because of low respondent rate (respondent's unwillingness or inability to accurately respond), and data analysis, often through careless data entry and processing (DeMarrais *et al*. 2004). Further, prior to designing a survey, a researcher should also review existing literature on previously used validated questionnaires which can be very helpful and useful for similar settings and research goals (Kazi and Khalid 2012). The review of related existing literature can also help in setting the survey objectives (Fink 2003). These validated questionnaires could be further adapted to researcher goals and objectives and utilized for their own research purpose. Apart from this, "special characteristics of the potential responders, reliability and validility of the survey content, format(s) of the items, and length of the survey" (DeMarrais *et al*. 2004, 292) have to be taken into consideration. Some of the important respondent characteristics which may influence the quality of survey data include cultural background, primary language, reading level, and interest in the content (DeMarrais *et al*. 2004). Besides this, three relevant respondent conditions which have to be considered are: their understanding, ability, and willingness (Bateson 1984). The respondent's understanding involves their ability to adequately interpret questions and response options in the questionnaire (DeMarrais *et al*. 2004). Ability refers to familiarity with the topic and accuracy to recall the information (DeMarrais *et al*. 2004). Lack of willingness can be manifested through lying, providing socially desirable responses, or refusing to answer some or all questions (DeMarrais *et al*. 2004). It is the researcher's responsibility to ensure, through adequate planning and implementation of the survey, that all three conditions (understanding, ability, and willingness) are present among respondents (DeMarrais *et al*. 2004). Apart from this, crucial aspects of the survey which can affect survey responses include length, format, and content or topic (DeMarrais *et al*. 2004). How relevant is the survey length, one research has shown in which respondents were willing to spend, on average, 5 minutes to answer 10 questions, but only 10 minutes to answer 25 questions (Story and Tait 2019). This showed that as the number of questions increases, the time spent on each question decreases, leading to superficial and questionable answers (Story and Tait 2019). If the survey takes more than 10 minutes to complete, data have shown that up to 20% of respondents will abandon the survey before completing it (Story and Tait 2019). Overall, the survey research includes several steps:

- Setting objectives for information collection, identification, and documentation of the purpose and scope of the survey study;
- Designing the study and preparing reliable and valid survey instrument (questionnaire);
- Survey administration and data collection;
- Managing and analysis of the obtained information;
- Reporting the results and key findings (Fink 2003; Rogelberg 2008). Fig. 1 shows the general pathway and steps of the survey study.

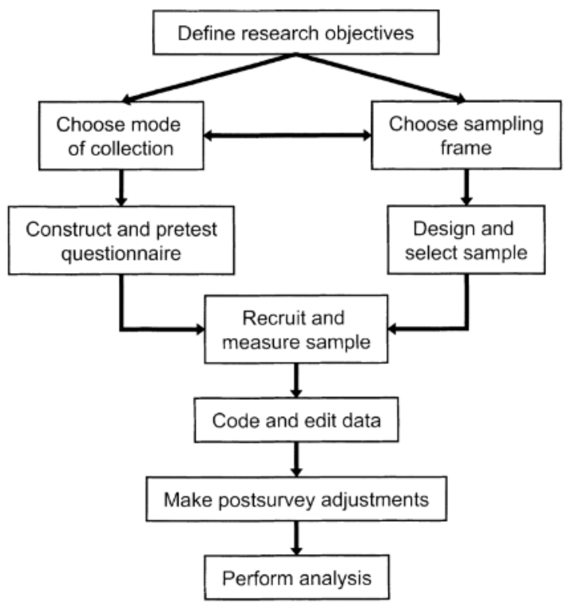


Fig. 1 Survey research process (Groves *et al*. 2021)

There are two types of questionnaires: structured and unstructured (Roopa and Rani 2012). In the structured questionnaire, questions are definite, concrete, and predetermined (Roopa and Rani 2012). They are presented with exactly the same wordings and in the same order to all respondents (Roopa and Rani 2012). Usually, all questions and answers are specified, and comments in the respondent's own words are minimized (Roopa and Rani 2012). Unlike structured, unstructured questionnaire does not include these elements. Regardless of which questionnaire type is being used, it has to be carefully designed in order to perform reliable data collection and later obtain valid results. Hastily constructed surveys, without a clear understanding of the potential survey participants, carelessness, and superficial development of the survey content and format can seriously compromise the value of the entire study (DeMarrais *et al*. 2004). Thus, special attention should be given to the questionnaire design. There are three main aspects which need to be considered in a questionnaire design:

- General form
- Question sequence
- Question formulation and wording (Roopa and Rani 2012).

The appearance and style of the questionnaire are very important aspects which can have a very strong impact on the survey outcome (Kazi and Khalid 2012). Thus, features such as design, wording, form, layout, content, response structure, and question sequence have to be carefully considered (Kelley *et al*. 2003; Rameshbhai and Jeslyn 2016). It is essential to determine how and what kind of questions are going to be asked and their general organization. The question sequence has to be clear and smoothly moving, as it can influence general understanding (Roopa and Rani 2012). Also, the language of questionnaires should be at the level of understanding of the participants (Kazi and Khalid 2012). They should be worded in a way that respondents could easily understand them and according to their culture and educational level (Kazi and Khalid 2012). Questions have to be simple, clear, easy to understand, asking only what needs to be asked, and impartial in order (Roopa and Rani 2012; Kazi and Khalid 2012). The clarity and length of the questionnaire have a direct impact on data collection (Kazi and Khalid 2012). Lengthy and confusing questionnaires may result in inaccurate or incomplete surveys (Kazi and Khalid 2012). A questionnaire should be structured in such a way that all the participants are asked the same questions and in the same order and matter to obtain comparable results across the whole sample (Kazi and Khalid 2012; Addington-Hall *et al*. 2007). If the questions are interpreted differently by the participants, that can result in wrong answers and biased responses (Kazi and Khalid 2012). Questions and answer choices should be usually prepared with a statistical method in mind, as they are going to be the subject of later analysis and statistics (Kuter 2001). Typically, a valid questionnaire has to have the following characteristics:

- “simplicity and viability
- reliability and precision in the words
- adequate for the problem intended to measure
- reflect underlying theory or concept to be measured and
- capable of measuring change” (Kazi and Khalid 2012, 515). Fig. 2 shows questionnaire development steps.

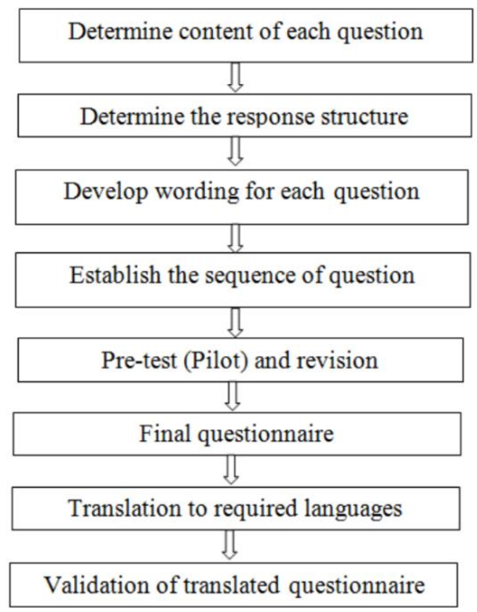


Fig. 2 Questionnaire development process (Rameshbhai and Jeslyn 2016)

"Survey instruments take four forms: self-administered questionnaire, interview, structured record review, and structured observation" (Fink 2003, 22). A self-administered questionnaire consists of questions which respondents complete by themselves (Fink 2003). There are two main types of questions in the survey questionnaire: open-ended (free-response) and closed-ended (forced-choice) (Rameshbhai and Jeslyn 2016; DeMarrais *et al*. 2004). In open-ended questions, respondents have to provide their own answers in their own words, reflecting personal experiences and beliefs (Story and Tait 2019). On the contrary, in closed-ended questions, respondents have to choose between several offered choices (Story and Tait 2019). Each form of question (open or closed) has advantages and disadvantages. The main advantage of open-ended questions is that they allow respondents to describe their views, opinions, and attitudes in their own words and how they see and interpret a certain phenomenon. They are useful in cases when the researcher is unsure of what kind of answers respondents might provide (Story and Tait 2019). Some respondents might prefer the freedom of expressing themselves, which these type of questions provide, instead of being forced to choose among already offered options (Fink 2003). However, some respondents might have limited knowledge about the topic or might not know how to express themselves and how much they should write, thus, these questions can be a daunting task (Rameshbhai and Jeslyn 2016). Further, the main disadvantage of open-ended questions is that they might be difficult for later interpretation, comparison, and analysis (Fink 2003), which poses a challenge to obtain end results and findings. Thus, they can increase the burden on work, as each response is unique and requires careful review before conducting a general conclusion and findings (Kazi and Khalid 2012). Regarding closed-ended questions, the main disadvantage is that they might be more difficult to write as the researcher has to think about and include all the possible answers in the questionnaire (Fink 2003). Thus, this type of questions could lead to errors in case they lack possible answers which respondents would normally choose (McDonald *et al*. 2003), instead, respondents might be forced to choose between answers which do not truly match their beliefs, attitudes, or opinions. Further, including every possible answer can result in excessively long lists of responses which can lead to survey fatigue and nonresponse (Story and Tait 2019). However, the major advantage of these type of questionnaires is that they provide more uniform answers. Thus, these questionnaires are easier and more convenient for later interpretation, analysis, and statistics (Fink 2003). Also, as the answer choices are clearly spelled out in closed questions, the obtained answers from respondents have a higher chance of being reliable or consistent (Fink 2003). Overall, the answer choices in closed questions can take three forms: nominal or categorical, ordinal, and numerical (Fink 2003). Nominal or categorical responses do not have any numerical or preferential values (e.g., asking respondents if they are male or female) (Fink 2003). In ordinal, respondents are asked to rate or order a list of items, usually from very positive to very negative (Fink 2003). One of the most widely used scales is the Likert scale, named by its inventor. In this scale, respondents are asked to indicate the degree of their agreement or disagreement with the ceratin phenomenon by choosing one of the five responses, which are ordered in such a way so that "strongly disagree" and "strongly agree" are the most extreme end options (Rameshbhai and Jeslyn 2016), while milder choices are between. Lastly, numerical responses involve numbers (e.g., when respondents are asked about their age or height) (Fink 2003). To have confidence in the end results, survey researchers must believe as well ensure that responders report information both correctly and truthfully according to their beliefs, opinions, and attitudes (DeMarrais *et al*. 2004). The items of information gathered from respondents are called variables (Aldridge and Levine 2001). They can be classified into three broad types, depending on the type of information they provide:

- Attributes
- Behavior
- Opinions, beliefs, attitudes, and preferences (Aldridge and Levine 2001).

Attributes are characteristics such as age, sex, marital status, or previous education (Aldridge and Levine 2001). Surveys usually measure and analyze attitudes, preferences, beliefs, and facts (Weisberg *et al*. 1996). Attitudes can be defined as likes and dislikes (Weisberg *et al*. 1996). More precisely, attitudes are positive or negative orientations towards a certain object, which can be strong or weak (Weisberg *et al*. 1996). Preferences refer to comparison of attitudes towards different objects, and beliefs are certain opinions about objects (Weisberg *et al*. 1996).

There are several ways to reach the target population and conduct a self-administered questionnaire, and these include: sending by post mail, administered by phone, administrated on site in person, delivered by e-mail, or accessed over the internet (Addington-Hall *et al*. 2007). They all have advantages but also limitations. E-mail and web surveys are one of the cheapest forms of surveys (Ruel *et al.* 2015). They are also very convenient in case of a geographically unavailable and dispersed population (Ruel *et al.* 2015). However, the response rates may be very low, meaning that people are less likely to complete and return them (Ruel *et al.* 2015). Further, with these types of surveys, people are on their own and responsible for reading and understanding the questionnaire, marking the appropriate answers, and returning the survey (Ruel *et al.* 2015). On the contrary, the main advantage of face-to-face or telephone surveys is high response rates (Roopa and Rani 2012). Further, they allow interactions between researchers and respondents, especially face-to-face surveys. This allows the researcher to assist or clarify questions if necessary, control the whole process, use longer or more complex questionnaires and motivate respondents to provide answers to all questions (Roopa and Rani 2012). However, this type of questionnaire might be costly and time-consuming (Roopa and Rani 2012).

In this case, prior to cautiously developing the survey, research was conducted, exploring the literature related to survey methodology in order to deeply and fully understand what is actually a survey, how to correctly develop it, and avoid common mistakes. A few dozen articles and books were read to gain a deeper understanding and enhance the survey development efficiency (e.g., DeMarrais *et al*. 2004; Ruel *et al.* 2015; Roopa and Rani 2012; Kazi and Khalid 2012; Story and Tait 2019; Fink 2003; and others). Apart from this, further research included finding and exploring similar articles, books, and journals, which were related to understanding the consumer's behavior, habits, and attitudes regarding the fast fashion industry (e.g., O'Cass 2000; Lira *et al*. 2022; Joung 2014; McNeill and Moore 2015; Mandaric *et al*. 2021; Gwozdz *et al*. 2017; Zhang *et al*. 2021; Daniel *et al.* 2021; and others). The objective was to determine what kind of questions were usually asked in these surveys. However, the found articles were just a guide and example of how such a survey should look like. The developed questions and the construction of the surveys in the articles were not suitable for what I had on my mind, as I could not find the survey that would completely fit my objection, but only small bits of the surveys that may be interesting. The main objectives and purpose of my survey research were to determine if consumers were aware of the negative environmental impacts of the fast fashion industry and how much and explore their purchasing and disposal habits of discarded clothing items. For that purpose, I decided that the best solution was to develop my own questionnaire. The decision to use a survey as a research method instead of an interview was mainly due to a lack of time and connections with relevant stakeholders in the fast fashion industry. During my research, I have found only one crucial project and report: "It's time for new fashion: Analysis of research on the life cycle of clothing items in the Republic of Serbia" (original headline: *Vreme je za novu modu: Analiza istraživanja o životnom ciklusu odevnih predmeta u Republici Srbiji*). This project included some questions of interest and served as inspiration for developing my own questionary. The survey was originally developed in English and then translated into Serbian language so that there was no language barrier and that everyone could understand it. It included 24 questions, of which 6 were related to a socio-demographic background of the respondents and 18 to fast fashion. The survey consisted of a closed type of questions, in which form the multiple offered responses choices, the respondents had to choose their answers. Some of the questions were nominal, such as questions related to respondent's gender, a few were numerical, such as ones about their age and income, while most of the questions were ordinal, asking responders to indicate, for example, their familiarity with the fast fashion industry. Choosing the location was carefully considered as it can majorly impact the outcome results. After long-term thinking and consultation with my mentor, the decision was to conduct the survey in a very busy mall "Ušće" in Belgrade. This mall was chosen mainly because of the high people frequency and presence of major fast fashion brands such as Zara, H & M, Stradivarius, Bershka, Pull and Bear, and others. The survey was conducted in August of 2022 and included a day of surveying people and gathering information in order to determine their familiarity with negative fast fashion environmental impacts and understand their attitudes and behavior regarding fast fashion clothes. Some of the faced challenges included people refusing to complete the survey or refusing to answer certain questions such as ones related to monthly income (salary). Another problem included the presence of mostly young people in the mall, while the presence of the middle-aged and especially senior people was not that frequent. Apart from this, the main challenge was the lack of time to conduct deeper survey research which would include a larger number of people. Thus, the survey included a limited and inefficient number of people to perform serious and large-scale research. A further step included data processing in Excel in order to obtain valuable information. Data processing consisted of interpretation, analysis, and comparison of different provided answers according to respondent's age, gender, income, and others. The following chapter will thoroughly illustrate and describe the survey research results, findings, and conclusions.

2. Results

The survey included 30 respondents, of which 14 were male (46.67%) and 16 (53.33%) female participants (table 2). Table 1 summarizes all respondent's characteristics such as age, gender, occupation, social status, and monthly income. The respondents were divided by their age (table 3), level of education (table 4), social status (table 5), and monthly income (table 6), which were valuable information for further data analysis and statistics. As can be seen from table 3, respondents were divided into four groups according to their age. The youngest age group from 15 to 25 years included 14 (46.67%) respondents, the age group from 26 to 35 years included 6 (20%) respondents, the age group from 36 to 45 years also included 6 (20%) respondents, while the age group from 46 to 65 years included 4 (13.33%) respondents. For each age group, percentages of male and female respondents were calculated in Excel.[1] Thus, 42.85% (6 male respondents) were in the age group 15-25 years, 21.43% (3) in the age group 26-35 years, also 21.43% (3) in the age group 36-45 years, and 14.29% (2) in the age group 46-65 years. Regarding female respondents, 50% (8) were in the age group 15-25 years, 18.75% (3) in the age group 26-35 years, also 18.75% (3) in the age group 36-45 years, and 12.5% (2) in the age group 45-65 years. Regarding the level of education, 23.33% (7 respondents) had high school education, 53.33% (16) bachelor's, 20% (6) master's, and only 3.33% (1) doctoral education. Same as with age groups, for each education level, the percentages of female and male respondents were calculated in Excel. Social status included five groups, from which 20% (6 respondents) belonged to the upper class, 13.33% (4) to the upper-middle class, 50% (15) to the middle class, and 16.67% (5) to the working class, while no one belonged to the poor class. For each social class, percentages of female and male respondents were calculated in Excel (table 5). Regarding monthly income, 23.33% (7 respondents) stated that they do not have any income as they were mostly students, no one had minimum wage, 16.67% (5) had monthly income 35,000-50,000 RSD (300-425 EUR), 30% (9) had monthly income 50,000-100,000 RSD (425-850 EUR), and also 30% (9) above 100,000 (850 EUR). Also, percentages of male and female respondents were calculated for each group of monthly income (table 6).

Age	Gender	Level of Education	Occupation	Social Status	Monthly Income
15	F	High School	Student	Middle class	None (student)
15	F	High School	Student	Middle class	None (student)
16	F	High School	Student	Upper-Middle class	None (student)
18	M	High School	Student	Middle class	50.000-100.000 RSD (425-850 EUR)
19	M	Bachelor	Student	Middle class	None (student)
21	M	Bachelor	Student	Middle class	50.000-100.000 RSD (425-850 EUR)

[1] Formula: N/total number of female or male respondents*100

22	M	High School	Repairer	Working class	35.000-50.000 RSD (300-425 EUR)
22	F	High School	Financial administrator	Middle class	50.000-100.000 RSD (425-850 EUR)
22	M	Bachelor	Repairer	Working class	35.000-50.000 RSD (300-425 EUR)
23	F	Bachelor	Student	Middle class	None (student)
24	F	Bachelor	Student	Middle class	None (student)
24	F	Bachelor	Seller	Working class	35.000-50.000 RSD (300-425 EUR)
25	F	Bachelor	Call operater	Working class	35.000-50.000 RSD (300-425 EUR)
25	M	Bachelor	Student	Middle class	None (student)
26	F	Bachelor	Teacher	Working class	35.000-50.000 RSD (300-425 EUR)
27	F	Master	Paid internship	Upper-Middle class	Above 100.000 RSD (850 EUR)
28	M	High School	Procurement and logistics	Upper-Middle class	Above 100.000 RSD (850 EUR)
29	M	Bachelor	Economist	Middle class	50.000-100.000 RSD (425-850 EUR)
29	F	Bachelor	Seller	Middle class	50.000-100.000 RSD (425-850 EUR)
30	M	Bachelor	Director of transportation	Upper class	Above 100.000 RSD (850 EUR)
36	F	Master	Scientist	Middle class	50.000-100.000 RSD (425-850 EUR)
38	M	Master	IT	Middle class	50.000-100.000 RSD (425-850 EUR)
39	M	Master	Electrical Engineer	Upper class	Above 100.000 RSD (850 EUR)
43	M	Bachelor	Sales Manager	Upper class	Above 100.000 RSD (850 EUR)
43	F	Bachelor	Procurement Manager	Upper class	Above 100.000 RSD (850 EUR)
45	F	Bachelor	Teacher	Middle class	50.000-100.000 RSD (425-850 EUR)
46	F	Master	Social worker	Middle class	50.000-100.000 RSD (425-850 EUR)
48	M	pH.D	Doctor	Upper class	Above 100.000 RSD (850 EUR)
50	F	Bachelor	Communicator	Upper-Middle class	Above 100.000 RSD (850 EUR)
52	M	Master	Electrical Engineer	Upper class	Above 100.000 RSD (850 EUR)

Table 1 Summarized characteristic of all respondents (30)

Gender	N	Percentages (%)
Male	14	46.67%
Female	16	53.33%
Total	30	100 %

Table 2 Percentages (%) of male and female respondents

Age group	Total (N/%)	Male (N/%)	Female (N/%)
15-25	14 (46.67%)	6 (42.85%)	8 (50%)
26-35	6 (20%)	3 (21.43%)	3 (18.75%)
36-45	6 (20%)	3 (21.43%)	3 (18.75%)
46-65	4 (13.33%)	2 (14.29%)	2 (12.5%)
Total	30 (100%)	14 (100%)	16 (100%)

Table 3 Respondents division by age group

Level of Education	Total (N/%)	Male (N and %)	Female (N and %)
Elementary School	0 (0%)	0 (0%)	0 (0%)
High Shool	7 (23.33%)	3 (21.43%)	4 (25%)
Bachelor	16 (53.33%)	7 (50%)	9 (56.25%)
Master	6 (20%)	3 (21.43%)	3 (18.75%)
Doctoral	1 (3.33%)	1 (7.14%)	0 (0%)
Total	30 (100%)	14 (100%)	16 (100%)

Table 4 Respondents division by level of education

Social Status	Total (N/%)	Male (N and %)	Female (N and %)
Upper class	6 (20%)	5 (35.71)	1 (6.25%)
Upper-Middle class	4 (13.33%)	1 (7.14%)	3 (18.75%)
Middle class	15 (50%)	6 (42.86%)	9 (56.25%)
Working class	5 (16.67%)	2 (14.29%)	3 (18.75%)
Poor class	0 (0%)	0 (0%)	0 (0%)
Total	30 (100%)	14 (100%)	16 (100%)

Table 5 Respondents division by social status

Monthly Income	Total (N/%)	Male (N and %)	Female (N and %)
I do not have an income (student, unemployed, retiree)	7 (23.33%)	2 (14.29%)	5 (31.25%)
Minimum wage 35.000 RSD (300 EUR)	0 (0%)	0 (0%)	0 (0%)
35.000-50.000 RSD (300 EUR- 425 EUR)	5 (16.67%)	2 (14.29%)	3 (18.75%)
50.000-100.000 RSD (425 EUR- 850 EUR)	9 (30%)	4 (28.57%)	5 (31.25%)
Above 100.000 RSD (850 EUR)	9 (30%)	6 (42.85%)	3 (18.75%)
Total	30 (100%)	14 (100%)	16 (100%)

Table 6 Respondents division by social status by monthly income

Regarding the concept of fast fashion, from the total number of survey participants, 11 (37%) were familiar with the term, 4 (13%) had only heard about it, and 14 (around 50%) did not know what fast fashion is at all (fig. 3). There was a great difference between male and female respondents, as 69% (11) female respondents were familiar with the concept of fast fashion (fig. 4), while only 29% (4) male respondents heard about it and 71% (10) did not know what fast fashion is at all (fig. 5). Thus, according to the survey women were more familiar with the concept of fast fashion compared to men. This question was also analyzed by the level of education to determine if respondents with higher education level were more familiar with the term fast fashion (table 7). Thus, 28.57% of high school respondents knew what fast fashion is, the same percentage of 28.57% heard about it, while 42.86%, or almost a half, did not know what fast fashion is at all. With a response rate of around 44%, bachelor respondents had greater familiarity with the concept of fast fashion compared to high school respondents. However, also around 6% of bachelor respondents only heard about the concept of fast fashion, and half did not know what fast fashion is at all. Regarding master respondents, response rates were equal for each answer option, around 33%. Therefore, a higher education level did not necessarily mean greater familiarity with the concept of fast fashion.

Fig. 3 Familiarity with the concept of fast fashion

Level of Education	Yes, I know well what is fast fashion (N/%)	I heard about it, but I do not know exactly what is fast fashion (N/%)	No, I am not (N/%)
Elementary school (0)	0 (0%)	0 (0%)	0 (0%)
High School (7)	2 (28.57%)	2 (28.57%)	3 (42.86%)
Bachelor (16)	7 (43.75%)	1 (6.25%)	8 (50%)
Master (6)	2 (33.33%)	2 (33.33%)	2 (33.33%)
pH.D (1)	0 (0%)	0 (0%)	1 (100%)

Table 7 Are you familiar with the concept of fast fashion?

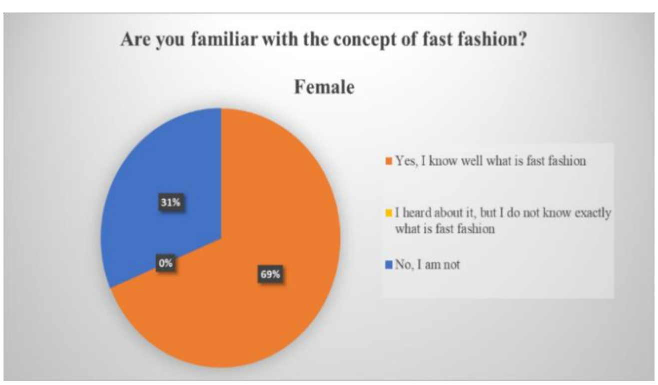


Fig. 4 Familiarity with concept of fast fashion (F)

Fig. 5 Familiarity with concept of fast fashion (M)

When it comes to the concept of slow fashion, from a total number, 19 (around 64%) respondents did not know at all what slow fashion is, and 4 (13%) heard about it. Only 7 (23%) knew what slow fashion is (fig. 6). Again, female respondents were more familiar with a term than male respondents, as 44% (7) of female participants knew what slow fashion is (fig. 7). In contrast, 86% (12) male participants did not know at all what slow fashion is, and 14% (2) only heard about it (fig. 8). However, also 44% (7) female respondents did not know what slow fashion is, suggesting that they were more familiar with the concept of fast fashion. This question was also further analyzed by education level. Respondents were poorly informed about the concept of slow fashion regardless of their education level. Thus, among high school respondents, only 14% knew what slow fashion is, from bachelor respondents around 31%, and master respondents around 17% (table 8).

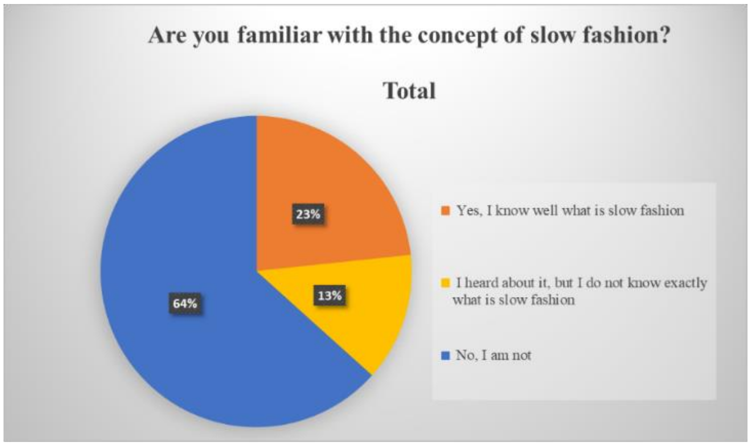


Fig. 6 Familiarity with the concept of slow fashion

Fig. 7 Familiarity with concept of slow fashion (F) Fig. 8 Familiarity with concept of slow fashion (M)

Level of Education	Yes, I know well what is fast fashion (N/%)	I heard about it, but I do not know exactly what is fast fashion (N/%)	No, I am not (N/%)
Elementary school (0)	0 (0%)	0 (0%)	0 (0%)
High School (7)	1 (14.29%)	2 (28.57%)	4 (57.14%)
Bachelor (16)	5 (31.25%)	0 (0%)	11 (68.75%)
Master (6)	1 (16.67%)	2 (33.33%)	3 (50%)
pH.D (1)	0 (0%)	0 (0%)	1 (100%)

Table 8 Are you familiar with the concept of slow fashion?

The survey also included a question about respondent's familiarity with the fact that fast fashion is the second most polluting industry, right after the oil industry. From a total number of survey participants, 22 (around 73%) respondents did not know that fast fashion is the second most polluting industry in the world, right after the oil industry, while only 8 (around 27%) gave a positive response (fig. 9). Regardless of education level, majority of respondents did not know that fast fashion industry is ranked as the second most polluting industry (table 9). Thus, only around 14% of high school respondents knew this, around 31% of bachelor respondents, and around 33% of master respondents (table 9).

Level of Education	Yes, I am familiar with that (N/%)	No, I did not know that (N/%)
Elementary school (0)	0 (0%)	0 (0%)
High School (7)	1 (14.29%)	6 (85.71%)
Bachelor (16)	5 (31.25%)	11 (68.75%)
Master (6)	2 (33.33%)	4 (66.67%)
pH.D (1)	0 (0%)	1 (100%)

Table 9 Did you know that fast fashion is the second polluting industry, right after the oil industry?

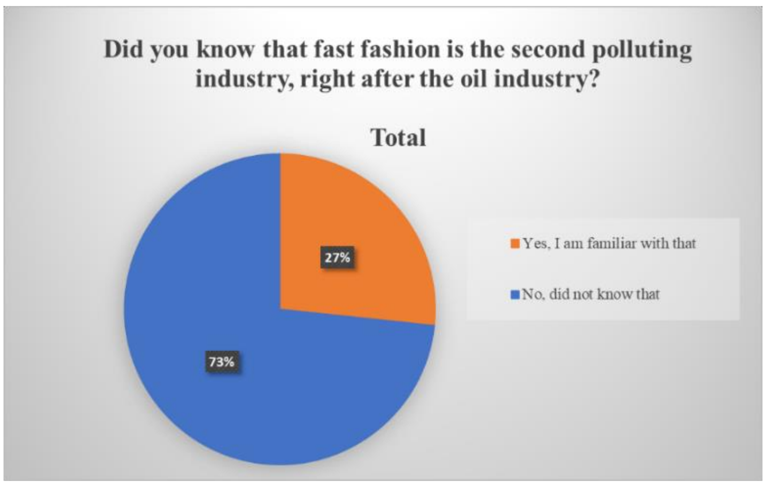


Fig. 9 Familiarity with pollution intensity of fast fashion

Regarding awareness about fast fashion environmental consequences, from a total number of survey participants, 18 (60%) respondents were familiar with the fast fashion industry's environmental problems, while 12 (40%) respondents were not (fig. 10). Female respondents were more familiar with environmental problems than male respondents, as 87% (14) female respondents gave positive response to the question, while 13% (2) negative (fig. 11). Regarding male respondents, 71% (10) did not know about environmental consequnces of fast fashion, while only 29% (4) were familiar with (fig. 12). When it comes to education, around 72% high school respondents were familiar with environmental problems of the fast fashion industry, around 56% bachelor respondents, and around 67% master respondents (table 10).

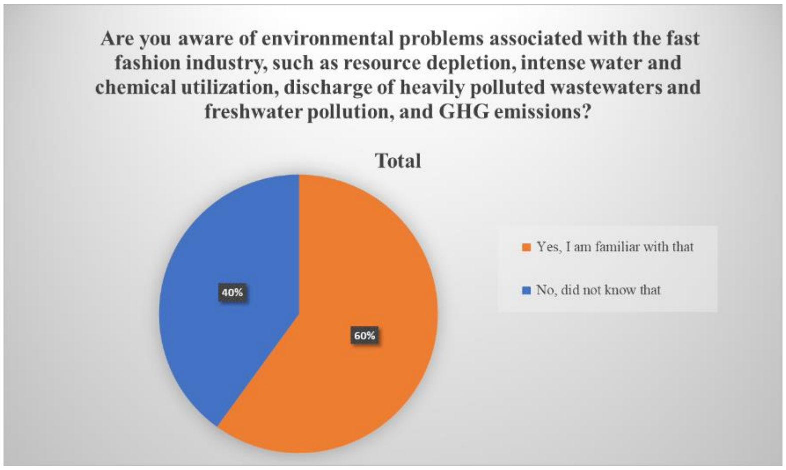
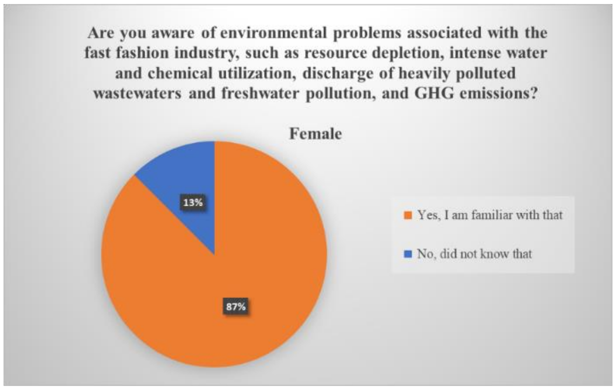


Fig. 10 Awareness about fast fashion industry environmental problems



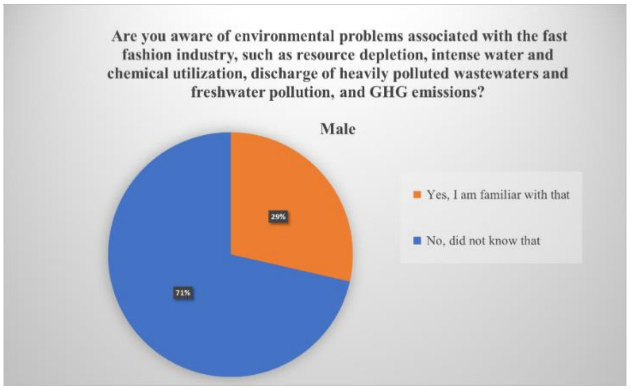


Fig. 11 Female and fig. 12 Male awareness about fast fashion industry environmental problems

Level of Education	Yes, I am familiar with that (N/%)	No, I did not know that (N/%)
Elementary school (0)	0 (0%)	0 (0%)
High School (7)	5 (71.43%)	2 (28.57%)
Bachelor (16)	9 (56.25%)	7 (43.75%)
Master (6)	4 (66.67%)	2 (33.33%)
pH.D (1)	0 (0%)	1 (100%)

Table 10 Are you aware of environmental problems associated with the fast fashion industry, such as resource depletion, intense water and chemical utilization, discharge of heavily polluted wastewaters and freshwater pollution, and GHG emissions?

Respondents were much more familiar with the poor working conditions in the fast fashion industry than environmental problems. Thus, from the total number, 25 (83%) respondents stated that they were familiar with poor working conditions, while 5 (17%) gave a negative response (fig. 13). Both male and female awareness was high, in the case of female 87% (14 respondents) (fig. 14), and male 79% (11 respondents) (fig. 15). Regarding the level of education, familiarity with poor working conditions was much higher compared to environmental problems, as all high school respondents gave a positive response, 81% bachelor respondents, and 67% master respondents (table 11).

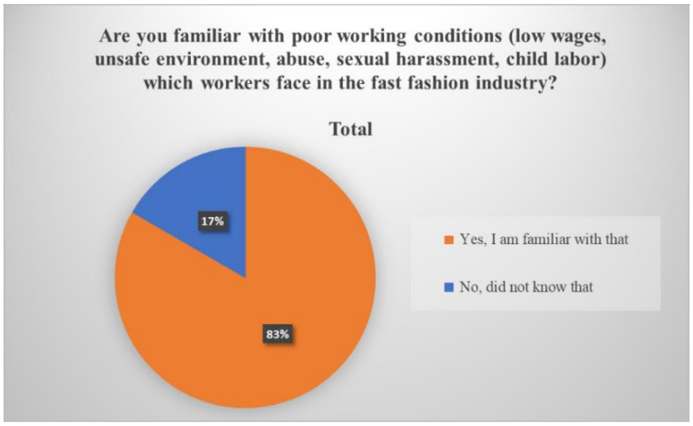


Fig. 13 Familiarity with poor working conditions in the fast fashion industry

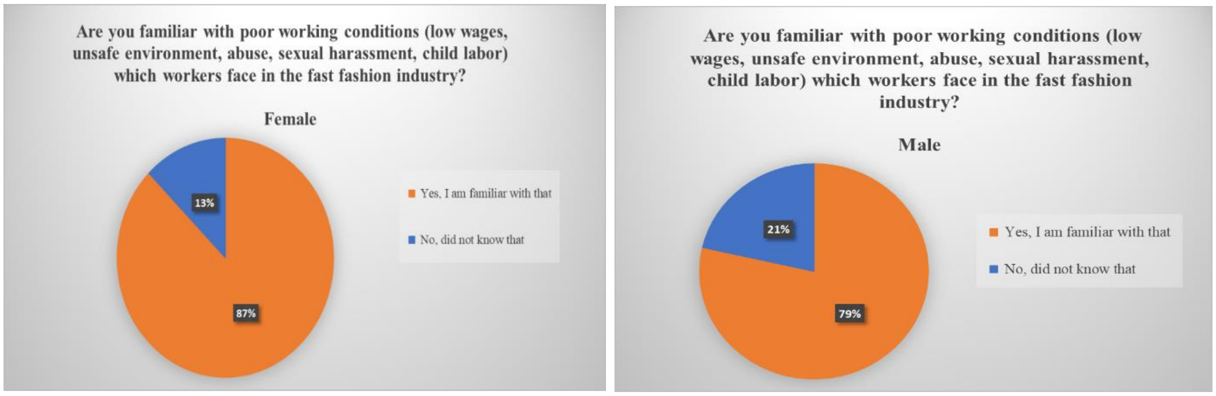


Fig. 14 and fig. 15 Familiarity with poor working conditions in the fast fashion industry (F) and (M)

Level of Education	Yes, I am familiar with that (N/%)	No, I did not know that (N/%)
Elementary school (0)	0 (0%)	0 (0%)
High School (7)	7 (100%)	0 (0%)
Bachelor (16)	13 (81.25%)	3 (18.75%)
Master (6)	4 (66.67%)	2 (33.33%)
pH.D (1)	1 (100%)	0 (0%)

Table 11 Are you familiar with poor working conditions (low wages, unsafe environment, abuse, sexual harassment, child labor) which workers face in the fast fashion industry?

When it comes to fast fashion seasons and trends, 2 (around 7%) respondents follow every new style, season and trend, 11 (around 36%) follow only sometimes, 9 (30%) very rarely, and 8 (around 27%) do not follow fast fashion at all (fig. 16). According to the survey results, women follow fast fashion seasons and trends more than man, as 12% (2 female respondents) always follow fast fashion, and 44% (7 female respondents) follow sometimes (fig. 17), while only around 28% (4 male respondents) follow fast fashion occasionally (fig. 18). Further, around 43% (6 male respondents) follow fast fashion very rarely, and around 28% (4 male respondents) do not follow fast fashion at all (fig. 18).

Fig. 16 Total following of fashion seasons and trends

Fig. 17 Fast fashion seasons and trends (female)

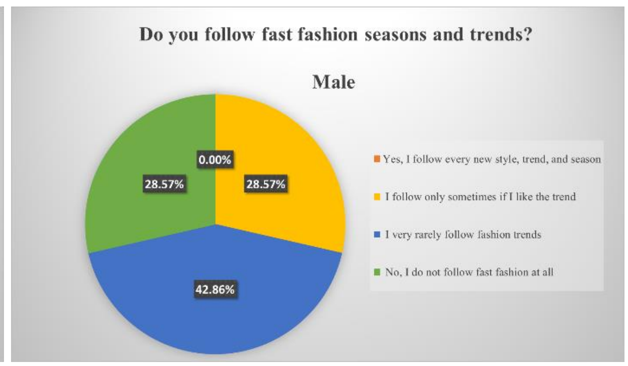


Fig. 18 Fast fashion seasons and trends (male)

This question was also analyzed by age in order to determine if the younger population follows fast fashion more than the older population. From the age group 15-25 years, around 7% follow every new style, trend and season, around 43% follow sometimes, around 36% rarely, and around 14% do not follow at all. In the age group 26-35, around 17% follow every new style, trend and season, also around 17% follow sometimes and rarely, and half do not follow fast fashion at all. Regarding the age group 36-45, half stated that they do follow fast fashion seasons and trends sometimes, around 33% rarely, and 17% do not follow fast fashion at all. Lastly, from the age group 45-65, 25% follow fast fashion seasons and trends sometimes and rarely, while half do not follow fast fashion at all. This might show a correlation between age and following fast fashion trends, as usually, a younger population is more familiar with fast fashion and tends to follow it (table 12).

Age group	Yes, I follow every new style, trend, and season (N/%)	I follow only sometimes if I like the trend (N/%)	I very rarely follow fashion trends (N/%)	No, I do not follow fast fashion at all (N/%)
15-25 (14)	1 (7.14%)	6 (42.86%)	5 (35.71%)	2 (14.29%)
26-35 (6)	1 (16.67%)	1 (16.67%)	1 (16.67%)	3 (50%)
36-45 (6)	0 (0%)	3 (50%)	2 (33.33%)	1 (16.67%)
46-65 (4)	0 (0%)	1 (25%)	1 (25%)	2 (50%)

Table 12 Do you follow fast fashion seasons and trends?

Further, the survey included a question about purchasing habits in fast fashion stores such as H&M, Zara, Stradivarius, and others. Of the total number, around 27% (8 respondents) stated that they always purchase clothes in fast fashion stores, around 53% (16 respondents) purchase sometimes, 10% (3 respondents) rarely, and also 10% (3 respondents) do not purchase there at all (fig. 19). This, shows that majority of respondents purchase their clothes in fast fashion stores. Further, charts (fig. 20 and 21) show a difference between male and female purchasing rates in fast fashion stores, as women purchase more clothes in fast fashion stores compared to men. Thus, among female respondents, 25% (4 respondents) always purchase clothes in fast fashion stores, around 63% (10 respondents) occasionally, 6% (1 respondent) rarely, and also 6% (1 respondent) do not purchase there at all (fig. 20). Regarding male respondents, 29% (4 respondents) always purchase their clothes in fast fashion stores, 43% (6 respondents) occasionally, 14% (2 respondents) rarely and also 14% (2 respondents) do not purchase there at all (fig. 21).

Fig. 19 Clothes purchasing in fast fashion stores

Fig. 20 Clothes purchasing in fast fashion stores (F) Fig. 21 Clothes purchasing in fast fashion stores (M)

This question was also analyzed by age (table 13), social status (table 14), and monthly income (table 15). Regarding age, from the age group 15-25 years, around 29% stated that they always purchase clothes in fast fashion stores, 57% occasionally, 17% rarely, and also 17% do not purchase there at all. Within the age group 26-35 years, around 17% purchase clothes always in fast fashion stores, a half occasionally, 17% rarely, and also 17% do not purchase there at all. Regarding the age group 36-45 years, around 17% always purchase clothes in fast fashion stores, and up to 83% occasionally. Lastly, within the age group 46-65 years, half always purchase clothes in fast fashion stores, while 25% rarely and also 25% do not purchase there at all. This might show that there is a lower correlation between age and purchasing rate in fast fashion stores than expected.

Age group	Yes, I always purchase my clothes in fast fashion stores (N/%)	I purchase clothes in fast fashion stores occasionally (N/%)	I very rarely purchase clothes in fast fashion stores (N/%)	No, I do not purchase my clothes in fast fashion stores at all (N/%)
15-25 (14)	4 (28.57%)	8 (57.14%)	1 (7.14%)	1 (7.14%)
26-35 (6)	1 (16.67%)	3 (50%)	1 (16.67%)	1 (16.67%)
36-45 (6)	1 (16.67%)	5 (83.33%)	0 (0%)	0 (0%)
46-65 (4)	2 (50%)	0 (0%)	1 (25%)	1 (25%)

Table 13 Do you purchase clothes in fast fashion stores such as H&M, Zara, Stradivarius, Bershka, and other?

Regarding social status, in the upper class, around 33% always purchase clothes in fast fashion stores, half occasionally, and around 17% do not purchase there at all. Within the upper-middle class, 75% purchase occasionally in fast fashion stores, and 25% rarely. In the middle class, 40% always purchase clothes in fast fashion stores, 40% occasionally, around 7% rarely, and around 13% do not purchase there at all. Lastly, from the working class, 80% always purchase clothes in fast fashion stores, and 20% rarely. Thus, the survey did not show a correlation between social status and the rate of clothes purchasing in fast fashion stores (table 14). This can be explained by the low price of fast fashion clothes. Due to their cheap price, they are affordable for everyone, including the middle and working class. A similar situation was with monthly income (table 15).

Social Status	Yes, I always purchase my clothes in fast fashion stores (N/%)	I purchase clothes in fast fashion stores occasionally (N/%)	I very rarely purchase clothes in fast fashion stores (N/%)	No, I do not purchase my clothes in fast fashion stores at all (N/%)
Upper class (6)	2 (33.33%)	3 (50%)	0 (0%)	1 (16.67%)
Upper-middle-class (4)	0 (0%)	3 (75%)	1 (25%)	0 (0%)
Middle class (15)	6 (40%)	6 (40%)	1 (6.67%)	2 (13.33%)
Working-class (5)	0 (0%)	4 (80%)	1 (20%)	0 (0%)
Poor (0)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Table 14 Do you purchase clothes in fast fashion stores such as H&M, Zara, Stradivarius, Bershka, and other?

Monthly Income	Yes, I always purchase my clothes in fast fashion stores (N/%)	I purchase clothes in fast fashion stores occasionally (N/%)	I very rarely purchase clothes in fast fashion stores (N/%)	No, I do not purchase my clothes in fast fashion stores at all (N/%)
I do not have an income (student, unemployed, retiree) (7)	2 (28.57%)	4 (57.14%)	0 (0%)	1 (14.29%)
Minimum wage 35.000 RSD (300 EUR) (0)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
35.000-50.000 RSD (300 EUR- 425 EUR) (5)	0 (0%)	4 (80%)	1 (20%)	0 (0%)
50.000-100.000 RSD (425 EUR- 850 EUR) (9)	4 (44.44%)	3 (33.33%)	1 (11.11%)	1 (11.11%)
Above 100.000 RSD (850 EUR) (9)	2 (22.22%)	5 (55.56%)	1 (11.11%)	1 (11.11%)

Table 15 Do you purchase clothes in fast fashion stores such as H&M, Zara, Stradivarius, Bershka, and other?

When it comes to second-hand clothes, from the total number, 53% (16 respondents) do not purchase their clothes in second-hand stores at all, 17% (5 respondents) rarely, 20 % (6 respondents) occasionally, and only 10 % (3 respondents) always (fig. 22). This shows, that clothes purchasing in second-hand stores is much lower than in fast fashion stores. Again, there is a difference between male and female respondents, as women purchase clothes in second-hand stores much more compared to men. Thus, 19% (3 respondents) of female respondents always purchase their clothes in second-hand stores, 31% (5 respondents) occasionally, 6% (1 respondent) rarely, and 44% (7 respondents) do not purchase there at all (fig. 23). Regarding male respondents, only 7% (1 respondent) purchase clothes in second-hand stores occasionally, while 29% (4 respondents) rarely, and 64% (9 respondents) do not purchase there at all. This might be due to women's higher awareness of social and environmental problems associated with the fast fashion industry.

Fig. 22 Clothes purchasing in second-hand stores

Fig. 23 Clothes purchasing in second-hand stores (F) Fig. 24 Clothes purchasing in second-hand stores (M)

This question was analyzed by age (table 16), social status (table 17), and monthly income as well (table 18). Regarding age, within the age group 15-25 years, around 14% always purchase their clothes in second-hand stores, around 29% occasionally, 14% rarely, and up to 43% do not purchase there at all. In the age group 26-35 years, only around 17% purchase their clothes in second-hand stores occasionally, also around 17% rarely, while 67% do not purchase there at all. Regarding the age group 36-45 years, around 17% purchase their clothes in second-hand stores occasionally, around 33% rarely, and half do not purchase there at all. Lastly, in age the group 46-

65 years, only 25% always purchase their clothes in second-hand stores, while 75% do not purchase there at all. This was analyzed in order to determine if there is a correlation between age and purchasing rate in second-hand stores. However, it seems that the purchasing rate for each age group was quite low. Regarding social status, from the upper class, only around 17% purchase their clothes in second-hand stores occasionally, while 83% do not purchase there at all. In the upper-middle class, 25% always purchase their clothes in second-hand stores, while 25% rarely and a half do not purchase there at all. Within the middle class, around 13% purchase their clothes in second-hand stores always, occasionally, and rarely, while 60% do not purchase there at all. Lastly, within the working class, 60% always purchase their clothes in second-hand stores, while 40% rarely. This has shown a correlation between social status and purchasing rate in second-hand stores, as upper and upper-middle classes purchase the least clothes in second-hand stores. A similar situation was with the monthly income (table 18).

Age group	Yes, I always purchase my clothes in second-hand stores (N/%)	I purchase clothes in second-hand stores occasionally (N/%)	I very rarely purchase clothes in second-hand stores (N/%)	No, I do not purchase my clothes in second-hand stores at all (N/%)
15-25 (14)	2 (14.29%)	4 (28.57%)	2 (14.29%)	6 (42.86%)
26-35 (6)	0 (0%)	1 (16.67%)	1 (16.67%)	4 (66.67%)
36-45 (6)	0 (0%)	1 (16.67%)	2 (33.33%)	3 (50%)
46-65 (4)	1 (25.00%)	0 (0%)	0 (0%)	3 (75%)

Table 16 Do you purchase clothes in second-hand stores?

Social Status	Yes, I always purchase my clothes in second-hand stores (N/%)	I purchase clothes in second-hand stores occasionally (N/%)	I very rarely purchase clothes in second-hand stores (N/%)	No, I do not purchase my clothes in second-hand stores at all (N/%)
Upper class (6)	0 (0%)	1 (16.67%)	0 (0%)	5 (83.33%)
Upper-middle-class (4)	1 (25%)	0 (0%)	1 (25%)	2 (50%)
Middle class (15)	2 (13.33%)	2 (13.33%)	2 (13.33%)	9 (60%)
Working-class (5)	0 (0%)	3 (60%)	2 (40%)	0 (0%)
Poor (0)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Table 17 Do you purchase clothes in second-hand stores?

Monthly Income	Yes, I always purchase my clothes in second-hand stores (N/%)	I purchase clothes in second-hand stores occasionally (N/%)	I very rarely purchase clothes in second-hand stores (N/%)	No, I do not purchase my clothes in second-hand stores at all (N/%)
I do not have an income (student, unemployed, retiree) (7)	2 (28.57%)	1 (14.29%)	0 (0%)	4 (57.14%)
Minimum wage 35.000 RSD (300 EUR) (0)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
35.000-50.000 RSD (300 EUR- 425 EUR) (5)	0 (0%)	3 (60%)	2 (40%)	0 (0%)
50.000-100.000 RSD (425 EUR- 850 EUR) (9)	1 (11.11%)	1 (11.11%)	2 (22.22%)	5 (55.56%)
Above 100.000 RSD (850 EUR) (9)	0 (0%)	1 (11.11%)	1 (11.11%)	7 (77.78%)

Table 18 Do you purchase clothes in second-hand stores?

Regarding awareness that purchasing clothes in second-hand stores is more environmentally friendly than in fast fashion stores, from the total number of survey participants, 17 (around 57%) respondents knew that, 6 (20%) respondents were familiar but did not know why, and 7 (around 23%) respondents did not know at all (fig. 25). Again, there is a difference between male and female respondents. In the case of female respondents, 75% (12) knew that purchasing clothes in second-hand stores is more environmentally friendly than in fast fashion stores, 12,5% (2) female respondents heard about and also 12,5% (2) did not know that (fig. 26). Regarding male respondents, an even percentage of 35.71% (5) knew that and did not know that, while 28.57% (4) only heard about it (fig. 27).

Fig. 25 Awareness that clothes purchasing is more environmentally friendly

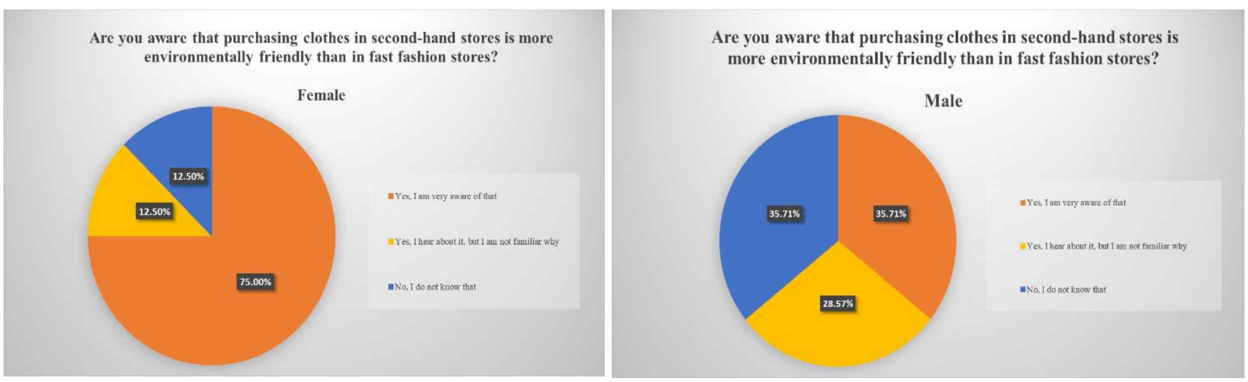


Fig. 26 Awareness that clothes purchasing is more environmentally friendly (F) and Fig. 27 (M)

This was also further analyzed by the level of education (table 19) and age (table 20). Regarding level of education, around 86% of high school respondents were aware that purchasing clothes in second-hand stores is more environmentally friendly than in fast fashion stores, while 14% did not know that. Of bachelor respondents, around 37% knew that, and the same percentage (37%) heard about it, while 25% did not know that at all. Master respondents had a high awareness rate of up to 83%. However, there is no necessary correlation between the level of education and awareness rate (table 19). Regarding age, in the age group 15-25 years a half were aware that purchasing clothes in second-hand stores is more environmentally friendly than in fast fashion stores, around 21% heard about it, and around 29% did not know that. Within the age group 26-35 years, around

66% knew that, and around 33% did not know that. Regarding the age group 36-45 years, also around 66% knew that, while around 17 heard about it and also 17% did not know that. Lastly, in the age group 46-65, half were aware, while half did not know that at all. This analysis was conducted to determine if there is a correlation between age and awareness, however, it seems that no matter the age, 50-60% of respondents were not aware in each age group.

Level of Education	Yes, I am very aware of that (N/%)	Yes, I hear about it, but I am not familiar why (N/%)	No, I do not know that (N/%)
Elementary school (0)	0 (0%)	0 (0%)	0 (0%)
High School (7)	6 (85.71%)	0 (0%)	1 (14.29%)
Bachelor (16)	6 (37.50%)	6 (37.50%)	4 (25%)
Master (6)	5 (83.33%)	0 (0%)	1 (16.67%)
pH.D (1)	0 (0%)	0 (0%)	1 (100%)

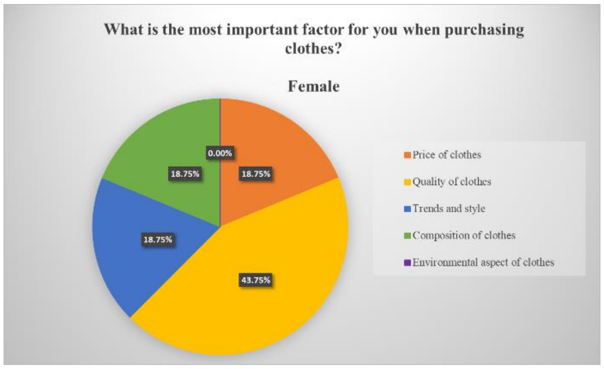
Table 19 Are you aware that purchasing clothes in second-hand stores is more environmentally friendly than in fast fashion stores?

Age group	Yes, I am very aware of that (N/%)	Yes, I hear about it, but I am not familiar why (N/%)	No, I do not know that (N/%)
15-25 (14)	7 (50%)	3 (21.43%)	4 (28.57%)
26-35 (6)	4 (66.67%)	2 (33.33%)	0 (0%)
36-45 (6)	4 (66.67%)	1 (16.67%)	1 (16.67%)
46-65 (4)	2 (50%)	0 (0%)	2 (50%)

Table 20 Are you aware that purchasing clothes in second-hand stores is more environmentally friendly than in fast fashion stores?

One of the questions included an examination of the most important factors when purchasing clothes. For the majority of the respondents, 43% (13 respondents), the most important factor was the quality of clothes, followed by trends and style with 27% (8 respondents), clothes composition 17% (5 respondents), and price 13% (4 respondents), while the environmental aspect was not considered at all (fig. 28). There was no huge difference between male and female respondents, as for both the most important factor was quality of clothes with around 43% (6 male respondents/7 female respondents). Regarding the price of clothes, 3 (around 19%) female respondents selected that as the most important factor, while 1 (7%) respondent in the case of male respondents. According to the survey, trends and style were a bit more important for male respondents, as 5 (36%) selected that as the most important factor, while in the case of females, 3 (around 19%) chose trends and style. It was expected that trends and style would be more important for women than men, however, in the case of this survey, female respondents also chose clothes composition as the most important factor, more precisely 3 (around 19%), making it even with trends and style, while of male respondents only 2 (14%) chose clothes composition (fig. 29 and fig. 30).

Fig. 28 The most important factor while purchasing clothes



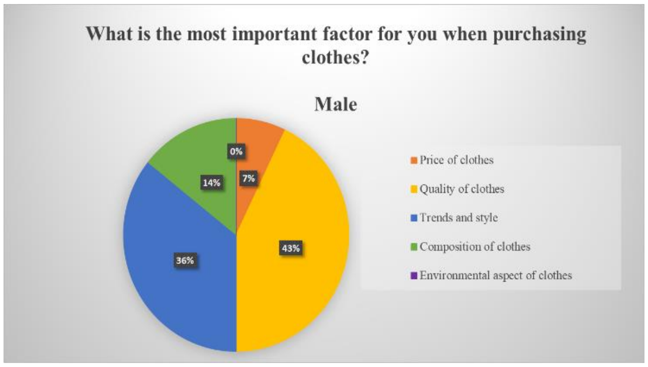


Fig. 29 The most important factor while purchasing clothes for female and fig. 30 male respondents

This question was analyzed by age (table 21), social status (table 22), and monthly income (table 23) as well. In the case of the age group 15-25 years, the quality of clothes, trends and style were equally important with around 36%, followed by the price of clothes around 22%, and composition around 7%. In the age group 26-35 years, quality of clothes prevails as the most important factor with 67%, followed by trends and style with around 33%. Regarding the age group 36-45 years, half selected quality of clothes as the most important factor, no one chose trends and style, while the share of clothes composition is around 33%. Lastly, within the age group 46-65 years, quality of clothes and trends and style were equally important with 25%, while half selected composition of clothes as the most important factor. The hypothesis was that trends and style are the most important factors for the younger population, while clothes price, quality and composition might be more relevant for the older population. In the case of this survey, the results matched the hypothesis (table 21).

Age group	Price of clothes (N/%)	Quality of clothes (N/%)	Trends and style (N/%)	Composition of clothes (N/%)	Environmental aspect of clothes (N/%)
15-25 (14)	3 (21.43%)	5 (35.71%)	5 (35.71%)	1 (7.14%)	0 (0%)
26-35 (6)	0 (0%)	4 (66.67%)	2 (33.33%)	0 (0%)	0 (0%)
36-45 (6)	1 (16.67%)	3 (50%)	0 (0%)	2 (33.33%)	0 (0%)
46-65 (4)	0 (0%)	1 (25%)	1 (25%)	2 (50%)	0 (0%)

Table 21 What is the most important factor for you when purchasing clothes?

This question was further analyzed by social status to determine if there is a difference between social groups when purchasing clothes (table 22). For the upper class, the most important factor was the quality of clothes, as half of the respondents chose this response option, followed by clothes composition with around 33%, and trends and style with around 17%. Within the upper-middle class, for up to 75% of the respondents, the most important factor was again quality of clothes, followed by trends and style with 25%. Regarding the middle class, the most important factor was trends and style with 40%, quality of clothes around 27%, clothes price 20%, and lastly, the composition of clothes with around 13%. Within the working class, the quality of clothes was the most important factor with 60%, while clothes composition and price of clothes were equal with 20%. The assumption was that the quality of clothes would be the most important factor for upper and upper-middle classes, while the clothes price would be the most important for middle and working classes. The survey results partially matched the hypothesis, as even though for the upper and upper-middle class, the quality of clothes was a crucial factor, the working class also had a high response rate of 60%. Regarding monthly income, for the respondents with monthly income above 100,000 RSD (850 EUR), the most important factor was the quality of clothes with around 56%, while trends and style and clothes composition share were around 22%. For respondents with a monthly income of 50,000-100,000 RSD (425-850 EUR), the quality of clothes and trends and style were equally important with around 33%, while clothes composition around 22%, and clothes price around 11%. Regarding respondents with a monthly income of 35,000-50,000 RSD (300-425 EUR), again, the quality of clothes was the most important factor with 60%, while the share of clothes price and composition were 20%. Respondents without any income mostly choose trends and style as the most important factor, about 43%, while the share of clothes price and quality were equal with around 29% (table 23).

Social Status	Price of clothes (N/%)	Quality of clothes (N/%)	Trends and style (N/%)	Composition of clothes (N/%)	Environmental aspect of clothes (N/%)
Upper class (6)	0 (0%)	3 (50%)	1 (16.67%)	2 (33.33%)	0 (0%)
Upper-middle-class (4)	0 (0%)	3 (75%)	1 (25%)	0 (0%)	0 (0%)
Middle class (15)	3 (20%)	4 (26.67%)	6 (40%)	2 (13.33%)	0 (0%)
Working-class (5)	1 (20%)	3 (60%)	0 (0%)	1 (20%)	0 (0%)
Poor (0)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Table 22 What is the most important factor for you when purchasing clothes?

Monthly Income	Price of clothes (N/%)	Quality of clothes (N/%)	Trends and style (N/%)	Composition of clothes (N/%)	Environmental aspect of clothes (N/%)
I do not have an income (student, unemployed, retiree) (7)	2 (28.57%)	2 (28.57%)	3 (42.86%)	0 (0%)	0 (0%)
Minimum wage 35.000 RSD (300 EUR) (0)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
35.000-50.000 RSD (300 EUR- 425 EUR) (5)	1 (20%)	3 (60%)	0 (0%)	1 (20%)	0 (0%)
50.000-100.000 RSD (425 EUR- 850 EUR) (9)	1 (11.11%)	3 (33.33%)	3 (33.33%)	2 (22.22%)	0 (0%)
Above 100.000 RSD (850 EUR) (9)	0 (0%)	5 (55.56%)	2 (22.22%)	2 (22.22%)	0 (0%)

Table 23 What is the most important factor for you when purchasing clothes?

One of the questions included an examination if the respondents pay attention to clothes composition while purchasing. Half of the respondents (15) always pay attention, 23% (7 respondents) sometimes, around 17% (5 respondents) rarely, while for 10% (3 respondents) that is not important at all (fig. 31). Regarding female respondents, around 44% (7 respondents) always pay attention to clothes composition, around 31% (5 respondents) sometimes, 12.5% (2 respondents) pay attention rarely and also 12.5% not at all (fig. 32). When it comes to male respondents, 57% (8 respondents) always pay attention to clothes composition, 14% (2 respondents) sometimes, 22% (3 respondents) rarely, while for 7% (1 respondent) that was not important at all (fig. 33). Thus, the clothes composition was highly relevant for both, male and female respondents.

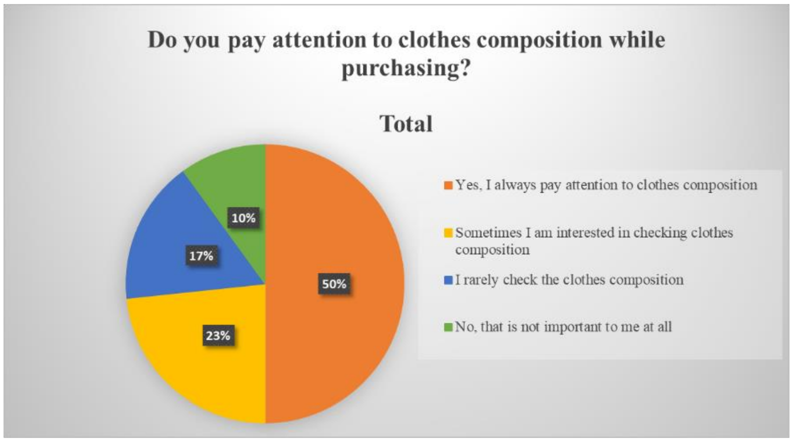


Fig. 31 Attention to clothes composition

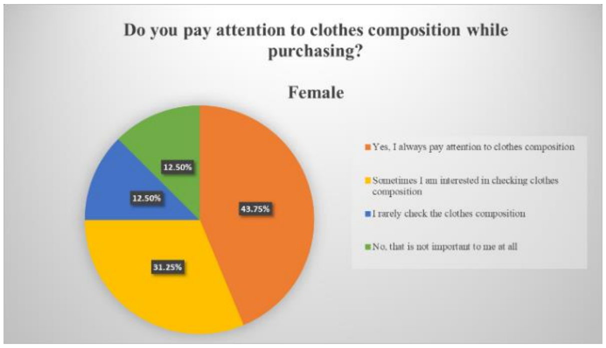


Fig. 32 Attention to clothes composition (F)

Fig. 33 Attention to clothes composition (M)

The survey also included a question about fibers in order to determine respondent's consciousness about the environmental footprint of different fibers. The majority of respondents, around 47% (14 respondents) thought that cotton is the most environmentally friendly fiber, followed by hemp with 30% (9 respondents), wool with 20% (6 respondents), and lastly synthetic fibers with only 3% (1 respondent) (fig. 34).

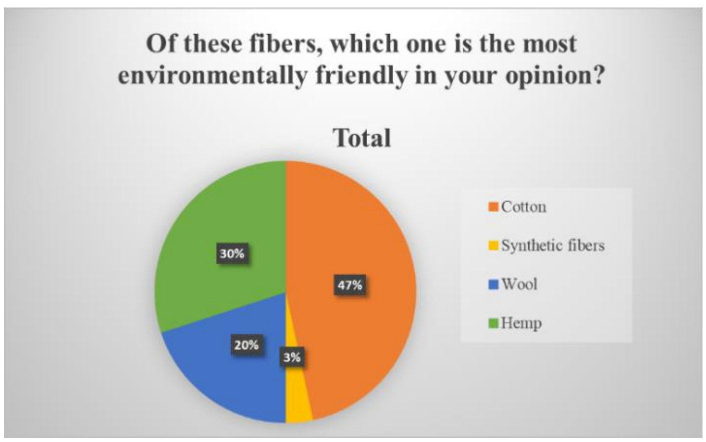


Fig. 34 Consciousness about environmental footprint of different fibers

Further, one of the questions was if the respondents are willing to give more money for environmentally friendlier clothes. The majority, which is around 77% (23 respondents) would give more money, while 23% (7 respondents) would not (fig. 35). This question was also further analyzed by social status (table 24) and monthly income (table 25). Regarding social status, within the upper class, around 83% would give more money for environmentally friendlier clothes, while around 17% would not. In the upper-middle class, 75% would give more money, while 25% would not. When it comes to the middle class, around 73% would give more money, and around 27% would not. Lastly, regarding the working class, 80% would give more money, while 20% would not (table 24). This shows that regardless of social status, the majority of respondents would give more money for environmentally friendlier clothes. A similar situation was with monthly income (table 25).

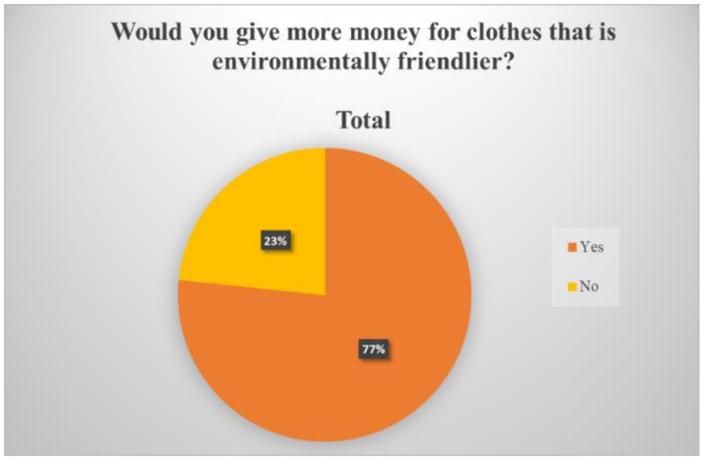


Fig. 35 How many respondents (%) would give more money for environmentally friendlier clothes

Social Status	Yes (N/%)	No (N/%)
Upper class (6)	5 (83.33%)	1 (16.67%)
Upper-middle-class (4)	3 (75%)	1 (25%)
Middle class (15)	11 (73.33%)	4 (26.67%)
Working-class (5)	4 (80%)	1 (20%)
Poor (0)	0 (0%)	0 (0%)

Table 24 Would you give more money for clothes that is environmentally friendlier?

Monthly Income	Yes (N/%)	No (N/%)
I do not have an income (student, unemployed, retiree) (7)	6 (85.71%)	1 (14.29%)
Minimum wage 35.000 RSD (300 EUR) (0)	0 (0%)	0 (0%)
35.000-50.000 RSD (300 EUR- 425 EUR) (5)	4 (80%)	1 (20%)
50.000-100.000 RSD (425 EUR- 850 EUR) (9)	6 (66.67%)	3 (33.33%)
Above 100.000 RSD (850 EUR) (9)	7 (77.78%)	2 (22.22%)

Table 25 Would you give more money for clothes that is environmentally friendlier?

When it comes to clothes consumption, women consume more clothes compared to men, more precisely 12.62 kg/per year (table 26), while men purchase 9.86 kg/per year (table 27).[2] Regarding the number of pieces of clothes purchased per year, for women, the average is again higher, 52.12 (table 26), while for men, 40.71 (table 27). Women also spend more money on clothing per year than men, around 130,300 RSD (around 1,106 EUR) (table 26), while men spend on average 113,930 RSD (around 967 EUR) per year (table 27). The average clothes consumption for all respondents was 11.33 kg/per year, the average number of pieces of clothes purchased yearly was 46.27, and the average income spending per year was 122,670 RSD (1,042 EUR) (table 28). These

[2] Note: exactly one kg of clothes was brought into the mall (which is usually 4-5 pieces of clothing such as T-shirts and jeans) so that respondents could more easily assess the consumption of clothing and give more precise and accurate answers and avoid errors.

data were also analyzed by age (table 29), social status (table 30), and monthly income (table 31) to determine if the younger population spends more money on clothing than the older population and if people with higher social status and monthly income spends more money on clothing.

Age	Purchased clothes in kg/per year	Number of pieces of clothes purchased per year	Average income spent on clothing per year in RSD
15	6	25	60,000
15	5	20	50,000
16	20	80	200,000
22	8	30	70,000
23	25	100	220,000
24	20	80	210,000
24	10	35	80,000
25	10	35	75,000
26	20	100	200,000
27	10	40	80,000
29	6	25	60,000
36	10	40	120,000
43	20	80	220,000
45	20	80	220,000
46	2	8	20,000
50	10	40	200,000
Max	**25**	**100**	**220,000**
Min	**2**	**8**	**20,000**
Average	**12.62**	**51.12**	**130,312.5**

Table 26 Clothes consumption for female respondents

Age	Purchased clothes in kg/per year	Number of pieces of clothes purchased per year	Average income spent on clothing per year in RSD
18	20	80	200,000
19	3	15	60,000
21	5	20	50,000
22	3	12	30,000
22	4	16	30,000
25	15	70	150,000
28	3	12	25,000
29	5	25	50,000
30	30	120	470,000
38	5	20	60,000
39	2	8	20,000
43	18	72	200,000
48	20	80	200,000
52	5	20	50,000

Max	**30**	**120**	**470,000**
Min	**2**	**8**	**20,000**
Average	**9.86**	**40.71**	**113,928.6**

Table 27 Clothes consumption for male respondents

Total	Purchased clothes in kg/per year	Number of pieces of clothes purchased per year	Average income spent on clothing per year in RSD
30	11.33	46.27	122,666.67

Table 28 Average clothes consumption (for both male and female)

Regarding age, the age group 36-45 years old consumes the most clothes of about 12.5 kg/per year, followed by the age group 26-35 years old with 12.33 kg/per year, 15-25 years old consume around 11kg/per year of clothing, while age group 46-65 years old consume the least amount with 9.25 kg/per year (table 29). When it comes to the number of pieces of clothes purchased per year, the age group 26-35 years old purchases the highest amount of around 54 pieces/per year, followed by the age group 36-45 years old with 50 pieces/per year, age group 15-25 year old 44 pieces/per year, and lastly age group 46-65 years old with 37 pieces/per year. Regarding average income spent on clothing per year, the age group 26-35 years spends the most on clothing per year, around 147,500 RSD (1,255 EUR), followed by the age group 36-45 years with 140,000 RSD (1,190 EUR)/per year, age group 46-65 spends 117,500 RSD (1,000 EUR) per year, while age group 15-25 years spends the least, 106,071 RSD (900 EUR) per year. Although the clothes consumption rate for the age group 15-25 years was lower compared to age groups 26-35 years and 36-45 years, obtained survey results still matched the assumption. Lower clothes consumption rate within the age group 15-25 years can be explained by the lack of income, given that such young adults are either still in high school/university and do not work, or they are just starting their careers and do not have a high monthly income. On the contrary, age groups 26-35 years and 36-45 years had the highest clothes consumption rates as they are employed and can afford to purchase greater amounts of clothing. The lowest clothes consumption rate was for the oldest age group 46-65 years.

Age group	Purchased clothes in kg/per year (average/max/min)	Number of pieces of clothes purchased per year (average/max/min)	Average/max/min income spent on clothing per year in RSD
15-25 (14)	11 Max 25 Min 3	44.14 Max 100 Min 12	106,071 Max 220,000 Min 30,000
26-35 (6)	12.33 Max 30 Min 12	53.66 Max 120 Min 12	147,500 Max 470,000 Min 25,000
36-45 (6)	12.5 Max 20 Min 2	50 Max 80 Min 8	140,000 Max 220,000 Min 20,000
46-65 (4)	9.25 Max 20 Min 2	37 Max 80 Min 8	117,500 Max 200,000 Min 20,000

Table 29 Average clothes consumption by age group

When it comes to social status, as assumed, the upper class consumes the highest amount of clothing with around 16 kg/per year (table 30). Upper-middle and middle classes consume similar amounts, around 10 kg/per year while working class consumes the least amount of clothing, around 9 kg/per year. Regarding the number of pieces of clothes purchased per year, results were similar as with kg, with the upper class purchasing the highest number of clothes per year, more precisely 63, upper-middle and middle class around 43 pieces/per year, while for the working class the difference was not that high, as they purchase around 40 pieces/per year. The upper class spends the most average income on clothes per year, about 190,333 RSD (1,600 EUR), followed by the upper-middle class with 126,250 RSD (1,070 EUR), the middle class with 106,666 RSD (900 EUR), while the working class spends 83,000 RSD (700 EUR). Regarding monthly income, the results were similar to social status (table 31).

Social Status	Purchased clothes in kg/per year (average/max/min)	Number of pieces of clothes purchased per year (average/max/min)	Average/max/min income spent on clothing per year in RSD
Upper class (6)	15.83 Max 30 Min 2	63.33 Max 120 Min 8	193,333 Max 470,000 Min 20,000
Upper-middle-class (4)	10.75 Max 20 Min 3	43 Max 80 Min 12	126,250 Max 200,000 Min 25,000
Middle class (15)	10.33 Max 25 Min 2	42.53 Max 100 Min 8	106,666 Max 220,000 Min 20,000
Working-class (5)	9.4 Max 20 Min 3	39.6 Max 100 Min 12	83,000 Max 200,000 Min 30,000
Poor (0)	0	0	0

Table 30 Average clothes consumption by social status

Monthly Income	Purchased clothes in kg/per year (average/max/min)	Number of pieces of clothes purchased per year (average/max/min)	Average/max/min income spent on clothing per year in RSD
I do not have an income (student, unemployed, retiree) (7)	13.43 Max 25 Min 3	55.71 Max 100 Min 15	135,714 Max 220,000 Min 50,000
Minimum wage 35.000 RSD (300 EUR) (0)	0	0	0
35.000-50.000 RSD (300 EUR- 425 EUR) (5)	9.4 Max 20 Min 3	39.6 Max 100 Min 12	83,000 Max 200,000 Min 30,000
50.000-100.000 RSD (425 EUR- 850 EUR) (9)	9 Max 20 Min 2	36.44 Max 80 Min 8	94,444 Max 220,000 Min 20,000
Above 100.000 RSD (850 EUR) (9)	13.11 Max 30 Min 2	52.44 Max 120 Min 8	162,777 Max 470,000 20,000

Table 31 Average clothes consumption by monthly income

Regarding clothes service time, 40% (12 respondents) utilize clothes 1-2 years before discarding them, 33% (10 respondents) 3-4 years, only 20% (6 respondents) 5 years or more, while 7% (2 respondents) less than a year (fig. 36). No one chose the option less than a month and less than 6 months. There was a slight difference between female and male respondents. In the case of female respondents, 37% (6 respondents) use clothes for 1-2 years, 44% (7 respondents) for around 3-4 years, while 19% (3 respondents) use clothes for 5 years or more (fig. 37). When it comes to male respondents, around 43% (6 respondents) utilizes clothes for 1-2 years, around 21% (3 respondents) for 3-4 years and around 21% (3 respondents) for 5 years or more as well, while around 14% (2 respondents) less than a year (fig. 38). It was expected that female respondents would utilize clothes less and discharge them more often than male respondents as they follow more fast fashion, however from female respondents no one chose the option less than a year, while in case of male respondents 14% did. Also, the response rate to the option 3-4 years was higher among female respondents compared to male respondents. Answer rates to the option 5 years or more were similar between male and female respondents.

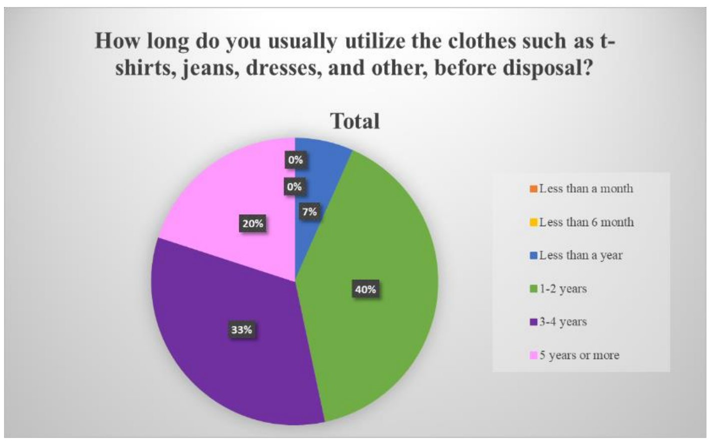


Fig. 36 Clothes service time

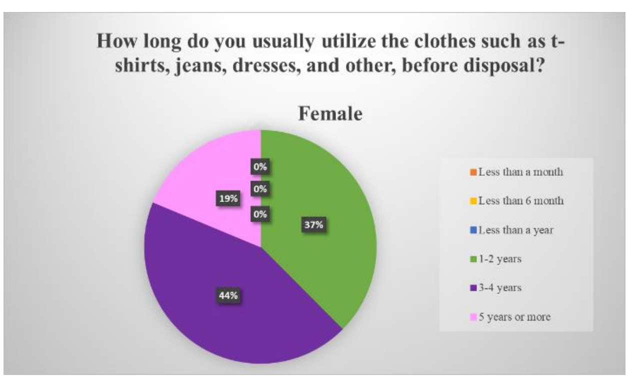


Fig. 37 Clothes service time (Female)

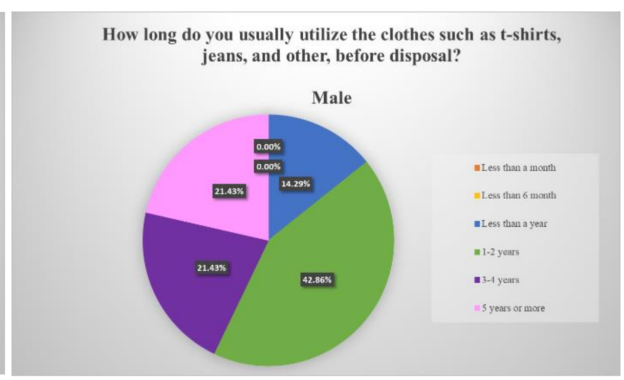


Fig. 38 Clothes service time (Male)

This question was also further analyzed by age (table 32), social status (table 33), and monthly income (table 34) to determine if the younger population and respondents with higher social status and monthly income use their clothes for a shorter period and discharge them more often. When it comes to age, only the age group 15-25 years old chose the answer option less than a year, more precisely 14%, while from the older age groups, no one chose that option. The highest response rate for the answer option 1-2 years was among the age group 26-35 years with around 83%, followed by the age group 15-25 years with around 36%, age group 46-45 years 25%, and lastly age group 36-45 years with around 17%. The response rate for the answer option 3-4 years was the highest among the age group 46-65 years with 50%, followed by the age group 15-25 years old with the same response rate as for the previous answer option 36%, age group 36-45 years with around 33%, and lastly, age group 26-35 years with around 17%. When it comes to answer option, 5 years or more, the highest response rate was among the age group 36-45 with 50%, followed by the age group 46-65 years, the age group 15-25 years around 14%, while the age group 25-35 years did not choose that option at all. Thus, the survey results matched the hypothesis, as only the age group 15-25 years chose the option for less than a year, the majority of respondents within the age group 26-35 years utilize their clothes for only 1-2 years, while the highest response rate for the answer option 3-4 years was among the age group 46-65 years, and for the option 5 years or more among the age group 36-45 years.

Age group	Less than a month (N/%)	Less than 6 months (N/%)	Less than a year (N/%)	1-2 years (N/%)	3-4 years (N/%)	5 years or more (N/%)
15-25 (14)	0 (0%)	0 (0%)	2 (14.29%)	5 (35.71%)	5 (35.71%)	2 (14.29%)
26-35 (6)	0 (0%)	0 (0%)	0 (0%)	5 (83.33%)	1 (16.67%)	0 (0%)
36-45 (6)	0 (0%)	0 (0%)	0 (0%)	1 (16.67%)	2 (33.33%)	3 (50%)
46-65 (4)	0 (0%)	0 (0%)	0 (0%)	1 (25%)	2 (50%)	1 (25%)

Table 32 How long do you usually utilize the clothes such as t-shirts, jeans, dresses, and other, before disposal?

Regarding social status, the upper class had the same response rates, 33.33%, for three answer options (1-2 years, 3-4 years and 5 years or more), while no one chose the remaining two answer options (less than a year and less than 6 months). When it comes to the upper-middle class, about 75% use their clothes for only 1-2 years before discharging them, while 25% use them for 3-4 years. The majority of respondents within the middle class use their clothes for 3-4 years, more precisely 47%, while 27% use 1-2 years, 20% for 5 years or more, and around 7% for less than a year. Within the working class, 60% use their clothes for only 1-2 years, 20% for less than a year, and 20% for 5 years or more. Thus, the survey results were a bit different than expected, as surprisingly, within the working class majority of respondents chose the option for only 1-2 years, and some less than a year. However, this can be explained by working class income. Due to lower income, the working class cannot afford high quality clothes, and thus they usually purchase lower quality clothes which are less durable and have a shorter service lifetime. On the contrary, the upper class usually purchases high quality clothes that last longer. The lowest clothes utilization time was among the upper-middle class (up to 75% uses clothes for only 1-2 years), while the majority of the middle class uses their clothes for 3-4 years. When it comes to monthly income, around 43% of respondents without any income use clothes for 1-2 years, also around 43% use for 3-4 years, and only around 14% for 5 years or more. The majority of respondents with a monthly income of 35,000-50,000 RSD (350-425 EUR) use clothes for 1-2 years, more precisely 60%, 20% for less than a year, and also 20% for 5 years or more. Around 44% of respondents with a monthly income of 50,000-100,000 RSD (425-850 EUR) use their clothes for 3-4 years, around 22% for 1-

2 years, 22% for 5 years or more as well, and around 11% less than a year. Lastly, around 44% of respondents with monthly income above 100,000 RSD (above 850 EUR) uses clothes for 1-2 year, around 33% for 3-4 years, and around 22% for 5 years or more.

Social Status	Less than a month (N/%)	Less than 6 months (N/%)	Less than a year (N/%)	1-2 years (N/%)	3-4 years (N/%)	5 years or more (N/%)
Upper class (6)	0 (0%)	0 (0%)	0 (0%)	2 (33.33%)	2 (33.33%)	2 (33.33%)
Upper-middle-class (4)	0 (0%)	0 (0%)	0 (0%)	3 (75%)	1 (25%)	0 (0%)
Middle class (15)	0 (0%)	0 (0%)	1 (6.67%)	4 (26.67%)	7 (46.67%)	3 (20%)
Working-class (5)	0 (0%)	0 (0%)	1 (20%)	3 (60%)	0 (0%)	1 (20%)
Poor (0)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Table 33 How long do you usually utilize the clothes such as t-shirts, jeans, dresses, and other, before disposal?

Monthly Income	Less than a month (N/%)	Less than 6 months (N/%)	Less than a year (N/%)	1-2 years (N/%)	3-4 years (N/%)	5 years or more (N/%)
I do not have an income (student, unemployed, retiree) (7)	0 (0%)	0 (0%)	0 (0%)	3 (42.86%)	3 (42.86%)	1 (14.29%)
Minimum wage 35.000 RSD (300 EUR) (0)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
35.000-50.000 RSD (300 EUR- 425 EUR) (5)	0 (0%)	0 (0%)	1 (20%)	3 (60%)	0 (0%)	1 (20%)
50.000-100.000 RSD (425 EUR- 850 EUR) (9)	0 (0%)	0 (0%)	1 (11.11%)	2 (22.22%)	4 (44.44%)	2 (22.22%)
Above 100.000 RSD (850 EUR) (9)	0 (0%)	0 (0%)	0 (0%)	4 (44.44%)	3 (33.33%)	2 (22.22%)

Table 34 How long do you usually utilize the clothes such as t-shirts, jeans, dresses, and other, before disposal?

Regarding, the question about what respondents usually do with the clothes that they do not need or use any more, the majority of respondents, around 70% (21 respondents), give their discharged clothes to someone else (friends or family members), around 10% give them to charity (3 respondents), 3% just keep clothes in their wardrobes (1 respondent), 7% (2 respondents) repair the clothes or use them for something else, 3% (1 respondent) toss them away, and 7% (3 respondents) something else (fig. 39).

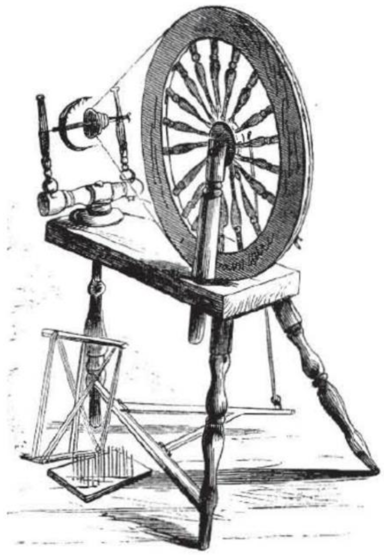
Fig. 39 What respondents usually do with discharged clothes

3. Liteature review

3.1 History of apparel industry and emergence of fast fashion

3.1.1 Early beginnings

To understand the emergence of fast fashion as a new and dominant concept, first, we need to take a look back into the history and development of the apparel industry. Anthropologists embraced the idea that humans first started wearing clothing made from animal skins and vegetation to protect themselves from the outside weather conditions (http://www.historyofclothing.com/). It is unknown precisely when humans first started wearing clothing; however, some evidence indicates somewhere between 100.000 and 500.000 years ago (Bellis 2020). The earliest piece of evidence is the discovery of 36.000 year old clothing made from dyed flax found in the cave of the Republic of Georgia (http://www.historyofclothing.com/). To make clothes, humans needed to develop tools and techniques such as spinning, weaving, and knitting (Bellis 2020). Primitive needles made from bones and other materials were the first tools for making clothes, dating as far back as 40.000 years ago (http://www.historyofclothing.com/). Except for needles, significant inventions which made clothing-making possible include the spinning wheel and various types of looms. Weaving is the most universal method for making clothes (Wilson 2021). It occurred sometime before 6000 BC (Wilson 2021). Other methods for making clothes, such as Nalebinding, a type of knitting, occurred around 6500 BC (http://www.historyofclothing.com/). The spinning wheel is one of the most important inventions (fig. 40). It transforms animal or plant fibers into thread or yarn, which is then woven into clothes using looms (Bellis 2021). Before the invention of the spinning wheel, yarn was spun using a spindle (fig. 41), a very simple hand tool, which dates back as far as 5000 BC (Bellis 2020). It is unknown exactly when and where the first spinning wheel was invented, as various evidence indicates different places, such as China, Egypt, and India (Bellis 2021). However, some historical evidence suggests that its origin is from India sometime between 500 and 1000 A.D. (Bellis 2021). Other theories indicate that this technology is originally from China and that it migrated from China to Iran, later to India, and finally to Europe during the late Middle Ages (Bellis 2021). Another essential invention was the loom, a machine for weaving threads into clothes (fig. 42). It dates as far back as the 5th millennium B.C. (Britannica 2013).



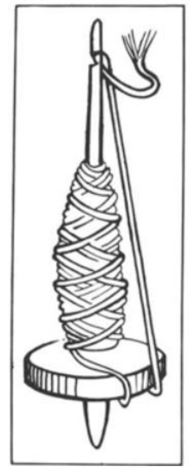


Fig. 40 Spinning wheel (https://www.pinterest.com/pin/465489311468624215/) Fig. 41 Spindle (Wilson 2021)

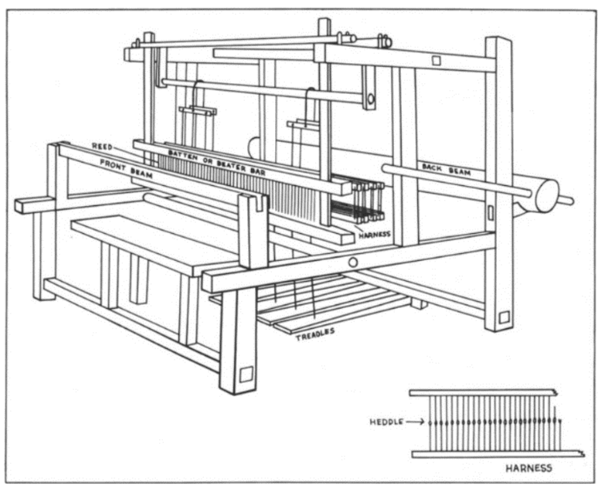


Fig. 42 Loom (Wilson 2021)

People used natural fibers to make clothes. The most common materials were flax, silk, cotton, and wool. These materials were also associated with great civilizations – such as Egypt with flax, China with silk, India, and Peru with cotton, and Mesopotamia with wool (Wilson 2021). Flax might be the first known plant for making clothes (Wilson 2021). Its cultivation started about 8000 BC in the Near East (http://www.historyofclothing.com/). Further, Ancient Egyptians wore linen clothes from the Neolithic period (http://www.historyofclothing.com/). They developed different techniques for spinning flax and tools for making linen clothes (http://www.historyofclothing.com/). Evidence for the production and utilization of silk in China dates back sometime between 5000 and 3000 BC (http://www.historyofclothing.com/). Apart from flax, cotton is also one of the oldest discovered plants for clothing production. The archaeological evidence suggests it was cultivated in India around 3500 BC and Peru around 3000 BC (Wilson

2021). In India, cotton was utilized from the 5th millennium B.C. (http://www.historyofclothing.com/). Regarding wool, since shears were not discovered until the Iron age, sometime about 1000 BC, it is supposed that this was the last fiber spun into clothes (Wilson 2021). Domestication of sheep first occurred in Mesopotamia, and it became the land of wool (Wilson 2021).

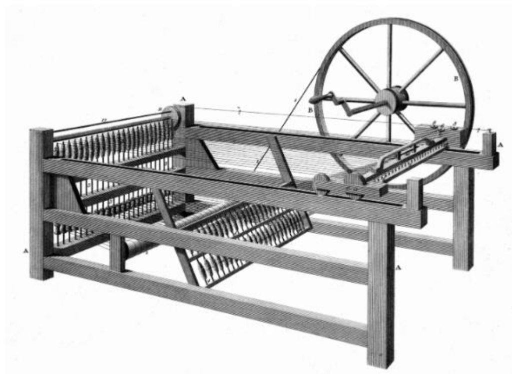
Discovery of plant and animal fibers, techniques, and tools such as loom and spinning wheel made clothing production possible. However, making clothes did not radically change throughout a long period of history. It was handmade, using the same technology for spinning and weaving as thousands of years ago. That was until the Industrial Revolution. Significant inventions and industrialization transformed the apparel industry like never before. This was the catalyst for later globalization and the emergence of fast fashion, which will be discussed in the next part of this paper.

3.1.2 Industrial Revolution and transformation of the apparel industry

Since man first discovered tools and techniques, clothes production did not change much until the Industrial Revolution. This period brought great inventions which shaped and set a pathway toward mechanization and industrialization of clothing production. Back, throughout history, for thousands of years making clothes was pretty much the same. It was a labor-intense and time-consuming process, as it was handmade using simple hand tools. Before industrialization, by the second half of the 19th century (Solinger 2017) all clothes were manufactured by tailors or skilled family members in households or home workshops called cottage industries (Monet 2022). Important inventions such as the sewing machine shifted textile production from households and tailors to a factory-like setting environment for mass-production (Nayak and Padhye 2015). Previously, each garment was made individually, sewing was viewed as art done by experienced hands as thousands of years before until the invention of the sewing machine in the 19th century (Nayak and Padhye 2015). The first sewing machine was invented by Thomas Saint in 1790 (Nayak and Padhye 2015), yet it didn't have a major success. In 1829, also a French tailor Barthélemy Thimonnier patented the first functional sewing machine, which the French government granted in 1830 (Nayak and Padhye 2015; Hilger 2008). Ordered by the French government, he opened the first factory for clothes manufacturing to produce uniforms for the French army (Hilger 2008). However, a mob of tailors who feared that they would lose jobs over the machines broke into the factory and burned it (Nayak and Padhye 2015). Even though many inventors patented the sewing machine, it hadn't had a significant breakthrough and success until Elias Howe's sewing machine; invented in 1846 (Monet 2022) (fig. 43). His sewing machine set a pathway towards great changes in the clothing industry. However, it didn't go to mass production until Isaac Singer added modifications, perfected it, and commercialized it in the 1850s (Bellis 2020). With sewing machines, workers could quickly put together pieces of clothing. However, the first hand-powered sewing machines from the 19th century could sew only 20 stitches per minute (Solinger 2017). As sewing machines continued to be improved, by the turn of the century, electrically powered machines could sew 200 stitches, and by the mid-20th century, the speed had risen to 4.500 stitches, and finally by 1970, machines were sewing up to 7.000-8.000 stitches per minute (Solinger 2017).

Fig. 43 Elias Howe's sewing machine
(https://americanhistory.si.edu/collections/search/object/nmah_630930)

Apart from sewing machines, other essential inventions led to the mechanization of clothes production and shifted it to factories. This revolutionized the garment industry as faster and larger-scale production led to a drop in clothing prices, making it affordable for everyone. Another significant invention was the roller spinning machine for spinning cotton into thread, invented by Lewis Paul and John Wyatt in 1738 (Monet 2022). In 1764 James Hargreaves invented spinning jenny, a multiple spinning hand-powered machine which significantly reduced the time needed for spinning as it became industrialized for the first time (Bellis 2021) (fig. 44). This was the first machine which was an improvement of the spinning wheel, used for thousands of years prior (Bellis 2021). Further, in 1770 Richard Arkwright invented the water frame, which produced stronger threads and significantly contributed to the shift of textile production from cottages to factory-like environments (Monet 2022) (fig. 45). In 1779 Samuel Crompton invented a spinning mule, a machine which combined the technology of both the water frame and the spinning jenny (Bellis 2020) (fig. 46). It spins fibers into yarn and it is even today an essential part of the textile industry (Bellis 2020). The spinning mule produced a finer thread of much higher quality (Bellis 2020). It transformed yarn manufacturing, making it faster and more profitable (Bellis 2020).



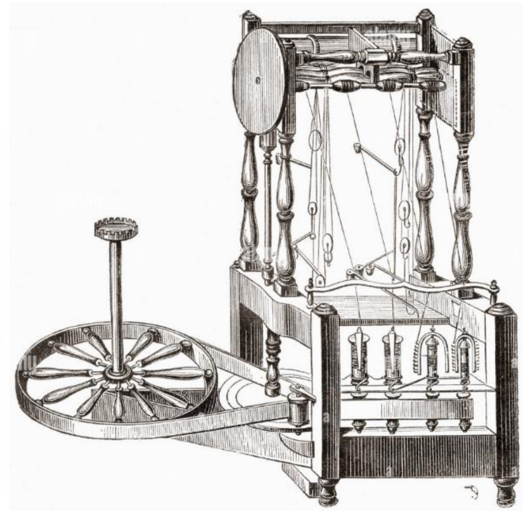


Fig. 44 Spinning jenny Fig. 45 Water frame
(https://www.britannica.com/technology/spinning-jenny) (https://www.alamy.com/stock-photo-richard-arkwrights-water-frame-53395044.html)

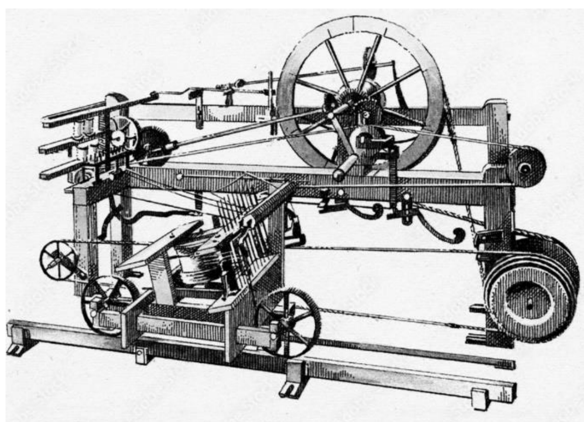


Fig. 46 Spinning mule
(https://stock.adobe.com/search?k=%22spinning+mule%22&asset_id=75649594)

Looms have been used for thousands of years for weaving fabrics into clothes (fig. 47). However, they were manually operated, making clothes production a very slow process. That changed with the power loom, the first mechanical loom, another paramount invention, patented by Edmund Cartwright in 1785 (Bellis 2020). Later, improved by William Hordocks and Francis Cabot Lowell, it was commercialized in the 1820s (Bellis 2020). Further, James Bullough and William Kenworthy developed a fully automated loom in 1842, which have become a standard for the clothing industry in the next century (Bellis 2020). Eli Whitney's cotton gin was one of the most influential inventions of the American Industrial Revolution, as it revolutionized cotton production (Longley 2021). It's a machine which separates seeds from cotton fibers, a time-consuming and laborious process done by hand before Eli Whitney's invention in 1792 (Bellis 2020) (fig. 48). Thanks to the cotton gin, cotton soon became the main export commodity, which boostered the US economy, as cotton exports have risen from 500.000 pounds in 1793 to 93 million pounds in 1810 (Longley 2021).

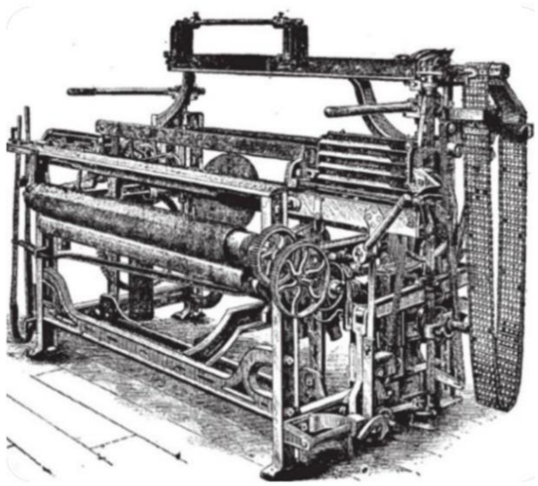


Fig. 47 Power loom (https://co.pinterest.com/pin/581597739372602880/)

Fig. 48 Eli Whitney’s cotton gin (Podushak 2014)

Except for inventions and technological progress, a crucial impact on large-scale and mass clothing productions had also standardization of man's and women's measurements. In the US, women's measurements were taken from July 1939 until June 1940 in order to determine average sizing (Monet 2022). For men, the Civil War in the US created a demand for ready-made uniforms, which led to earlier standardized sizes (Earl and Schondelmeyer 2022). Another crucial invention that significantly altered the apparel industry were synthetic fibers such as rayon, spandex, nylon, and polyester. A French chemist Hilaire de Chardonnet was the first who invented and manufactured artificial silk or rayon, known as Chardonnet silk (Britannica 2022). In 1891 he opened the first factory for its production (Lazić and Popović 2009). Wallace Hume Carothers was another relevant chemist who largely contributed to the development of synthetic fibers, and in 1938 discovered nylon, the first synthetic fiber produced for commercial purposes (Britannica 2022). By the end of 1930, huge progress had been made in the field of synthetic fiber production thanks to Carothers's discovery of polymer synthesis by condensation (Lazić and Popović 2009). Polyester was discovered in 1941, and since then, it has become a paramount synthetic fiber in the clothing industry (Twombly 2016). Apart from synthetic fibers, the invention of synthetic dyes revolutionized dyeing processes and the clothing industry. Before that, natural dyes extracted from nature were used for dyeing clothes. They were of plant and animal origin. Natural dyes did not fix to the fabrics and were easily washed out. Synthetic dyes were the major breakthrough, discovered in the middle of the 19th century (Lazić and Popović 2009). William Perkin was the first who synthesized the first commercialized synthetic dye mauve in 1856 (Lazić and Popović 2009). This discovery altered the chemical industry, as later, thousands of synthetic dyes were synthesized and commercialized (Lazić and Popović 2009).

Development of agroindustry with discovery of pesticides and artificial fertilizers enabled improvement in cultivation of natural fibers such as cotton (Lazić and Popović 2009). The Industrial Revolution brought machines for spinning, weaving, and sewing, which replaced the hard and time-consuming process of clothes production with faster large-scale production. Innovations and improvements in chemistry, mechanical engineering, and technology shaped the apparel industry. Quick and mass production of clothing became a reality, clothes prices dropped, and soon enough, everyone could afford to buy them. The next step was globalization, which further remodeled the apparel industry and opened a door for the emergence of fast fashion, a new business model.

3.1.3 Emergence of fast fashion

Clothing is one of the necessary commodities for everyday life. However, today, the amount of clothing that we have in our wardrobes far exceeds our survival needs. Over the last few decades, clothing purchasing has changed drastically, as it is viewed as a form of entertainment, and we tend to buy more clothes than we actually need. Before this, attention was given to the quality of clothes. People were saving money to buy clothes at certain times of the year, usually with a change of seasons, such as spring and winter. That all changed with the emergence of fast fashion as brands started to introduce more and more ,,seasons" which following was becoming increasingly important to consumers. Consumers began to appreciate more ,,staying in trend" and following the last fashionable season than the certain quality of clothing. Fast fashion enabled consumers to wear the latest modern style and high fashion pieces of clothing for a much lower price. To do so, fast fashion brands catch and replicate the latest fashion trends from catwalks of luxury brands and turn those trends into cheap, mass-produced products (Macchiona et al., 2015). In the past, fashion was only accessible to the wealthy elite. Clothes were expensive and viewed as valuable goods. They were embellished, reused, repaired, and inherited among family members. Today, we buy fast fashion clothes and toss them away after a fraction of wearing.

Industrialization and mechanization of the clothing industry enabled mass production, causing a drop in prices, and soon enough, clothes became affordable and ordinary commodities. The invention of the sewing machine led to the emergence of ready-to-wear clothes, which paved the route to the fast fashion industry. However, fast fashion as a concept did not emerge until the late 80s beginning of the 90s of the last century. Technological progress, with globalization, era of internet and social networks opened a route to emergence of fast fashion. The simultaneous change in consumer's preferences with outsourcing clothing production to developing countries were the two main factors for the rise of fast fashion. Until the first half of the 20th century, clothing production was concentrated in developed countries, such as the United States and the United Kingdom (Solinger 2017), which had already gone through industrialization of the textile industry during the previous century. However, with the beginning of globalization, clothing manufacturing started to shift towards developing countries. ,,At present, more than 60 percent of world clothing exports are manufactured in developing countries" (International Labour Organization). The cheap labor force, vast tax breaks, weak laws, and legislations of developing nations attract fast fashion brands to outsource their production (Klein 1999). This enabled the emergence of fast fashion as it significantly reduced the costs of clothes manufacturing. Now, fast fashion clothes can be sold for a fraction of the price. Fast fashion brands mostly shifted their production to Asian countries such as China, India, Bangladesh, Cambodia, Korea, Pakistan, and Vietnam (Tewari 2005). Asia became a major world supplier of apparel, accounting for 60% of the global exports (International Labour Organization 2017). Among Asian countries, China has become a leading exporter, both globally and regionally, accounting for 40% of the global clothing exports (International Labour Organization 2017). Fast fashion is mainly exported to the market of wealthy countries of the Global North, such as the United States, Canada, Australia, and European countries. For example ,,80% of EU-consumed finished textiles are manufactured outside of the EU" (Niinimäki *et al*. 2020, 193). Major fast fashion exporters to the EU market in 2015 were countries such as China, Turkey, Bangladesh, Cambodia, India, and Vietnam (Šajn 2019).

Before the 1990s, consumers did not give too much attention to fashion, and they preferred basic clothing (Bhardwaj and Fairhurst 2010). However, since the beginning of the 1990s, there has been a sudden increase in women's fashionable clothing (Bailey and Eicher 1992), and brands have started introducing more seasons. As fig. 49 shows, the life cycle of fashion apparel has four stages: ,,introduction and adoption by fashion leaders; growth and increase in public acceptance; mass conformity (maturation); and finally the decline and obsolescence of fashion" (Bhardwaj and Fairhurst 2010, 167). However, from the late 1980s, fashion brands started to introduce two additional intermediate seasons to regular winter/spring seasons (Hilger 2008). More add-on collections with lower volumes than the main collection were introduced as intermediate seasons called Special Programs or Pre-Season Programs (Hilger 2008). The middle of the 1990s was marked by a dizzying increase of seasons, as more and more splits and collections were introduced (Hilger 2008). The term fast fashion indicates fast replacement of clothing collections in fast fashion stores. Fast fashion thrives on frequent and quick replacement of trends and collections. Today, instead of four seasons, spring, summer, autumn, and winter, there are as many as 52 seasons, as new trends are introduced every week (The True Cost, 2015). This led to increased purchasing habits as new clothes are introduced almost every week in stores, which consumers find attractive and addictive. Thanks to social media and the internet, following the latest fashion trends have become easy and feasible. To simulate consumers buying fast fashion clothes, designers combine elements of attraction such as color, silhouette, drape, texture, and line balance (Solinger, 2017). Fast fashion clothes give a sense of well-being by feeling modern and attractive to oneself and others (Solinger, 2017). Today, people tend to buy 60% more clothing per year than 15 years ago (Remy et al. 2016), while the average service life has decreased by 36% (Morlet et al. 2017). Fast fashion prospers on consumerism, fast replacement of trends, mass production of cheap clothing, and disposal behavior. In the last 15 years, the production of clothes has doubled

(Souchet, 2019), as now, nearly 80-100 billion pieces of clothing are bought each year (Patwary 2020), which is 1.2 trillion in sales (Bick et al. 2018). The average global annual consumption of clothes has increased from 7 kg to 13 kg per person in the last two decades (Milburn 2016a). Fast fashion clothes have low quality, and they last only a limited number of washes. Because fast fashion clothes are cheap to produce and buy, consumers may not value them and toss them away after a few wearing. Such a business model has led to environmental degradation and social problems. Many of today's dominant fashion houses, which play a major role in the fast fashion industry, were founded between 1950 and 1975 (Hilger 2008). Examples of fast fashion are brands such as H&M, Zara, Forever 21, Primark, and Mango, among others (fig. 50). The following chapter will closely review the two largest leading fast fashion brands: Zara and H & M.

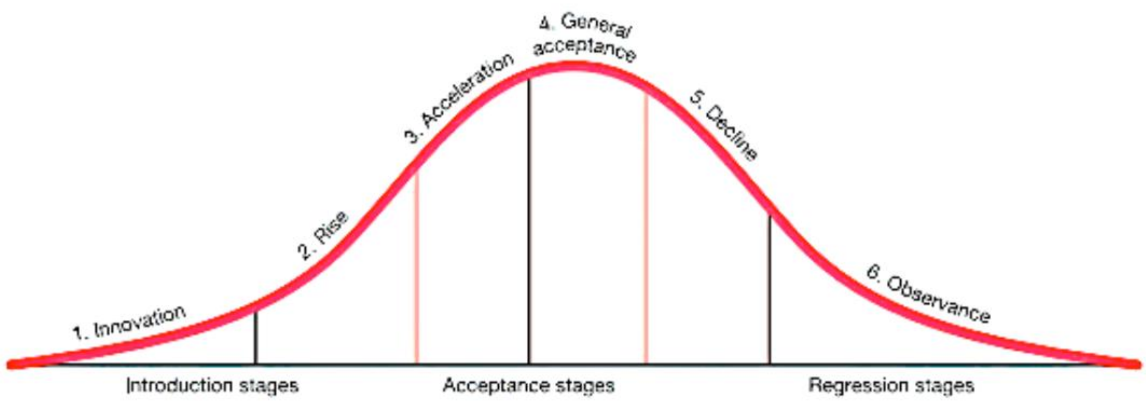


Fig. 49 Fashion life cycle (Solomon *et al*. 2006)

Fig. 50 The most famous fast fashion brands (Caro and Martı´nez-de-Albeniz 2015)

3.2 Fast fashion brands

Fast fashion is a novel business model adopted by many big fashion brands. Its success rests on fast production of cheap, mass-produced clothing which follows the latest trends from catwalks of luxury brands. Fast fashion brands ,,are not "haute couture" or trend-setters but rather fashion followers that target the mid-to-low price range" (Caro and Martinez-de-Albeniz 2015, 238). Elements such as quick response, frequent assortment changes, and fashionable design at affordable prices are characteristics of fast fashion brands that adopted such a business model (Caro and Martinez-de-Albeniz 2015). With outsourcing clothing production to developing, mostly Asian countries, fast fashion became a reality, as reduced clothing production costs enabled fast fashion brands to sell for a fraction of the price. Frequent replacement of clothes assortment in fashion stores and short lead time are essential elements of fast fashion business strategy. Some of the key features common to fast fashion brands that embraced fast fashion as a business model include:

- ,,Thousands of styles, which touch on all the latest trends.
- Extremely short turnaround time between when a trend or garment is seen on the catwalk or in celebrity media and when it hits the shelves.
- Offshore manufacturing where labour is the cheapest, with the use of workers on low wages without adequate rights or safety and complex supply chains with poor visibility beyond the first tier.
- A limited quantity of a particular garment—this is an idea pioneered by Zara. With new stock arriving in store every few days, shoppers know if they don't buy something they like, they'll probably miss their chance.
- Cheap, low quality materials like polyester, causing clothes to degrade after just a few wears and get thrown away" (Rauturier 2022)

Founded by Amancio Ortega Gaona, Inditex (Industria de Diseño Textil) is a textile giant and today the world's largest fast fashion retailer, which includes seven separate brands such as Zara, Zara Home, Stradivarius, Bershka, Pull and Bear, Massimo Dutti, and Oysho (Inditex Annual Report 2021; Ghemawat and Nueno 2006). The company started as Confecciones GOA in 1963, a small workshop for making women's clothing (Inditex website). At the beginning, in the 1960s, Ortega's business was small scale, privately held, and local, with annual sales of 30 million USD (Crofton and Dopico 2007). However, the company's business grew as it achieved sales from 0.086 billion USD in 1985 to 0.8 billion USD in 1990, 1.2 billion USD in 1995, 2.4 billion USD in 2000, and 8.2 billion USD in 2005 (Crofton and Dopico 2007). In 2021 Inditex reached net sales of 27,716 million EUR, from which 25,5% were online sales (Inditex Annual Report 2021). As the company expanded its business across the borders of Spain, its international sales grew from the late 1980s to 30 percent in 1995, 52 percent in 2000, and 57 percent in 2005 (Crofton and Dopico 2007). From total sales in 2021, Europe (excluding Spain) accounted for 48.4%, Asia 19.7%, Spain 14.4%, and Americas 17.5% (Inditex Annual Report 2021). Also, the number of stores significantly increased from only 41 in 1985 to 424 in 1995, 1,080 in 2000, 2,717 in 2006 (Crofton and Dopico 2007), and finally to 6,477 in 2021 (Inditex Annual Report 2021). ,,In 2006, Inditex had 1,464 stores in Spain, 859 in the rest of Europe, 19 in the US, 198 in the rest of the Americas, 140 in the Middle East and North Africa, and 37 in Asia-Pacific" (Crofton and Dopico 2007, 46). However, in 2021, according to the Inditex Annual Report (2021), of total 6,477 Inditex stores, 1,267 were located in Spain, 3,200 in the rest of Europe, 757 in the Americas, and 1,253 in the rest of the world. In 2021 Inditex employed 165,042 people, from which 76% were women and 24% man (Inditex Annual Report 2021). The majority of the employed workforce is engaged in the store sector 86%, while in logistics 6%, manufacturing 1%, and central services 7% (Inditex Annual Report 2021). Like most companies, Inditex has also shifted its production towards China and other developing countries. That is ,,by 2004, 52 percent of production took place in Spain, Portugal, and Morocco; 18 percent in other European countries; 13 percent in China; and 14 percent in other Asian countries" (Crofton and Dopico 2007, 46). Each of Inditex's brands operates independently as a separate retailing chain (Ghemawat and Nueno 2006). They are responsible for managing their own business strategy, product design, manufacturing and distribution, and financial results (Ghemawat and Nueno 2006). Each brand has its own stores, ordering system, subcontractors, and organizational structure (Crofton and Dopico 2007).

From Inditex brands, Zara became a flagship brand and the company's pride, having major success in retailing and the fast fashion industry. Zara accounts for more than 75% of total Inditex sales (Ferdows et al. 2003). In 2021, from total Inditex sales of 27,716 million EUR, Zara accounted for 19,586 million EUR (Inditex Annual Report 2021). The first Zara store was opened in 1975 in the center of La Coruna in Spain (Ferdows et al. 2003). The company started with only six stores in 1979 (Ghemawat and Nueno 2006). Already, in the 1980s, Zara established retailing in all major cities in Spain (Ghemawat and Nueno 2006). It expanded its business across the borders of Spain by opening the first store in 1988 in Porto, Portugal, and further overseas by opening the store in New York in 1989 and Paris in 1990 (Ghemawat and Nueno 2006). When Zara opened the store in New York, people heard for the first time the term ,,fast fashion" (Rauturier 2022). Its name became a synonym for fast fashion. Between 1992 and 1997, Zara further expanded its business, entering about one country per year (Ghemawat and Nueno 2006). According to Inditex Annual Report (2021) by 2021, Zara owned 2,025 stores in 96 countries across the globe. From 80 employed designers in Zara, 80% of them analyze runway designer collections and 20% up-to-the-minute street and celebrity fashion (Kim *et al*. 2013). Around 80% of Zara's products represent fashion garments, and the rest are basic items (Ferdows et al. 2003). Zara made an effort to reduce its design-to-retail cycle, which enabled the company to bring new styles more frequently and update its collections constantly in stores (Crofton and Dopico 2007). While many retailers ship their products to stores every twelve weeks, Zara receives shipments twice per week (Crofton and Dopico 2007; Ferdows et al. 2003). The journey of item takes only four weeks from designer's sketch to finished product on the store racks ready for sale (Hayes 2022). Every week Zara introduces at least two newly-designed products, which is around 10,000 items per year (Kim *et al*. 2013). The company believes that frequent changes in collections and introduction of new styles will attract customers to visit the stores more often (Crofton and Dopico 2007), scaling up the sales. Further, first introduced by Zara, stores have low levels of inventory, only a few pieces of each model (Ferdows et al. 2003), so consumers know that they have to buy products immediately or they will not be there the next time when they visit. Zara carefully analyses the market, as only 15-20% of total production is pre-made, and the rest of 80-85% is market-based (Kim *et al*. 2013). What is interesting about Zara is that it does not spend as much money on advertising as its competitors. Compared to other retailers, which spend 3%-4% on media advertising, Zara spends only 0.3 % (Ghemawat and Nueno 2006). Instead, Zara's stores advertise in the company's name, with specially arranged collections and storefronts always located in prime and high traffic locations (Ghemawat and Nueno 2006). Regardless of the location, each store is identical. This is accomplished thanks to instruction manuals and strict enforcement of the Visual Merchandising Display (VMD) in each store (Kim *et al*. 2013).

Hennes and Mauritz, commonly known as H&M, is one of the oldest fast fashion brands, founded by Erling Persson in 1947 in the country town Va¨stera˚s, Sweden (Giertz-Mårtenson 2012). As well as Zara, it started as a small local shop for women's clothing. Today, right after Zara, it's the second-largest fast fashion retailer (Robertson 2022). Like Inditex (Zara), H&M is also a fast fashion retailer, offering trendy fashion for low prices, constantly introducing new products, and has limited inventories to encourage consumers to visit stores more often and buy products immediately (Crofton and Dopico 2007). H&M includes eight brands such as H&M, COS, Weekday, Monki, H&M HOME, & Other Stories, ARKET, and Afound (Sustainability Performance Report 2020). Starting from a single store named „Hennes" (H&M Annual Report 2017), today, H&M is one of the most recognizable fast fashion brands. It started its expansion outside Sweden by opening the first store in Norway in 1964, followed by Denmark in 1967 and London in 1976 (H&M Annual Report 2017). Since then, H&M has continued to grow and expand its business. In 1968 when Erling Persson bought the hunting and fishing store Mauritz Widfross in Stockholm, he also changed the company's name to Hennes and Mauritz, or today known as H&M (H&M Annual Report 2017). In the same year, H&M started to sell also man's and children's clothing (H&M Annual Report 2017). From 1980 it continues further global expansion by entering new markets such as Germany, the Netherlands, Belgium, Austria, Luxembourg, Finland, and France (H&M Annual Report 2017). In 2000 H&M crossed the Atlantic and brought its business to the American market by opening the first store in the US (H&M Annual Report 2017). Further, between 2007 and 2009, H&M enters also East Asia by opening stores in Hong Kong, Shanghai, and Tokyo (H&M Annual Report 2017). Today H&M employs 153,000 people, and it has around 5,000 stores in 74 markets (Sustainability Performance Report 2020). While H&M clothes collections are designed by more than 100 in-house designers in headquarters in Stockholm (Giertz-Mårtenson 2012), production is outsourced to Europe and Asia. Unlike Zara, H&M does not own factories, instead it cooperates with around 700 suppliers namely located in Asia and Europe (Giertz-Mårtenson 2012).

3.3 Stages of clothes production

Fast fashion supply chain has become a complex global network. It is characterized by vertical disintegration and global dispersion (Niinimäki *et al*. 2020), as various stages of clothes production are performed in different regions and countries. With globalization, it is unusual that the whole cycle of clothes production is performed in one country, from growing natural fibers to fabric manufacturing, clothing manufacturing, and finally retailing. Instead, the whole cycle is stretched among different regions and countries. Clothes industry links several industries, from agriculture (for production of natural fibers) and petrochemicals (for production of synthetic fibers) to manufacturing, logistics, and retail (Niinimäki *et al*. 2020). It transforms fibers into yarn, yarn into fabrics, dyes and finishes these materials through various processes to finally assemble clothes (Madhav *et al.* 2018). However, clothes production starts with raw material extraction, such as growing natural fibers like cotton or extraction of synthetic fibers in the petrochemical industry from crude oil. As fig. 51 shows, further stages of clothes production include yarn formation, fabric formation, fabric processing (wet processing), and textile fabrication (Madhav *et al.* 2018).

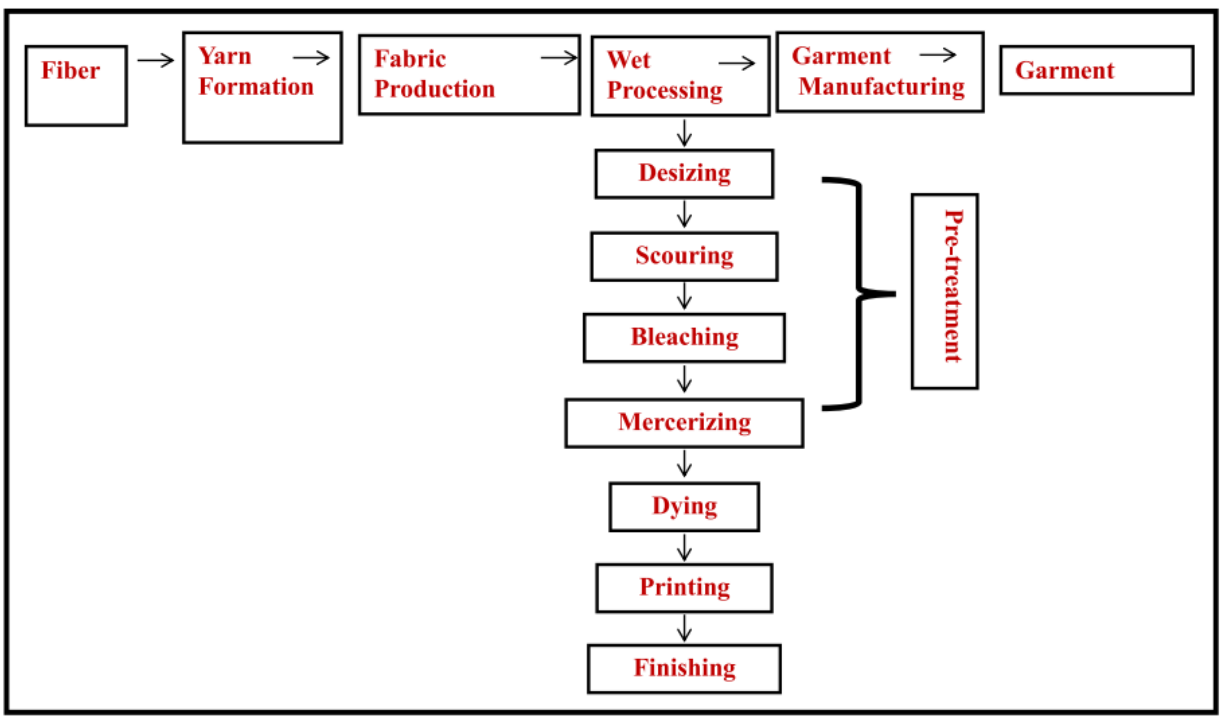


Fig. 51 Stages of clothes production (Madhav *et al.* 2018)

Yarn is manufactured through process called spinning, in which fibers are twisted into thread or yarn (fig. 52). Yarns are further used for fabric production through knitting or weaving (fig. 53). Spinning, knitting, and weaving are energy-intensive processes (Munasinghe et al. 2021). Wet processing includes steps such as desizing, scouring, bleaching, mercerizing, dyeing, printing, and finishing (Madhav *et al.* 2018). As water is used as a medium, this stage of clothes production utilizes a great amount of water and also chemicals. In sizing, chemicals such as carboxymethyl cellulose (CMC), polyvinyl alcohol (PVA), polyacetate and polycyclic acids are used to provide strength to fibers and minimize the breakage, which eases the spinning and weaving process (Khan and Malik 2014; Madhav *et al*. 2018). Sizing majorly contributes to water pollution as ,,it is estimated that about 750 kilograms (kg) of sizing material is present in the effluent discharged from an average mill that produces about 60,000 meters of fabric" (Madhav *et al*. 2018, 32). The second step includes desizing in which unwanted chemicals and sizing materials are removed from the fabrics. Which chemicals are going to be used depends on the type of size applied, as water-soluble size could be simply washed out, while water-insoluble size requires the utilization of enzymes and auxiliary chemicals (Khan and Malik 2014). ,,The desizing process contributes approximately 50% to the total amount of wastewater, which contains high levels of biological oxygen demand (BOD)" (Madhav *et al*. 2018, 33). Scouring is a process in which impurities such as fats, waxes, oils, and surfactants are removed from the fabric (Kishor *et al*. 2021). Alkali agents such as glycerol, ethers, sodium hydroxide, detergent, or soap are used to break down these impurities and clean the fabrics (Kishor *et al.* 2021). Scouring of cotton fibers is usually preformed at high temperatures, up to 120℃ in vigorous basic solution, while polyester scouring is mostly conducted with moderate alkaline conditions with detergents (Toprak and Anis 2017). This step majorly contributes to highly alkaline effluent, with the values ranging from 10 to 11 (Sarayu and Sandhya 2012). Bleaching is a very important step in which unwanted color is removed from the fabric with chemicals such as sodium hypochlorite and hydrogen peroxide (Khan and Malik 2014). A result of this process are highly toxic chlorinated by-products (Madhav *et al*. 2018). Another safer alternative to hypochlorite, one of the oldest bleaching agents in the industry, is peracetic acid (CH3CO3H) (Madhav *et al*. 2018). After bleaching, mercerization is the next step, usually characteristic for cotton fibers (Khan and Malik 2014). In this step, fibers and fabrics are treated with cold or hot caustic soda (NaOH) for up to 1 to 3 minutes and then are rinsed (Madhav *et al*. 2018; Kishor *et al*. 2021). This process improves physical and chemical properties of fibers, such as luster, strength, and dye uptake (Kishor *et al*. 2021).

Fig. 52 Clothes spinning Fig. 53 Clothes weaving

(https://depositphotos.com/201660914/stock-photo-textile-industry-yarn-spools-spinning.html)

(https://www.ukft.org/spotlight-john-spencer-textiles/)

In dying process, dyes are added to fabrics or fibers to provide color (fig. 54). This step requires a significant amount of water as it is used as a medium in dye bath and also later for rinsing (Khan and Malik 2014). There are three methods of dyeing using batch, usually the most common one, continuous and semicontinuous (Khan and Malik 2014). Dyes can be of natural or synthetic origin. Natural dyes were used until the discovery of synthetics dyes in the middle of the 19th century. Today, synthetic dyes are used for dyeing clothes. As fig. 55 shows, synthetic dyes can be classified into two main groups based on their water solubility (Sharma *et al*. 2021). Soluble dyes include dyes such as acid or anionic dye, basic or cationic dye, reactive dye and direct dye, while insoluble dyes include dyes such as sulfur, disperse, vat and pigments (Sharma *et al.* 2021). Dyeing is a water-intensive process which largely contributes to water pollution. „For example, 0.6 to 0.8 kg of sodium chloride (NaCl), 30 to 60 grams of dyestuff, and 70 to 150 liters (L) of water are required for dyeing 1 kg of cotton with reactive dyes" (Madhav *et al*. 2018, 34). Many chemicals such as formaldehyde, heavy metals, surfactants, salts, and sulfide are added in order to reinforce dye uptake of the fibers, and these usually end up in effluents (Madhav *et al*. 2018) making it highly toxic.

Fig. 54 Textile dyeing
(https://www.rajlaxmitextile.in/textile-dyeing-services.html)

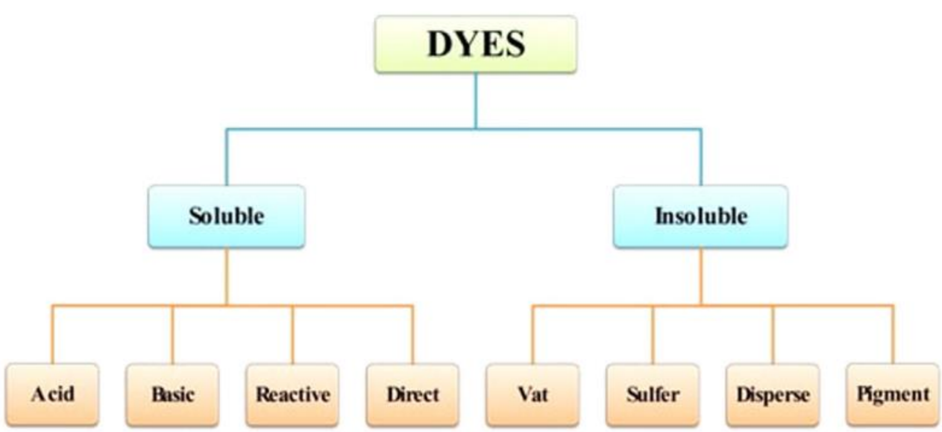


Fig. 55 Classification of dyes (Sharma et al 2021)

While in dyeing color is added in solution form, in printing color is applied using a thick paste of the dye (Madhav *et al.* 2018). Printing is usually done at selected parts of the fabric which constitute the design (Madhav *et al.* 2018). In printing chemicals such as phthalates, dyes, metals, solvents, formaldehyde, and urea are commonly used (Kishor *et al*. 2021). Finishing is the final stage of fabric or fiber processing. It includes the use of finishing agents such as biocides, synthetic organic or inorganic chemicals which provide specific properties to the clothes like stain proofing, softening, waterproofing, flame retardance, and protection from microbial activities (Kishor *et al*. 2021). Biocides are usually used to disinfect, sanitize, sterilize and preserve materials from microbiological degradation (Madhav *et al.* 2018). Garment manufacturing is the closing stage in which garments are made from previously processed fabrics (fig. 56). It includes processes such as cutting, sewing, assembly, embellishments, ironing, and finally, packaging (fig. 57) (Munasinghe et al. 2021).

Fig. 56 Clothes assemballing Fig. 57 Clothes packing
(https://garmentsmerchandising.com/list-of-sewing-machine-used-in-apparel-industry/)
(https://www.alamy.com/stock-photo/worker-garment-industry-packing.html)

3.4 Fibers

According to their origin, textile fibers can be classified into two main groups: natural and manufactured (fig. 58) (Muthu et al. 2012; Claudio 2007). Natural fibers include vegetable and animal fibers, while manufactured could be divided into synthetic, regenerated cellulosic, inorganic, and recycled fibers. While synthetic fibers were first discovered in the late 19th and the beginning of the 20th century, natural fibers were used for thousands of years. Unlike synthetic fibers, natural fibers are biodegradable. However, the advantage of synthetic fibers is that they do not require a significant amount of water as natural fibers such as cotton, but they have a higher carbon footprint. Of the total amount of fibers produced globally, 60% are utilized in the fast fashion industry, while the rest goes into the production of geotextiles, industrial textiles, agrotextiles, and hygienic textiles (Niinimäki *et al*. 2020). Synthetic fibers dominate the textile and fashion industry, accounting for 51% (polyester), while natural fibers, mainly cotton, accounted for 25% of the total fiber production in 2018 (Niinimäki *et al*. 2020). Of synthetic fibers, polyester is the most relevant due to its cost-efficiency and performance characteristics (Niinimäki *et al.* 2020).

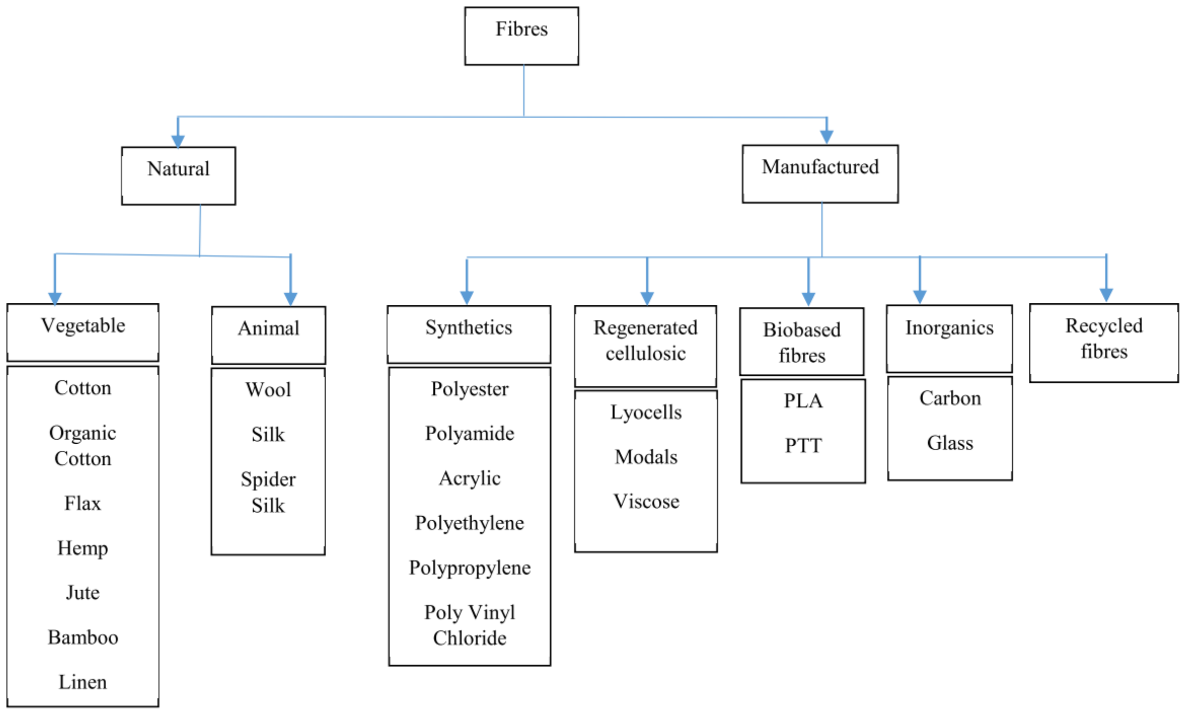


Fig. 58 Classification of textile fibers (Muthu et al. 2012; Claudio 2007)

Depending on their origin, natural fibers can be divided into vegetable, animal or mineral fibers (fig. 59). Vegetable fibers are collected form different plant parts such as seed, bast and leaf and according to that are further classified (see fig) (Nayak *et al*. 2012). Among vegetable fibers the most common fibers used in the textile industry are cotton, flax, hemp, jute and sisal (Jabbar and Shaker 2016). Animal fibers include wool and slik. While plant fibers are cellulose based, animal fibers are protein based (El Nemr 2012). Regarding mineral fiber, asbestos is the most relevant fiber in this class. However, unlike other fibers, especialy cotton and synthetic, mineral fibers do not have such a significance for the clothing industry. Asbestos is usually used for production of special fire-proof and industrial fabrics because of its properties (Jabbar and Shaker 2016). It is resistant to heat and burning, and chemicals such as acids and alkalis (Jabbar and Shaker 2016).

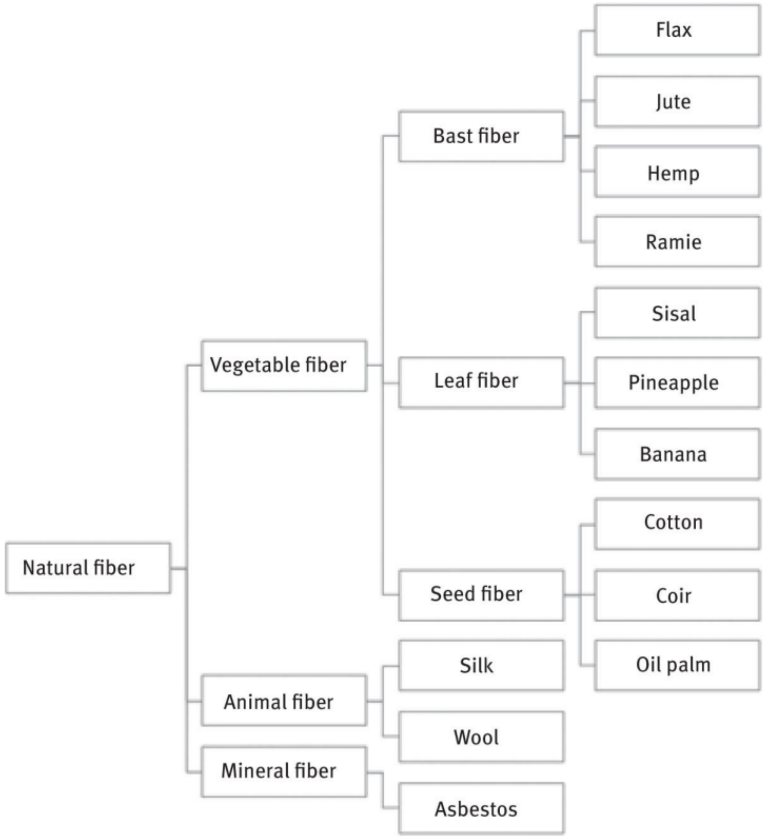


Fig. 59 Natural fibers classification (Jabbar and Shaker 2016)

3.4.1 Cotton

Cotton is a white and soft fibrous material which grows around seeds in a protective capsule of the cotton plant (Jabbar and Shaker 2016) (fig. 60). Cotton plant includes a variety of plants which belong to the genus Gossypium of the Malvaceae family (El Nemr 2012). It belongs to the group of seed fibers. Like all vegetable fibers, cotton is composed of cellulose. It is almost pure cellulose as it accounts for 95% (El Nemr 2012). Cotton is one of the oldest fibers used and known to man for clothes production. Its utilization originates from India as far back as 3000 BC (Jabbar and Shaker 2016). From India, growing and utilization of cotton transferred to Egypt, China, and the South Pacific (Jabbar and Shaker 2016). In North America, cotton became a relevant fiber with the invention of the cotton gin, which caused the expansion of cotton production. Today, cotton is essential and the most widely used natural fiber in the clothing industry. Since the 1940s, the world's cotton consumption had an annual growth rate of about 2% (El Nemr 2012). China, the United States, India, and Pakistan accounted for more than 55% of the global cotton consumption for the period 1980-2008 (El Nemr 2012). Of around 50 species of cotton, only four are cultivated for fiber production: „Gossypium barbadense of Peruvian origin, Gossypium arboreum (which originated in the Indo-Pakistan subcontinent), Gossypium herbaceum (from southern Africa) and Gossypium hirsutum originated in Mexico" (El Nemr 2012, 16). Of these cotton species, the last three are vital and the most common, accounting for more than 90% of world fiber production, while Gossypium barbadense accounts for only about 5% (El Nemr 2012). The United States and China are the two major cotton producers accounting for half of the world's cotton production (Lazić and Popović 2009). Other relevant producers are also India, Pakistan, Uzbekistan, and Turkey (Lazić and Popović 2009). Growing cotton is especially relevant for developing countries, as in 2007/08 from 65 cotton-producing countries, 52 were developing countries (El Nemr 2012).

Fig. 60 Cotton plant
(https://www.worldwildlife.org/industries/cotton)

Cotton production starts with agriculture by growing cotton. Successful cotton cultivation is conditioned by essential elements such as temperature, sunlight, precipitations, fertilizers, and irrigation (Lazić and Popović 2009). Cotton requires a vast amount of water, fertilizers, and pesticides. More than 60% of cotton production originates from irrigated land (Lazić and Popović 2009). It is estimated that water consumption for the production of 1 kg of cotton requires from 7.000 to 29.000 liters (Lazić and Popović 2009). Cotton thrives in a warm climate with temperatures ranging between 11°C and 25°C, usually in dry tropical and subtropical regions (El Nemr 2012). It is sensitive to freezing temperatures, usually below 5°C and temperatures higher than 25°C (El Nemr 2012). Even though cotton is a tropical plant, its cultivation is not limited only to the tropics. With new cotton varieties and advancements in cultivation practices, cotton cultivation expanded from 47 degrees North latitude to 32 degrees South (El Nemr 2012). Cotton flowering usually occurs six to eight weeks after its planted (El Nemr 2012). After flowering, it takes approximately two months for cotton bolls to mature (El Nemr 2012). When fully mature cotton bolls burst open, reliving soft cotton fibers ready for harvesting. Cotton is harvested either manually or mechanically (El Nemr 2012) (fig. 61 and 62). Usually, 1 kg of cotton obtains 0,35 kg of cotton fibers, 0,62 kg of cottonseeds, and 0,03 kg of waste (leaves and twins) (Lazić and Popović 2009). Handpicking is the most common method of cotton harvesting in most cotton-producing countries (Lazić and Popović 2009). The United States and Israel are the only two counties where 100% of cotton is harvested mechanically (Lazić and Popović 2009). Manual or handpicking is a labor-intensive and time-consuming process; however, it produces higher quality lint (cotton fibers) as only completely mature cotton bolls are carefully collected with limited amount of trash (leaves and twins) (Jabbar and Shaker 2016; El Nemr 2012). Under normal conditions, an experienced worker could pick 300 lbs. of seed cotton per day (Jabbar and Shaker 2016). Mechanical harvesting is done with cotton pickers or strippers (El Nemr 2012). Mechanical harvesting requires the application of defoliants and desiccants, chemicals which reduce the moisture in leaves, facilitating the harvesting as leaves dry and fall out. It is faster than handpicking, but it collects all cotton balls, mature and unmatured, along with unwanted leaves and twins (El Nemr 2012). Production of 1 kg of cotton makes around 0,07 kg of trash with handpicking, while mechanical harvesting makes 0,17 kg of trash (Lazić and Popović 2009). Because of that, mechanically harvested cotton requires sorting trash in order to clean cotton and obtain higher quality cotton fibers (lint) (El Nemr 2012). After its harvested, cotton is transported to a cotton gin which separates cotton fibers from seeds (Jabbar and Shaker 2016). Separated cottonseeds could be used for the extraction of oil for edibles or soap/candle production (Jabbar and Shaker 2016). To obtain one pound of cottonseeds usually takes up to 50-100 cotton bolls (Jabbar and Shaker 2016). Cottonseed oil accounts for 4% of the world's consumption, and it is ranked as the fifth oil in use among vegetable oils (El Nemr 2012). Afterward, cotton is compacted in bales and stored.

Fig. 61 Mechanical cotton harvesting Fig. 62 Cotton handpicking

(https://www.quilting-in-america.com/cotton-cultivation-process.html)

(https://www.agrifarming.in/cotton-farming-guide)

Cotton fibers are mainly used for clothes production (around 60% of cotton consumption) but also for home furnishings and industrial uses (El Nemr 2012). Some of the home fashion applications of cotton include the production of bed sheets, towels, curtains, draperies, table cloths, table mats, and napkins (Jabbar and Shaker 2016). For industrial purposes, cotton fibers are used for the production of ropes, shoes, bags, conveyors, filter cloth, belts, and medical supplies (Jabbar and Shaker 2016).

3.4.2 Flax

Flax belongs to the group of bast fibers, and it is one of the most important fibers in this group. Bast is natural fiber obtained from a bast which surrounds the stem of the plant (El Nemr 2012). Flax is collected from the steam of the plant Linum usitatissimum (Jabbar and Shaker 2016). It is probably the oldest plant known to man for making clothes. Flax cultivation dates far back as 8000 BC (El Nemr 2012). The fabric old 36 000 years made from flax, has been found in the cave of the Republic of Georgia, which is the oldest found piece of clothing (http://www.historyofclothing.com/). In northern Europe, flax utilization for clothes production dates from the Neolithic period (El Nemr 2012). With the invention of cotton gin in the 18th century, cotton became a dominant natural fiber, which suppressed the flax as a fiber source in North America (El Nemr 2012). Now, in the United States and Canada, flax is mainly grown for its seeds (El Nemr 2012). Flax belongs to the genus Linum of the Linaceae family (El Nemr 2012). It is an annual plant with slender and erect steam, with narrow lance-shaped leaves and blue flowers (El Nemr 2012) (fig. 63). It has shallow taproots and can reach a height from 30 to 120 cm (El Nemr 2012). There are two main types of flax, whereby one is grown for fibers and the other for the oil-seed (Jabbar and Shaker 2016). While fiber flax is cultivated for the production of strong and thin fibers, seed flax gives more linseed and coarser fibers, and therefore it is ideal for the production of oil-seed (Jabbar and Shaker 2016). Fiber flax thrives in humid and moderate climate regions, while oil flax likes more dry and warm areas (Jabbar and Shaker 2016). Cultivation of fiber flax takes place on estimated 12 million hectares, while oil-seed varieties are cultivated on 500,000 hectares (El Nemr 2012). Leading flax-producing countries are Canada, China, India, the United States, and Ethiopia (El Nemr 2012). In the United States, major flax-producing states are North Dakota, South Dakota, Minnesota, and Montana, where soils are the most suitable for flax cultivation (El Nemr 2012). Usually, the ideal conditions for flax growth are north and south temperate zones, where summer is cool and damp with fertile and sandy soil (El Nemr 2012). Fiber flax is mainly cultivated in Europe, especially in Belgium, the Netherlands, and Luxemburg (El Nemr 2012). In North America, flax is primarily grown for oil-seed (El Nemr 2012). Regions such as Saskatchewan and Manitoba stand out as primary regions for flax growth in North America (El Nemr 2012). Argentina, India, and China also cultivate flax for its oil (El Nemr 2012).


Fig. 63 Flax plant
(https://www.etsy.com/ca/listing/506212471/flax-seed-flax-linum-usitatissimum)

Flax is harvested by pulling the stalk either by hand or with a mechanical puller (Jabbar and Shaker 2016). Another method includes cutting the plant closer to the ground, but pulling is preferred as it obtains longer stalks (Jabbar and Shaker 2016). After harvesting, flax stalks are left to dry. The next step includes rippling, in which flower heads and leaves are removed from the stem (Jabbar and Shaker 2016). Further, stalk bundles are spread on the ground for retting. There are three types of retting: water retting, enzyme retting, and dew retting (Jabbar and Shaker 2016). Water rentting includes immersion of flax stems in rivers or standing water (ponds) (fig. 64) (Jabbar and Shaker 2016). Pond retting is usually done in shallow pools, which are easily warmed up by the sun (El Nemr 2012). Pond retting is the fastest as it takes from a few days to a couple of weeks, but it results in dirtier and lower quality flax (El Nemr 2012). This is because flax can be over-retted, which damages the fibers (El Nemr 2012). Another disadvantage of pond retting is that it produces quite of odors (El Nemr 2012). Stream retting is similar to pond retting, but instead of ponds, the flax stems are immersed in rivers or streams. It takes a few weeks longer, but the flax is less dirty, and it is unlikely to be over-retted (El Nemr 2012). Also, with stream retting, there is no production of odors (El Nemr 2012). However, both retting methods pollute the water and are therefore less used (El Nemr 2012). The enzyme retting implies application of enzymes and warm water to degrade the flax stems (Jabbar and Shaker 2016). Drew retting includes spreading out the flax stems over the field (Jabbar and Shaker 2016) (fig. 65). Humidity in the environment stimulates the growth of aerobic fungi, which degrade the flax stems (Jabbar and Shaker 2016). Drew retting produces the highest quality fibers, and it does not pollute the water as the pond and stream retting (El Nemr 2012). However, it is the longest, as it takes a month or more to be completed (El Nemr 2012). The retting is finished when stems are soft and slimy (El Nemr 2012). Afterward, flax stems are dried. As a result of this process, fibers are loosened from the stem. In the next step, stems are broken with fluted rollers (Jabbar and Shaker 2016). Further, with a scutching machine, broken stems are removed from the fibers (Jabbar and Shaker 2016). As scutched fibers are still relatively coarse, coming is the final step which gives thinner and finer fibers (Jabbar and Shaker 2016).

Fig. 64 Water flax rentting Fig. 65 Drew flax retting

https://www.krishisewa.com/production-(technology/fibres/714-flax-cultivation-technique.html)
(https://www.krishisewa.com/production-technology/fibres/714-flax-cultivation-technique.html)

The flax fibers woven into fabrics are known as linen (Jabbar and Shaker 2016). High water absorption and low elasticity are the main linen characteristics (El Nemr 2012). It is a soft and lustrous fabric which allows the skin to breathe (El Nemr 2012; Jabbar and Shaker 2016). Thanks to low elasticity, upon washing, linen clothes do not deform (Jabbar and Shaker 2016). Apart from clothes production, coarser flax fibers could be used for twine and rope manufacturing (El Nemr 2012). Lower graded flax fibers are also used in the paper industry, automobile industry, and for insulation purposes (El Nemr 2012). Other flax utilization includes the production of dyes, medicines, fishing nets, hair gels, and soaps (El Nemr 2012). Flax seed is mainly used for the extraction of linseed oil for paints and other industrial products but also for human nutrition (El Nemr 2012).

3.4.3 Hemp

Hemp also belongs to the group of blast fibers, and its obtained from the plants of the Cannabis genus (El Nemr 2012) (fig. 66). The genus Cannabis includes three species: Cannabis indica, Cannabis sativa, and Cannabis ruderalis (Schluttenhofer and Yuan, 2017). Depending on the use, Cannabis can be divided into marijuana and hemp (Schluttenhofer and Yuan, 2017). While marijuana has a medical value, hemp is mainly used for its fibers and seeds (Schluttenhofer and Yuan, 2017). The main difference between hemp and marijuana is the content of tetrahydrocannabinol (THC), a substance naturally present in Cannabis, a psychoactive compound. In European countries and North America, Cannabis can be classified as hemp if it does not contain more than 0.2% or 0.3% of tetrahydrocannabinol (THC) (Schluttenhofer and Yuan, 2017). Hemp has been used for thousands of years as food and medicine and for its fibers. Humans have known the use of hemp fibers for the production of clothes, ropes, canvas, and paper since ancient times. Hemp cultivation dates far back as 12,000 years ago (Shahzad 2011). Hemp is a native plant to central Asia (Shahzad 2011). It can grow in wide range of climate zones and many different types of soil (Salentijn et al. 2015; Duque et al. 2020). However, the ideal environmental conditions for hemp cultivation are semihumid climate zones with temperatures ranging from 7.8 ℃ to 27 ℃ (Duque et al. 2020). Hemp is an annual plant with woody stem which can reach a height from 1.2 to 5 meters (El Nemr 2012).

Fig. 66 Hemp plant
(https://www.britannica.com/plant/hemp)

Harvesting of hemp usually occurs before the plant's flowering (Duque et al. 2020). Harvesting is done by cutting down the plants, which are afterward rolled into large bails and transported for further fiber extraction (Duque et al. 2020). Same as with flax, retting is the next step in hemp processing. Hemp stalks consist of bast fiber and hurd (Schluttenhofer and Yuan, 2017). In order to separate fibers from the inner hurd, retting relies on chemicals or bacteria and fungi to break down the pencin, which binds the fibers together (Schluttenhofer and Yuan, 2017; Duque et al. 2020). Further, the stems are broken down with breaker or fluted rolls (Duque et al. 2020). Afterward, in process called scutching, fibers are separated from the core (Duque et al. 2020). Hackling is the final stage which includes combing of fibers in order to remove any unwanted particles (Duque et al. 2020).

China, Europe, and Canada are the main hemp cultivation regions (Salentijn et al. 2015). ,,In 2011 hemp was cultivated globally on 61,318 ha, of which 11,400 ha in China, 14,344 ha in the European Union, and 15,720 ha in Canada" (Salentijn et al. 2015, 34). In Western Europe, cultivation of hemp was suppressed for decades by other natural fibers such as cotton and synthetic fibers (Salentijn et al. 2015). Another reason is prohibition due to Cannabis's psychoactive effects and its use as a narcotic (Salentijn et al. 2015). However, recently, European countries such as the United Kingdom, France, the Netherlands, and Germany have legalized hemp varieties with low THC content for cultivation for industrial purposes (El Nemr 2012). Currently, hemp is cultivated in 47 countries (Schluttenhofer and Yuan, 2017). ,,World production of hemp fiber grew from 50,000 tons in 2000 to almost 90,000 tons in 2005" (Shahzad 2011, 974). The hemp share in total world's production of natural fibers is 0.5% (Shahzad 2011). China is the largest hemp producer, accounting for almost half of the world's production (Shahzad 2011). Except for China, Canada, and France in Europe, Chile and North Korea are also relevant hemp-producing countries

(Schluttenhofer and Yuan, 2017). In North America, hemp was banned from the late 1930s until 1998, when the first licenses for hemp cultivation were issued in Canada (Salentijn et al. 2015). Since then, Canada's market share in hemp production gradually grew, and today is one of the most important suppliers. In the United States, the 2018 US Farm Bill enabled legal hemp cultivation (Duque et al. 2020). However, the United States is still the largest hemp importer, obtaining most of the seeds and fibers mainly from Canada and China (Schluttenhofer and Yuan, 2017).

Hemp is one of the most environmentally friendly fibers. Unlike cotton, it does not require extensive use of pesticides and fertilizers. Hemp is utilized for the production of clothing, paper, biodegradable plastics, oil, construction, health food, bio-fuel, cosmetics, and medicinal purposes (El Nemr 2012) (fig. 67). It is also used for home furnishing and floor coverings (El Nemr 2012). Around 25,000 different products are manufactured from hemp (Salentijn et al. 2015). Hemp is often blended with other natural fibers such as cotton, silk, linen, and wool, which gives a softer feel to the fabric while providing durability and resistance (El Nemr 2012). Hemp/cotton blends are usually blended at 55%/45% (El Nemr 2012). Short core hemp fibers are usually used for the production of insulation products, fiberboard, and erosion control mats (El Nemr 2012). ,,In comparison with cotton, hemp fibers are longer, stronger, more lustrous, absorbent, and more mildew resistant" (Jabbar and Shaker 2016, 5). The main features of fabrics made from hemp include aseptic properties, high absorbency, protection against UV radiation, and no allergenic effect (Duque et al. 2020). Oil extracted from hemp can be used for the production of oil-based paints, plastics, for cooking, in cosmetics, and as a fuel (El Nemr 2012; Schluttenhofer and Yuan, 2017).

Fig. 67 Hemp applications
(https://depositphotos.com/416694922/stock-illustration-products-with-hemp-and-cannabis.html)

3.4.4 Jute

Jute is a bast fiber extracted from the stem and ribbon (outer skin) of the jute plant (El Nemr 2012) (fig. 68). Jute belongs to Tiliaceae family which includes 30–40 Capsularis species of jute (Chandekar et al. 2020). However, only two species of jute are widely cultivated: Corchorus Capsularis (white jute) and Corchorus Olitorius (Tossa jute) (Chandekar et al. 2020). Right after cotton, jute is the second most important natural fiber (El Nemr 2012). Jute is also called the golden fiber because of its golden brown color and industrial importance (Jabbar and Shaker 2016). Jute is environmental friendly and the cheapest natural fiber. It does not require heavy use of pesticides and fertilizers (El Nemr 2012). Unlike other vegetable fibers, jute consists mainly of cellulose and lignin, whereby cellulose accounts for 61–73%, hemi-cellulose 13.6–23%, and lignin 12–16% (Jabbar and Shaker 2016; Chandekar et al. 2020).

Fig. 68 Jute plant
(https://theexplodedview.com/material/jute-walls-of-biofold/)

Optimal conditions for jute cultivation include warm and wet climate with standing water and plain alluvial soils (El Nemr 2012). Jute thrives at temperatures ranging from 20-40°C, relative humidity of 70–80%, and 5–8 cm of weekly precipitation (El Nemr 2012). It is a native plant to India, Banglades and Nepal (Chandekar et al. 2020). Jute plant is ready for harvesting after around 120 days (Jabbar and Shaker 2016). The harvesting is done by hand pulling or cutting with a sharp edge (Jabbar and Shaker 2016) (fig. 69). Afterward, stems are collected into bundles for retting. In this process, stems are immersed in water, where bacteria degrade the stalks, making it possible to separate the fibers (Jabbar and Shaker 2016). Retting takes about 12-25 days (Jabbar and Shaker 2016). Stripping is the next step, in which jute fibers are removed from the stems (Jabbar and Shaker 2016). Stripping is usually performed manually by beating the stalks with a wooden mallet (Jabbar and Shaker 2016). Afterward, fibers are separated and dried.

Fig. 69 Jute harvesting
https://www.daily-bangladesh.com/english/country/60472

Major jute-producing countries are Bangladesh, India, Thailand, China, Myanmar, and Nepal, accounting for 95% of the global production (El Nemr 2012). In India and Bangladesh, jute is cultivated together with kenaf and roselle (10%) at around 500 000 hectares (El Nemr 2012). China cultivates mainly kenaf, while jute accounts for 10% of the production at 56,000 ha (El Nemr 2012). China, India, and Pakistan are also relevant importers of local jute (El Nemr 2012). Britain, Spain, Germany, and Brazil also import jute, mainly from Bangladesh (El Nemr 2012). Even though jute production has been steadily declining due to substitution with polythene and other synthetic, global jute production accounts for around 3 million tons annually (El Nemr 2012).

Jute is usually used for the production of wrapping fabrics (for cotton bale), sacks, scrims, canvas bags, garden twine, and ropes (El Nemr 2012). It is also utilized in home furnishings for curtains, chair coverings, carpets, area rugs, upholstery, hessian cloth, and wall-coverings (El Nemr 2012). Apart from this, jute has applications in geotextile manufacturing, used in agriculture for control of soil erosion, weed control, and seed protection (El Nemr 2012). „Jute butts, the coarse ends of the plants, are used to make inexpensive cloth. Conversely, very fine threads of jute can be separated out and made into imitation silk" (El Nemr 2012, 49). Jute fabrics are 100% biodegradable and recyclable (El Nemr 2012). Even though jute fabrics are strong and durable, when wet, they can lose strength and become a subject to microbial attack (El Nemr 2012). Also, jute fabrics have anti-static properties and protect against UV radiation (El Nemr 2012). The main disadvantages of fabrics made from jute include poor durability, crease resistance, brittleness, fiber shedding, and yellowing with extensive sun exposure (El Nemr 2012).

3.4.5 Sisal

Sisal is the most important fiber among leaf fibers, extracted from the leaves of the sisal plant (Agava sisalana) (Jabbar and Shaker 2016) (fig. 70). In comparison with bast fibers, leaf fibers are harder and coarser (El Nemr 2012). Sisal accounts for around 2% of the world's natural fiber production and takes up a sixth place among natural fibers (El Nemr 2012). The origin of the sisal plant is unclear, however, it is believed that it is native to Yucatan (El Nemr 2012). Sisal is a sun-loving plant which thrives in regions with temperatures above 25℃ (El Nemr 2012). It grows in tropical and sub-tropical climate zones (Mishra et al. 2004). Sisal cultivation does not require the usage of chemical fertilizers. Also, the utilization of herbicides is negligible, as they are only occasionally used, and weeding is done mostly by hand (El Nemr 2012). However, sisal cultivation does cause some environmental degradation, mainly deforestation, as sisal plantations are replaced with native forests (El Nemr 2012). Sisal can have up to 200-250 leaves, and each leaf has around 1000-1200 fibers (Mishra et al. 2004). Sisal fibers are extracted through a process called decortication, in which the leaves are crushed with rollers and then mechanically scraped (Jabbar and Shaker 2016). Further, leaves are washed and dried. As moisture content determines the final fiber quality, drying must be carried out with special care (El Nemr 2012). Artificial drying has the upper hand over sun drying, as it results in higher quality fibers (El Nemr 2012). Sisal fibers are composed mostly of cellulose which accounts for 78%, while lignin accounts for 8%, hemicelluloses 10%, and waxes 1% (Mishra et al. 2004).

Fig. 70 Sisal plant (Andrade *et al.* 2009)

Global sisal production accounts for nearly 4.5 million tons per year (Mishra et al. 2004). Brazil and Tanzania are the two leading sisal-producing countries (Mishra et al. 2004). In 2007, from globally produced 240,000 tons of sisal fibers, Brazill accounted for 113,000 tons, Tanzania 37,000 tones, Kenya 27,600 tones, Venezuela 10,500 tones, Madagascar 9,000 tones, and China 40,000 tones with smaller amounts from also South Africa, Haiti, Cuba, and Mozambique (El Nemr 2012).

The higher-grade sisal fibers are used for the production of carpets, usually in a blend with wool and acrylic fibers for a softer touch, while medium-grade fibers are utilized in manufacturing of ropes, baler, and binder twine (Jabbar and Shaker 2016; El Nemr 2012). Sisal fibers have a long tradition in the cordage industry because of their strength, durability, and ability to stretch (Jabbar and Shaker 2016; El Nemr 2012). Apart from ropes, cordage and twines, sisal is also used for the production of paper, dartboards, geotextiles, filters, buffing cloth, mattresses, handicrafts, carpets, and wire rope cores (El Nemr 2012).

3.4.6 Wool

Wool is an animal fiber obtained from sheep (Jabbar and Shaker 2016). It is protein based, as protein keratin, naturally present in hair, nails, skin hooves, and feathers, is the main constructive component (El Nemr 2012). Other fibers from this group also include cashmere and mohair from goats, fibers from alpaca and other animals in the camel family, and angora from rabbits (Nayak *et al*. 2012). Cashmere is a very soft and luxurious fiber. The goat fibers are considered as cashmere if the diameter is under 18.5 µm and are at least 3.175 cm long (El Nemr 2012). Angora is also prized for its softness, and it can be obtained from different types of Angora rabbits such as English, French, German, and Giant (El Nemr 2012). However, sheep wool is the most widely used fiber in this group (fig. 71). Sheep are usually shorn once or twice a year (Lazić and Popović 2009) (fig. 72). Obtained raw fibers are known as fleece (Jabbar and Shaker 2016). An experienced shearer can remove the sheep's fleece in 2 minutes (Jabbar and Shaker 2016). Raw wool often contains natural fats, grease, and perspiration residues which are removed with wool scouring and wool carbonising in order to obtain a clean wool (El Nemr 2012). The breed of sheep and environmental conditions are the two main factors which affect the quality of wool (Jabbar and Shaker 2016). Also, wool fineness, length, and purity differ depending on from which body part of the sheep the wool is taken (Jabbar and Shaker 2016). If the sheep are exposed to stress during the growth of their fleece, that can result in damaged and lower quality fleece (El Nemr 2012).

Fig. 71 Wool fibers

Fig. 72 Sheep shearing

(https://stock.adobe.com/search?k=wool+fibre)

(https://www.shutterstock.com/search/sheep-shearing)

Wool can be classified into fine wool, medium wool, long wool, and carpet wool (Jabbar and Shaker 2016). The diameter of wool fibers ranges between 15 and 60 µm, and they are usually coarser than silk, rayon, cotton, or linen fibers (El Nemr 2012). Wool is considered as fine wool if the fiber length ranges from 4.0 to 7.5 cm, while coarse fibers have a length up to 35 cm (El Nemr 2012). When wet, wool has a lower breaking point than vegetable fibers (El Nemr 2012). As wool fibers are elastic, they can easily return to the original length after stretching (El Nemr 2012). That is why garments made from wool are resistant to wrinkling. Other relevant wool properties also include durability, bulk, loft, warmth, and resistance to abrasion. Wool is very sensitive to high temperatures and extensive chemicals, and therefore wool garments should be carefully maintained. Wool quality depends on parameters such as fiber diameter, crimp, yield, color, and staple strength (El Nemr 2012). However, the crucial factor which determines the quality and the price of wool is fiber diameter (El Nemr 2012). Clothes are usually manufactured from wool finer than 25 µm in diameter, while coarser wool is used for rugs. Finer wool is softer, while coarser is durable and resistant to pilling (El Nemr 2012). Wool from sheep breeds Lincoln, Romney, Tukidale, Drysdale, and Elliotdale provide coarser fibers, which are used for the production of carpets (El Nemr 2012). There are two types of yarns spun from wool: woolen and worsted (Jabbar and Shaker 2016). Woolen yarns are made of shorter fibers with limited twists during spinning, while worsted yarns are made from finer fibers which are tightly twisted and smoother (Jabbar and Shaker 2016).

Globally around 1.3 million tons of wool is produced every year, from which 60% is utilized for clothes production, 24% for carpet manufacturing, and 11% for other textile products (El Nemr 2012; Lazić and Popović 2009). Australia is the world's largest wool producer, accounting for around 450.000 tons of wool per year (Lazić and Popović 2009). New Zealand holds second place, followed by China as the third world producer (Lazić and Popović 2009). Australia and New Zealand account for 42% of the world's wool production (Lazić and Popović 2009). The United Kingdom is the largest producer of wool in Europe (Lazić and Popović 2009). Huge sheep farms are characteristic for Australia, South America, and New Zealand (Lazić and Popović 2009). The number of sheep per hectare varies from one sheep per hectare to ten sheep per hectare (Lazić and Popović 2009). The amount of wool obtained from sheep varies depending on sheep breed and the time between two shears (Lazić and Popović 2009). Usually, around 4,5-5 kg of fleece can be obtained from the Merino sheep (Lazić and Popović 2009). Apart from clothes production, wool is also used for the production of blankets, rugs, saddle cloths, carpeting, felt, wool insulation, and upholstery (El Nemr 2012).

3.4.7 Silk

Silk is a protein based natural fiber of insect origin obtained from the cocoons of the mulberry silkworm (Bombyx mori) (Nayak *et al*. 2012) (fig. 73). Other insects also produce silk, however, only silk from moth caterpillars is used for clothes manufacturing (El Nemr 2012). Utilization of silk is associated with China, and it dates back sometime between 5000 and 3000 BC (http://www.historyofclothing.com/). Some evidence suggests that Japan first domesticated silkworms for clothes production about 3,000 BC (El Nemr 2012). However, China is still considered as country of silk origin whereby the secret of silk-making transferred to Japan, Persia, and India (El Nemr 2012). Silk's main constructive components are fibroin which makes up the filament, accounting for 80 % and 20% of sericin or silk gum, which glues the filaments together (El Nemr 2012).

Fig. 73 Silk fibers
(https://www.tthme.com/?product_id=124059857_41)

The life cycle of silkworms includes four stages: egg, caterpillar, larva (cocoon), and butterfly (Jabbar and Shaker 2016) (fig. 74). Silkworms lay their eggs on special paper (El Nemr 2012). After around ten days, the eggs hatch in the incubator at 27°C (El Nemr 2012). During the growth period, caterpillars are fed with fresh mulberry leaves (Jabbar and Shaker 2016; El Nemr 2012). The hatched caterpillar, 3 mm long and 3 mg in weight, can reach up to 90 mm (El Nemr 2012). To produce 1 kg of silk, 3 000 silkworms must eat around 104 kg of mulberry leaves (El Nemr 2012). After around 35 days, caterpillars can weigh 10,000 times more than when hatched, and they are ready to spin cocoons from silk (El Nemr 2012). Silk is produced from two silk glands placed in the head of the silkworm (Jabbar and Shaker 2016). Caterpillar gradually constructs its cocoon from continuous silk strands (Jabbar and Shaker 2016). Within 2 to 3 days caterpillar can spin around 1 mile of filament (El Nemr 2012). Afterward, caterpillars are killed with heat, while some are left for the breed of the next generation of caterpillars (fig. 75) (El Nemr 2012). ,,Harvested cocoons are then soaked in boiling water to soften the sericin holding the silk fibers together in a cocoon shape. The fibers are then unwound to produce a continuous thread. ,,Since a single thread is too fine and fragile for commercial use, anywhere from three to ten strands are spun together to form a single thread of silk" (El Nemr 2012, 13). To obtain 1 kg of silk takes around 35,000 cocoons (El Nemr 2012). In order to improve the luster and softness, raw silk is boiled in water with soap (El Nemr 2012). Subsequently, the silk is treated with metallic salt solutions (El Nemr 2012). This process, called weighing, increases the density and the mass of the silk to up to 11% (El Nemr 2012). Weighing above 11% can cause silk decomposition (El Nemr 2012).

Fig. 74 Silk warm life cycle
(https://www.dreamstime.com/silk-moth-life-cycle-illustrated-vector-diagram-silk-moth-life-cycle-illustrated-vector-diagram-educational-biology-science-scheme-image168786811)

Fig. 75 Silk warm cultivation
(https://krishijagran.com/agripedia/sericulture-an-introduction-to-silk-cultivation-and-production-in-india-along-with-its-policy-initiatives/)

Major silk-producing countries are China, accounting for 54% of the world's production, and India accounting for 14% (El Nemr 2012). Together they produce around 541.000 tons of silk per year (El Nemr 2012). Because of its properties, especially softness and finesse, silk is considered a luxurious fabric, and it is highly esteemed. The main characteristic of silk fiber is a smooth and soft texture which is not slippery as with synthetic fibers (El Nemr 2012). Also, silk is more resistant to heat than wool, as it decomposes at the temperature of 170 °C (El Nemr 2012). Mold rarely attacks silk, however, if it is left dirty, it can attract insects (El Nemr 2012). Silk is sensitive to sunlight, and extensive sunlight exposure can weaken silk fabrics. It is the strongest natural fiber, however, when it is wet, it can lose up to 20 % of its strength (El Nemr 2012). Silk has very low elasticity and poor conduction of electricity (El Nemr 2012). Depending on the temperature and humidity conditions, silk shows excellent recovery from deformations (Jabbar and Shaker 2016). Great absorption property of silk makes it perfect to wear during warm summer months and activities (El Nemr 2012). Various luxurious clothes products are made from silk. Apart from clothes, silk is also used for many furnishing applications. Products such as upholstery, wall coverings, rugs, bedding, and wall hangings are made from silk. Other industrial uses of silk include production of parachutes, bicycle tires, comforter filling, and artillery gunpowder bags (El Nemr 2012).

4. Discussion

4.1 Impact of different stages of clothes production on the environment

Clothes production includes various stages, and each stage contributes to environmental degradation in some degree. Initial stages of clothes manufacturing, such as spinning and weaving, require a significant amount of energy (De Saxce *et al.* 2012) while generating solid wastes (Fletcher 2014) and emissions of particulate matter undermining the air quality (Mukherjee 2015). Wet processing involves high input of energy, water, and numerous environmentally unfriendly, non-biodegradable, and hazardous chemicals (Madhav *et al*. 2018; Munasinghe *et al.* 2021). Clothes production generates many waste streams such as liquid, gaseous and solid wastes (Bhatia 2017). ,,The nature of the waste generated depends on the type of textile facility, the processes and technologies being operated, and the types of fibers and chemicals used" (Bhatia 2017). Energy is required throughout the whole chain of textile operations (Kleinhückelkotten and Neitzke 2020). Further, high volumes of water are utilized in many stages of wet processing, from washing the fibers to bleaching, dyeing, and finishing. Fig. 76 shows the environvironmental impact of each life cycle stage of clothes, including clothes production. Further chapter will take a closer look into the various environmental effects of clothes manufacturing operations.

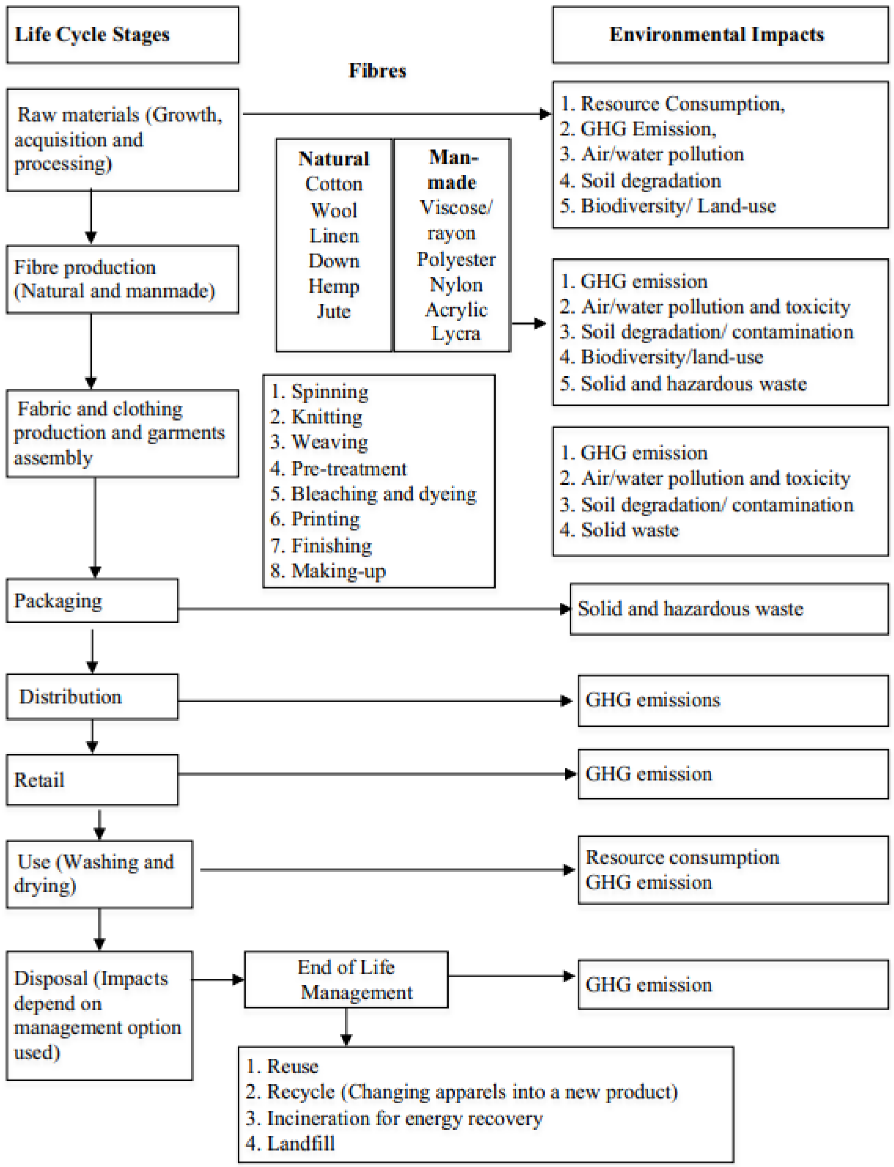


Fig. 76 Environmental impact of different life cycle stages of clothes (McGill 2009)

4.1.1 Spinning and weaving

The first step in clothes production is spinning, in which raw natural or synthetic fibers are transformed into thread or yarn. This is followed by weaving, in which yarn is woven into fabrics using looms. Spinning and weaving do not require use of water and chemicals, however, they do have negative environmental impacts. Only chemicals applied in these stages are twisting lubricants and twisting oils, which may end up in the wastewater, adding to the pollution load (Bhatia 2017). However, the main input in these stages is energy required for operating the spinning and weaving machines. Consumption of energy during spinning depends on the fiber type (natural or synthetic), yarn type (combed yarn, card yarn), yarn count, and yarn end-use (woven fabric, knit fabric) (Moazzem *et al.* 2021). Also, thermal energy is utilized for the fixation of the yarn (Moazzem *et al.* 2021). Thermal energy is usually dominant in later wet processing, mainly utilized for water heating and drying purposes, while electrical power is dominant in spinning and weaving steps (Muthu 2014). Yarn intended for weaving requires more twists and, therefore, energy than yarn for later knitting (Moazzem *et al.* 2021). Further, combed yarns also require higher energy intake due to additional step of combing (Moazzem *et al.* 2021). Regarding weaving, it consumes around 5.7–5.8 kWh/kg of electrical energy, from which 36.3% energy is used for operating the weaving machines and the rest for pre-processes, compressors, air conditioners, lighting, and cleaning (Koç and Çinçik, 2010). In general, energy consumption in weaving is higher than in knitting (Moazzem *et al.* 2021). Weaving consumes about 23% of the total share of energy, spinning accounts for 34%, chemical processing for 38%, and the remaining 5% is used for miscellaneous purposes (Muthu 2014).

Apart from energy consumption, spinning and weaving are also significant sources of dust particles which are emitted into the air during these processes, undermining the air quality (fig. 77). Emitted dust also includes traces of pesticides and soil (Shukla *et al*. 2021). Other preparation operations prior to spinning, such as cotton ginning, debaling, and combing are also sources of a particular matter. Workers employed in these facilities often face respiratory problems and diseases such as byssinosis. Coughing, wheezing, shortness of breath and tightening of the chest are typical symptoms of byssinosis (Konwar and Boruah 2020). Other diseases that might occur include dermatitis (atopic eczema), endotoxin induced effects, obstructive lung disease (e.g. asthma, bronchitis), other chronic effects (cough, dyspnoea, loss of lung function), interstitial lung diseases (e.g. follicular bronchiolitis), lung fibrosis (e.g. asbestosis), and lung cancer (e.g. lung cancer and mesothelioma) (Konwar and Boruah 2020). Further, allergic reactions and even toxic responses could occur among workers and people living close to these facilities (Muezzinoglu 1998). However, a chronic lung disease, byssinosis, is the most common and widely spread health problem throughout the entire textile industry.

Another problem is the noise pollution generated by operating spinning and weaving machines. The maximum permissible noise level should be around 96.5 dB for an 8-hour shift (Konwar and Boruah 2020). However, in the long run, continuous exposure to noise above 90 dB can cause serious damage to the eardrums and hearing problems (Konwar and Boruah 2020). Other health problems that might occur include fatigue, anxiety, reduction in efficiency, changes in the pulse rate and blood pressure, and sleep disorders (Shukla *et al.* 2021).

Fig. 77 Worker exposed to cotton dust (Jaiswal 2018)

4.1.2 Wet processing

Further step in clothes production includes wet processing, which utilizes an enormous amount of water and chemicals, resulting in emission of heavily polluted wastewaters into the environment. More than 8 000 different chemicals are used throughout various processes in the textile industry, including dying and printing (Konwar and Boruah 2020). As previously mentioned, wet processing includes various steps such as sizing, desizing, scouring, bleaching, mercerizing, dyeing, printing, and finishing. A large number of different highly toxic chemicals such as sizing, brightening, anti-creasing, sequestering, stabilizers, softening, and finishing agents are utilized during these processes (Kishor *et al*. 2021). Apart from this, many synthetic dyes such as azo, vat, direct, reactive, sulphide, acidic, and basic dyes are extensively used in dyeing and printing stages (Kishor *et al*. 2021). All of these chemicals, including dyes, end up in the wastewater, making it highly toxic and polluted. The textile industry uses ,,on average, about 1 kg of chemicals and auxiliaries per kg of finished textile" (Kleinhückelkotten and Neitzke 2020, 36). Water is used in each stage of wet processing, mainly as a medium for transportation of chemicals and for rinsing the fabrics (Toprak and Anis 2017). Further, water is also used for cooling, steam drying, and cleaning (Toprak and Anis 2017). ,,Average water spending of a medium sized textile factory producing around 8,000kg fabric/day is 1,6 million liters, approximately" (Toprak and Anis 2017, 435). Of these, 30-40% of water is utilized in dyeing process, and 60–70% in washing stage (Kishor *et al*. 2021). The amount of water used depends on the operating characteristics of the mill, equipment, and the water use policy (Verma *et al.* 2012).

4.1.3 Sizing

Sizing, the first step in wet processing, is essential process for the textiles, which will be further subject to mercerizing, dyeing, and printing. Chemicals such as carboxymethyl cellulose (CMC), polyvinyl alcohol (PVA), polyacetate, and polycyclic acids are utilized in order to strengthen the fabrics and minimize breakage, which usually end up in the wastewater, contributing to the pollution. Also, a range of additional agents are present in size preparations, such as viscosity regulators (for example sodium borate increases viscosity, while peroxysulphates decrease viscosity), antistatic agents (such as phosphoric acid esters, which are difficult to remove from the wastewater), wetting agents (they improve size penetration of the yarn), defoaming agents (they prevent the formation of foam), and preservatives (starch biocides are used to prevent degradation of sizes) (Walters *et al*. 2005). Up to 750 kg of sizing material could be present in the textile wastewaters discharged from the mill, producing 60,000 meters of fabric (Madhav *et al.* 2018).

4.1.4 Desizing

Desizing is a necessary next step in wet processing in order to remove the size from the fabrics. The presence of sizing chemicals can hinder the penetration of dyes into the fabrics and therefore impact further processes such as dyeing and printing (Babu *et al*. 2007). Desizing depends on the type of size previously applied, as some are water-soluble and can be washed out, while some require the use of chemicals. Therefore, desizing is usually accomplished either by hydrolysis (by enzymatic preparations or dilute mineral acids) or by oxidation (by sodium bromide, sodium chlorite) (Babu *et al*. 2007). In oxidative desizing, hydrogen peroxide is utilized with sodium hydroxide, surfactants, and stabilizers (Walters *et al.* 2005). One of the main problems in the textile industry is that different stages of textile processing are not performed in the same mill. Thus, often sizing and desizing are performed at different mills. The lack of information on which size chemicals were applied at the fabrics poses difficulty for further textile processing, and requires the use of heavy chemicals in order to ensure that the remains of the sizing chemicals are properly removed from the fabrics. Desizing can contribute up to 50% of the total amount of wastewater (Madhav *et al*. 2018). It increases chemical oxygen demand (COD) and biological oxygen demand (COD) of the wastewaters (Toprak and Anis 2017; Walters *et al.* 2005), which further has a negative impact on the aquatic life of the receiving water bodies.

4.1.5 Scouring

Scouring is the cleaning step in which impurities such as waxes, fats, oils, surfactants, pectins, and proteins are removed from the fabrics using hot alkali solution, most commonly sodium hydroxide, and other alkali agents such as glycerol, ethers, sodium hydroxide, detergent, or soap. „Scouring can be performed in batch or continuous processes, which contributes major organic loads to textile effluents that are accumulated from the use of sodium hydroxide (NaOH), disinfectants, detergents, insecticide residues, pectin, fats, oils, wax, spin finishes, knitting lubricants, and spent solvents" (Madhav *et al.* 2018, 33). The wastewater from the scouring process has very high alkalinity values, ranging from 10 to 11, with high values of total dissolved solids (TDS), chemical oxygen demand (COD), and biological oxygen demand (BOD) (Sarayu & Sandhya, 2012; Toprak and Anis 2017).

4.1.6 Bleaching

In bleaching, natural coloration and impurities are removed from the fabrics to achieve their brightness. Chemicals such as sodium hypochlorite and hydrogen peroxide are utilized in this process (Khan and Malik 2014). „Bleaching with sodium hypochlorite causes a number of subsidiary reactions leading to the production of a range of AOX (absorbableorganic halogens) including trichloromethane (Lacasse and Baumann 2004) and dioxin precursors (Stringer and Johnston 2001)" (Walters *et al.* 2005, 13). A safer alternative to sodium hypochlorite is sodium chlorite (NaClO2), as lower levels of AOX are produced (Walters *et al.* 2005). However, over the last decade, sodium hypochlorite and chloride have been replaced with other agents such as hydrogen peroxide (H2O2) (Toprak and Anis 2017) and peracetic acid (CH3CO3H) (Babu *et al.* 2007). Even though hydrogen peroxide (H2O2) is considered as environmentally friendly alternative, it has to be used with phosphate-based stabilizers, which increases the COD and TOC of the wastewaters (Toprak and Anis 2017). The advantage of peracetic acid (CH3CO3H) is that it decomposes to only oxygen and acetic acid, which is completely biodegradable (Babu *et al.* 2007). With peracetic acid (CH3CO3H), higher brightness values with less fiber damage can be achieved (Rott and Minke 1999). Bleaching of polyamides with hydrogen peroxide (H2O2) is not possible as it damages the fibers, instead, reductive dyeing with sodium hydrosulphite is utilized (Walters *et al.* 2005). However, sodium hydrosulphite is also considered as very toxic chemical and an irritant (Walters *et al.* 2005). Further, alkyl phenol ethoxylates (APEOs) are largely utilized in bleaching stage as detergent and wetting agents (Toprak and Anis 2017). They are hormone-disruptive, nonbiodegradable, and challenging to remove from the wastewaters (Toprak and Anis 2017). Apart from water pollution, bleaching can also contribute to air pollution as chlorinated organic gases could be generated during the process (Muezzinoglu 1998).

4.1.7 Mercerization

In mercerization, usually, cotton fibers are treated with hot or cold caustic soda (NaOH) in order to improve their properties such as luster, strength, and dye uptake (Madhav *et al*. 2018; Kishor *et al*. 2021). After treatment, fabrics are washed, and most of caustic soda (NaOH) can be recovered from the wash water with membrane techniques (Babu *et al*. 2007). If the wastewater from the mercerization is discharged, it requires neutralization, which leads to the formation of large quantities of salt (Walters *et al.* 2005). Utilization of ZnCl2 is an alternative for increment of the weight and dye uptake of the fabrics, with lower environmental impact as it does not require neutralization by acetic or formic acid, therefore, there is no formation of salts (Babu *et al*. 2007).

4.1.8 Dyeing

In dyeing process, fibers or fabrics are brought into contact with dye solutions containing also a variety of other chemicals (salts, acids) and dyeing auxiliaries (surfactants, dispersing agents, levelling agents) in order to provide color (Bhatia 2017). The type and the amount of dyes, chemicals, and auxiliaries applied depends on the product quality and the type of installed machinery (Bhatia 2017). Dyeing requires a significant amount of water, used for dissolution and transportation of dyes and other chemicals to the fabrics, for heating the treatment baths, and later for rinsing step. Depending on the used type of dye, dyeing can require up to 30-50 liters of water to dye one kilogram of fabric (Toprak and Anis 2017). Approximately 35% of chemicals released into the environment are the result of the dyeing process (Thiry 2011). Dyeing with rinsing is the major source of wastewater generation (Kishor *et al*. 2021). Estimates show that textile dyeing accounts for 20% of freshwater pollution (Kalliala and Talvenmaa 2000). Dyeing also requires a certain amount of energy, depending on the applied dyeing technology. For dyeing energy consumption is 6.0–17.0 GJ, while for jet dyeing 3.5–16.0 GJ for the production of one ton of material output (Moazzem *et al*. 2021).

Even though natural dyes are environment friendly, they are not that common in the textile industry, instead, synthetic dyes are extensively used. Due to their complex and stable structure, they are resistant to microbiological degradation and have hazardous effects on the environment and living organisms (Kishor *et al*. 2021). Form 7 × 107 tons of synthetic dyes produced annually worldwide, over 10,000 tons are utilized in the textile industry (Chandanshive *et al*. 2020). Azo dyes are the most extensively used of different classes of dyes, accounting for 80% of the total dyes used in the textile industry (Kishor *et al*. 2021). From 60 to 70 % of azo dyes have a carcinogenic and toxic effect and are non-biodegradable due to their chemical structure (Benkhaya *et al*. 2020; Berradi *et al*. 2019). Apart from them, reactive dyes are also widely used in the textile industry because of their variety in color, high wet fastness profiles, easy application, brilliant colors, and low energy consumption (Wang *et al*. 2009). Around 80,000 tons of reactive dyes are manufactured and utilized every year (Babu *et al*. 2007).

Once dyeing is complete, the wastewater is mostly discharged into the aquatic environment such as lakes, rivers, streams, and ponds without previous treatment. „The concentration of the dyes in textile wastewater may vary from 10 to 250 mg L-1, while others have reported concentrations as high as 1500 mg L-1" (Imran *et al*. 2015). Due to their high solubility in water, dyes are difficult to remove by conventional methods (Hassan and Carr 2018). Wastewater from the dyeing process is heavily polluted and colored, containing residues of dyes, among other chemicals, as dyes do not bind to the fabric and are often discharged alongside with wastewater posing a serious ecotoxicological threat to the aquatic environment and living organisms (fig. 78). During dyeing with azo dyes, up to 15-50% of the azo dyes do not bind to the fabrics and are lost to the effluent (Rehman *et al*. 2018). In dyeing with reactive dyes, 20-30% of reactive dyes are released with wastewater (Madhav *et al*. 2018). Regarding direct dyes, only about 80% are retained by the fabrics, and the rest is flushed out from the garment (Mukherjee 2015).

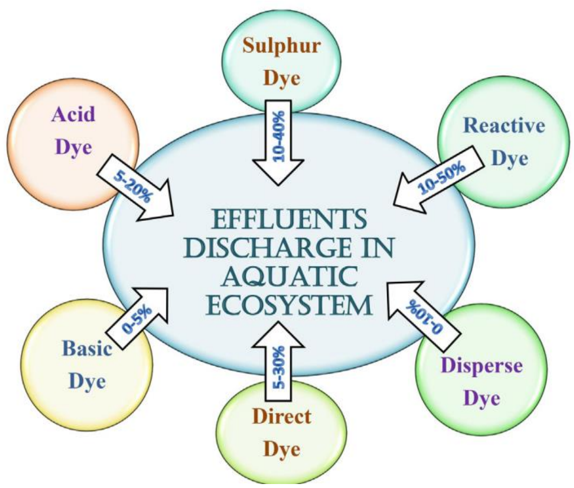


Fig. 78 Percentage of the different dyes lost to the effluent during dyeing process (Sharma *et al.* 2021)

It is estimated that each year around 200,000 tons of textile dyes worth 1 billion dollars are lost to the effluents due to inadequate dyeing processes (Ellen MacArthur Foundation 2017). Without proper treatment or purification, present dyes in the effluent discharged from the dyeing process can pose a serious problem and damage the quality of the receiving aquatic environment (Sharma *et al*. 2021). Apart from being highly colored and containing various hazardous chemicals, such wastewater also has a variable pH, increased biological oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), and suspended solids (Al-Tohamy *et al*. 2022). The dye houses usually discharge two types of wastewater, form the dye bath and wash/rinse wastewater. Discharged wastewater from the dye bath of a typical textile factory usually has values of chemical oxygen demand (COD) 5000–6000, total dissolved solids (TDS) 52,000, suspended solids 2,000 mg L-1, and pH 9 (Khan and Malik 2014). Regarding wash water, utilized for rinsing off the remaining dyes from the fabrics, it usually has values of chemical oxygen demand (COD) 400-860, total solids 4,000, total dissolved solids (TDS) 3,200 mg L-1, and pH 8 (Khan and Malik 2014). These wastewaters have a significant negative impact on the aquatic environment as they can alter the equilibrium, cause eutrophication, turbidity and fouling smells, impair photosynthesis, inhibit plant growth, enter the food chain, encourage bioaccumulation, and promote toxicity, mutagenicity, and carcinogenicity (Berradi *et al*. 2019; Lellis *et al*. 2019). Apart from degrading aesthetic quality of the receiving water bodies, such wastewater also increases chemical oxygen demand (COD) and biological oxygen demand (BOD) levels and prevents the penetration of sunlight which further reduces the rate of photosynthesis, affecting the entire aquatic biota (Lellis *et al*. 2019).

Besides dyes, this stage of clothes processing also utilizes a variety of other auxiliary chemicals in order to improve the attachment of dyes to the fabrics (Kishor *et al.* 2021). One of the problems is that organic substances or dyeing auxiliaries added during dyeing process cannot be recycled, hence, their presence in the wastewater contributes to the higher biological oxygen demand (BOD) and chemical oxygen demand (COD) (Babu *et al*. 2007). Heavy metals such as mercury, chromium, cadmium, lead, arsenic, copper, zinc, cobalt, nickel, and manganese are often associated with dye fixatives and dyes, as they are required for their production (Singha *et al.* 2021; Madhav *et al*. 2018). These heavy metals usually end up in the wastewater, further being transported to long distances (Kishor *et al.* 2021). Because of their biodegradation resistance, they are extremely dangerous and have a tendency for bioaccumulation (Toprak and Anis 2017). They can stay in the environment for a very long period of time, posing a severe health hazard for living organisms due to their cancerogenic, mutagenic, and toxic effects. From 4000 investigated dyes, more than 1000 showed toxicity, which are still available on the market and utilized by the textile industry (Lacasse and Baumann 2012). Textile dyes have been associated with various human diseases (Al-Tohamy *et al.* 2022). Workers who handle dyes are especially exposed and endangered. Usually, pathways of exposure to textile dyes include oral ingestion, inhalation, or direct skin contact (Al-Tohamy *et al.* 2022). They can cause skin and lung irritation, headaches, congenital malformations, and nausea (Madhav *et al*. 2018). Further, exposure to textile dyes can lead to allergic reactions such as contact dermatitis, allergic conjunctivitis, rhinitis, and occupational asthma (Hunger 2003). Apart from heavy metals, other chemicals such as salts, surfactants, organic processing aids, sulfide, and formaldehyde are commonly used in order to improve dye uptake (Khan and Malik 2014). Besides dyes, they are also the key contaminants in the wastewater, largely contributing the heavy water pollution. Formaldehyde is also often used in the production of stabilizers in the reactive and direct dyeing and for dispersants in the vat and disperse dyeing (Toprak and Anis 2017). Apart from causing skin irritations and affecting the respiratory system, it is suspected that it also has carcinogenic effects (Toprak and Anis 2017; Mukherjee 2015). Alkyl phenol ethoxylates (APEOs), such as nonylphenol ethoxylates and octylphenol ethoxylates, are utilized as wetting agents and as detergents in dye houses (Madhav *et al*. 2018). These chemicals are hazardous for aquatic life due to their hormone disruptive properties (Madhav *et al*. 2018). Furter, dioxins are also commonly used in the dyeing process, which are carcinogenic and hormon disruptive substances (Mukherjee 2015). Urea is frequently utilized in reactive dyeing, which adds to a heavy pollution load (Babu *et al*. 2007). Urea could be substituted with chemicals such as glycerin, cellosolve, sorbitol, polycarboxylic acid, PEG-200, and PEG-

4000 (Babu *et al*. 2007). Sodium chloride/sulphate used in direct and reactive cotton dyeing as an exhausting agent poses a particular problem, as it cannot be eliminated from the effluent (Toprak and Anis 2017). The only way to deal with this problem is to dilute the wastewater (Toprak and Anis 2017). Apart from this, during dyeing process, various volatile agents are released into the atmosphere, which are harmful to human health (Rukhaya et al. 2021).

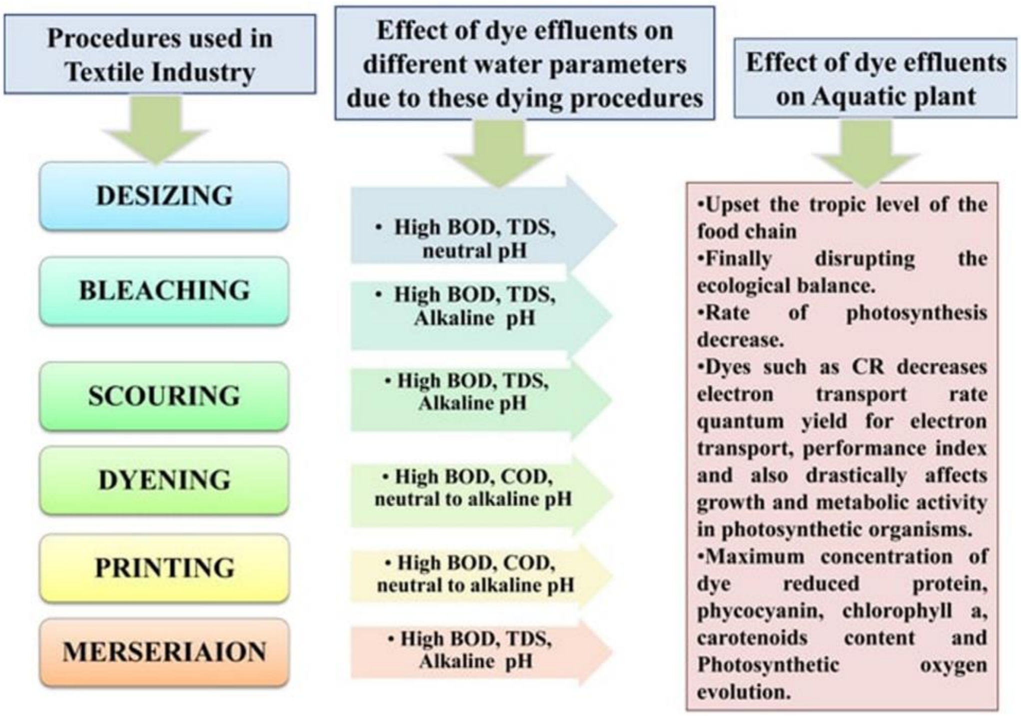


Fig. 79 Effect of dye effluents on different water parameter and aquatic plants (Sharma *et al.* 2021)

4.1.9 Printing

In printing, dye is applied in the form of a thick paste, usually on selected parts of the fabric (Madhav *et al*. 2018). Besides application of dyes, the printing stage also involves utilization of other various chemicals such as phthalates, metals, solvents, formaldehyde, and urea (Kishor *et al*. 2021), which contribute to the wastewater pollution load. The printing stage, alongside with bleaching, scouring, and finishing processes can generate a vast amount of wastewater, from 1 to 10 million liters per day (Kishor *et al*. 2021).

4.1.10 Finishing

Finishing, the final stage of wet processing, involves application of various chemicals in order to provide certain properties to the fabrics, such as stain proofing, softening, waterproofing, flame retardance, and protection from microbial activities (Kishor *et al*. 2021). Biocides, synthetic organic or inorganic chemicals are most commonly utilized during this stage (Kishor *et al*. 2021). Biocides used for disinfection, sanitization, sterilization and preservation of materials from microbiological degradation are linked with toxicity in dye house wastewaters (Madhav *et al.* 2018). Further, formaldehyde is often used as a fixing agent, softener, and cross-linking resin (Toprak and Anis 2017). It is considered as dangerous substance as long term and frequent exposure can lead to leukemia, lung and brain cancer (Shukla *et al.* 2021). Perfluoroalkyl chains are utilized in this stage in order to provide oil stain resistance to the fabrics (Sharma 2012). Their degradation leads to the formation of perfluoro octane sulphonate (PFOS) and perfluorooctanoic acid (PFOA), which are persistent, bioaccumulative and show toxicological properties to living organisms (Toprak and Anis 2017; Kant 2012). Further, many other finishing chemicals, such as polybrominated diphenyl ethers (PBDEs) used for providing flame-retardant properties to the fabrics, are toxic to humans (Saxena *et al*. 2017). Table 35 summarizes effluent characteristics from different wet processing stages and table 36 water consumption and organic load.

Processes	Possible pollutants	Nature of effluent (from finishing processes of cotton fabric)						
		COD (gO_2/l) Usage	BOD (gO_2/l)	TS (g/l)	TDS (g/l)	pH	Color (ADMI)	Water
Desizing	Starch, glucose, PVA, resins, fats, waxes	4.6-5.9	1.7-5.2	16-32	-	-	-	9-Mar
Scouring	Caustic soda, waxes, soda ash, sodium silicate and fragments of cloth	8	0.1-2.9	7.6-17.4	-	13-Oct	694	26-43
Bleaching	Hypochlorite, chlorine, caustic soda, hydrogen peroxide, acids	6.7-13.5	0.1-1.7	2.3-14.4	4.8-19.5	8.5-9.6	153	3-124
Mercerising	Caustic soda	1.6	0.05-0.1	0.6-1.9	4.3-4.6	5.5-9.5	-	232-308
Dyeing	Dye stuff, mordant and reducing agents like sulphides, acetic acids and soap	1.1-4.6	0.01-1.8	0.5-14.1	0.05	10-May	1450-4750	8-300

Table. 35 Characteristics of effluent from different textile wet processing stages (Toprak and Anis 2017)

Operation/ process	Water consumption (% from total consumption of the textile plant)			Organic load (% from total organic load of the textile plant)		
	Minimum	Medium	Maximum	Minimum	Medium	Maximum
General facilities	6	14	33	0.1	2	8
Preparation	16	36	54	45	61	77
Dyeing	4	29	53	4	23	47
Printing	42	55	38	42	59	75
Wetting	0.3	0.4	0.6	0	0.1	0.1
Fabric washing	3	28	52	1	13	25
Finishing	0.3	2	4	0.1	3	7

Table. 36 Water consumption and organic loads in different textile wet processing stages (Toprak and Anis 2017)

4.1.11 Garment construction, packing, and distribution

Garment production is the last stage, in which clothes are assembled from previously processed fabrics. Cutting, sewing, assembly, embellishments, and ironing are the common steps in this stage (Munasinghe et al. 2021). As it does not require the use of chemicals, the only input during clothes assembling is the energy required for operating the sewing, gluing, welding, and seam taping equipment (Šajn 2019). Around 2.472 MJ of energy is consumed during clothes production, from which 49.8 % is utilized in sewing, 29.6 % in cutting, and 20.6 % in packing (Toprak and Anis 2017). This stage of clothes production is mainly characterized by waste generation. The waste is produced during the cutting phase due to mistakes made in garment assembling (Niinimäki *et al*. 2020). Estimates show that around 15% of the fabrics utilized in the garment construction are going to be wasted (Cooklin 1997). This percentage varies and depends on garment type, design to fabric width, and fabric-surface design (Niinimäki *et al*. 2020). Aside from also contributing to generation of waste, packing does not have other negative environmental impacts. In most cases, packing substances are produced from petroleum-based and non-degradable materials, with a very short life span, ending up usually in landfills. Recently, increased attention has been given to packing activities. It faced stricter rules and regulations regarding used materials, reuse, and recycling. For instance, Directive 94/62/EC on "Packing and Packaging Waste" which regulates packing in the EU, has introduced and forced a series of stricter rules and regulations for packaging activities and related wastages (Toprak and Anis 2017). More and more brands are seeking for solution to reduce carbon footprint and other negative environmental impacts related to packing through use of environmentally friendly, natural, recyclable, or biodegradable materials produced without any use of chemicals such as pesticides. After production, the clothes are distributed to the fashion stores for their purchase. Transportation and clothes distribution requires a significant amount of energy (Moazzem *et al*. 2021), contributing to GHG emissions and climate changes. Fig. 80 shows the main environmental impacts of different stages of clothes production, and table 37 summarizes emissions and wastes generated during clothes manufacturing.

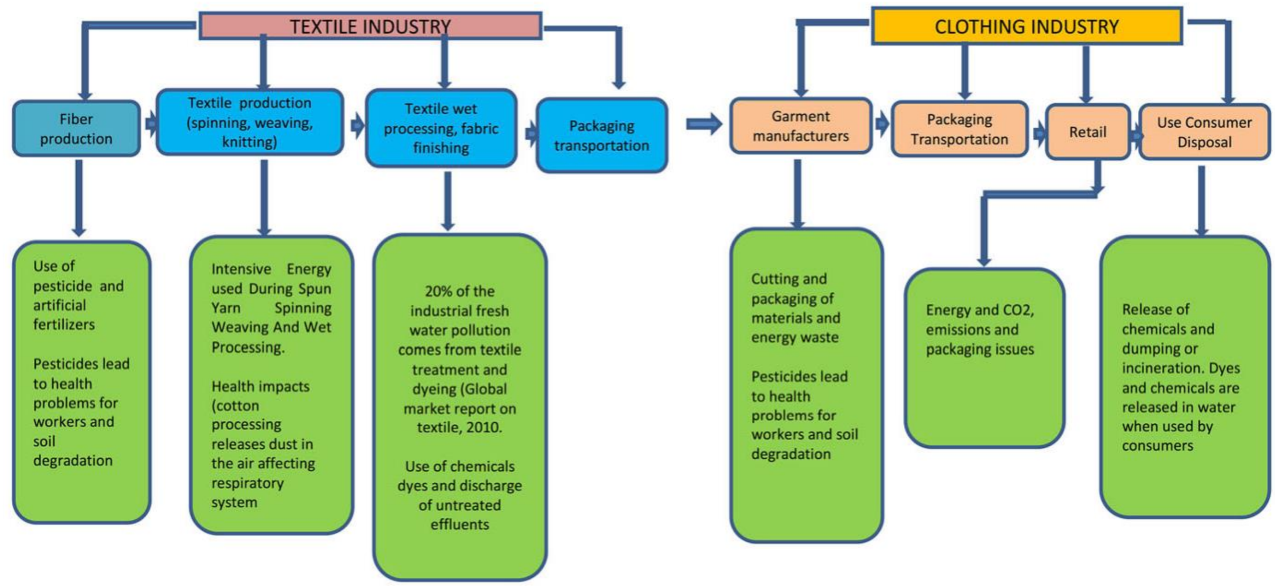


Fig. 80 Summary of environmental impacts of textile and clothes industry (Desore and Sapna 2018)

Process	Emission	Waste Water	Solid Waste
Fiber preparation	Little or none	Little or none	Fiber waste and packaging waste
Yarn Spinning	VOCs	Little or none	Packaging wastes, sized yarn, fiber waste, cleaning and processing waste
Slashing/sizing	VOCs	BOD, COD, metals, cleaning waste, size	Packaging waste, cleaning waste, fiber lint, yarn waste, size unused starch based size
Weaving	Little or none	Little or none	Packaging waste, yarn and fabric scraps, off-spec fabric, used oil
Knitting	Little or none	Little or none	Yarn and fabric scrap, and packaging waste, off spec fabric
Tufting	Little or none	Little or none	Packaging waste, cleaning waste, fiber lint, yarn waste, off spec fabric
Desizing	VOCs from glycol ether	BOD from sizes lubricants, biocides, antistatic compounds	Packaging waste, fiber lint, yarn waste, cleaning and maintenance materials
Scoring	VOCs from glycol ethers and scoring solvents	Disinfectant, insecticide residues, detergents, oils, NaOH, knitting lubricant, spin finishes, spent	Little or none
Bleaching	Little or none	H2O2 , stabilizers, high pH	Little or none

Singeing	Small amounts of exhaust gases from the burners	Little or none	Little or none
Mercerising	Little or none	High pH, NaOH	Little or none
Heat setting	Volatilization of spin finish agents synthetic fiber manufacture	Little or none	Little or none
Dying	VOCs	Metals, salt, surfactants, organic processing assistants, cationic materials, color, BOD, COD, sulphide, acidity/ alkalinity, spent solvents	Little or none
Printing	Solvents, acetic acid drying and curing oven emissions combustion, gases	Suspended solids, urea solvents, color, metals, heat, foam, BOD	Little or none
Finishing	VOCs, contaminants in purchased chemicals, formaldehyde vapors, combustion gases	COD, suspended solids, spent solvents, toxic materials	Fabric scraps and trimmings, packaging waste

Table 37 Summary of wastes generated during clothes manufacturing (Toprak and Anis 2017; Parvathi *et al*. 2009)

4.2 Impact of the textile and fast fashion industry on the environment

The fast fashion and textile industries are considered as the second most polluting industries in the world, right after the oil industry (Fletcher 2013). They represent important sectors contributing to the global economy, however, their impact on natural resources and environmental footprint are very high and intensive. Clothes, throughout their entire life cycle, such as fiber extraction, clothes production, utilization and finally, disposal, generate potential environmental and occupational hazards leaving various environmental consequences. The fast fashion industry uses vast amounts of water, land, fossil fuels, energy, chemicals, and raw materials, which contributes to the severe pressure on already scarce, endangered, and limited natural resources. Further, toxic and hazardous chemicals utilized during the production stage heavily pollute the environment, especially freshwater resources. Fast fashion lies on a linear business model, which follows the pattern take from nature, produce, and dispose, while creating great pollution at each stage and degrading the environment. The fast fashion business model is related with environmental problems such as GHG emissions and climate change, acidification, eutrophication, resource depletion, heavy freshwater and air pollution, agricultural land occupation, intense freshwater consumption, waste generation, human and environmental toxicity (Moazzem *et al*. 2021; Muthu, 2020). All of these mentioned environmental consequences, depending on the level of the environmental impact, can be divided into:

1. Global environmental impacts- include GHG emissions, which further contribute to global climate changes. GHG emissions are emitted mainly during clothes production but also

after disposal at the landfills. Second, ozone depletion, due to the utilization of certain chemicals, such as fluoro-chlorine-hydrocarbons and chlorinated hydrocarbons. They are still used in the textile industry in some countries.

2. Regional environmental impacts- eutrophication, acidification, freshwater consumption, land use, utilization of toxic chemicals and related environmental pollution.
3. Local environmental impacts- generation of local landfills, local air pollution and generation of noise and vibrations during clothes production, contamination of the work environment. (Lazić and Popović 2009)

The fig. 81 shows planetary boundaries. It becomes clear that our planet is already facing with enormous pressures on natural resources due to anthropogenic activity (Eder-Hansen *et al*. 2017), including fast fashion and textile industries as partial contributors. Climate change, waste pollution, changes in land use, and biochemical output have already crossed their safe lines (Eder-Hansen *et al*. 2017). By 2030, water use will increase by 50%, which is additional 39 billion cubic meters of water consumed annually by the fast fashion industry (fig. 82) (United Nations Report 2015; Lenzing 2016). If the pressure on water resources continues, the fashion industry and cotton-growing nations may face with water scarcity choosing between cotton production and securing clean drinking water (Eder-Hansen *et al.* 2017). Further, „the level of atmospheric CO2 already today exceeds by about 20% what is considered safe" (Eder-Hansen *et al*. 2017, 11). The generation of waste is expected to increase by around 60% by 2030, which is additional 57 million tons of waste generated annually (fig. 82) (Eder-Hansen *et al*. 2017). „The area of forested land has been exceeded the safe operating space by 17%" (Eder-Hansen *et al.* 2017, 15). It is estimated that by 2030, the fashion industry will use 35% more land for cotton cultivation, forests for the production of cellulosic fibers and grasslands for livestock such as sheep for the production of wool, which is additional 115 million hectares of land (Eder-Hansen *et al*. 2017). The following chapter will take a closer look into environmental impacts of fast fashion on each environmental element such as water, air, and soil resources.

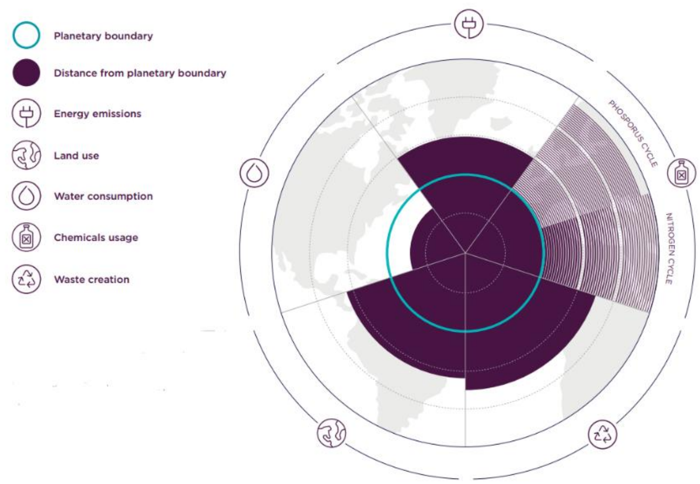


Fig. 81 Planetary boundaries (Eder-Hansen *et al.* 2017)

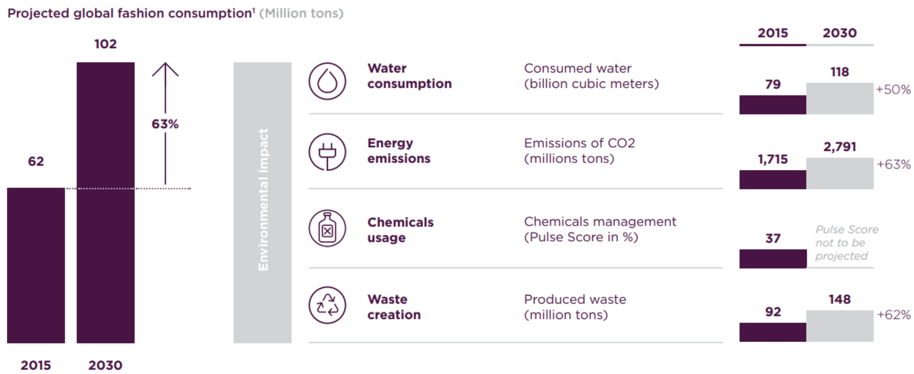


Fig. 82 Projection of global fashion consumption regarding water and chemical use, energy emissions and waste generation by 2030 (Eder-Hansen *et al.* 2017)

4.2.1 Impact on freshwater resources, aquatic life, and human health

Water resources are particularly vulnerable towards fast fashion and textile industries and largely impacted by their various operations. As mentioned before, fast fashion utilizes enormous amounts of water throughout every stage of a clothes life cycle, such as fiber production (mainly for cotton cultivation), clothes manufacturing (especially during wet processing), and later during the clothes utilization stage (for washing and maintenance). Fast fashion is the second largest consumer and polluter of freshwater resources, right after agriculture (Oecotextiles 2012). It is responsible for around 20% of global industrial water pollution (Kant 2012). Global fast fashion and textile industries consume approximately 93 billion cubic meters of water every year, which accounts for about 4% of the global freshwater withdrawal (Ellen MacArthur Foundation 2017). Further, they are responsible for around 7% of the local groundwater and drinking water losses caused by global fast fashion water utilization (Niinimäki *et al*. 2020). Production of raw materials such as cotton and clothes manufacturing, especially wet processing stage, require extensive amounts of water, mainly used as a medium. Water is utilized for dissolving various chemicals and dyes, as a means of transport, washing-off agent, and generation of steam for heating the process baths (Madhav *et al*. 2018). The amount of required water varies depending on the type of utilized dyes and chemicals, the nature of the substance being processed, and applied technology (Madhav *et al*. 2018). Usually, around 200 liters of water is required for the production of 1 kg of fabric (Mukherjee 2015). Unfortunately, water in textile processing is often unreasonably wasted. Some of the common routes of water wastage include:

- ,,Excessive use of water in washing
- Poor housekeeping measures such as broken or missing valves
- Unattended leaks through pipes and hoses
- Instances when cooling waters are left running even after shutdown of the machinery

- Use of inefficient washing equipment
- Excessively long washing cycles
- Use of fresh water at all points of water use" (Chowdhury 2014, 9)

The reutilization of wastewater is crucial and can largely contribute to reduction of water, energy, and chemical input (Chowdhury 2014). Reusing steam condensate and cooling water is especially feasible, as these waters are clean, and investment in recovering their thermal energy can pay back very quickly (Chowdhury 2014). Thus, water reuse is becoming more prevalent, as it decreases production costs through reduced charge of purchased water and wastewater treating and avoidance of discharging infringement (Toprak and Anis 2017). Water conservation also contributes to reduction of thermal and electrical energy consumption (Toprak and Anis 2017).

Apart from water utilization, the fast fashion industry also uses a significant amount of chemicals and dyes throughout clothes production operations, mainly dyeing and finishing. Fast fashion and textile industries are considered as one of the most intensive industries in terms of chemical use (Toprak and Anis 2017), utilizing around 15,000 different chemicals during clothes manufacturing (Roos *et al*. 2019), or about 25 % of the total global chemical production (Khandare and Govindwar 2015). According to Swedish Chemical Agency (2014), around 3.500 highly toxic chemicals are utilized by the fast fashion industry during clothes production. From these, about 1.000 are registered under Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) (Swedish Chemical Agency 2014). Approximately 10% of them are potentially toxic for human health and wellbeing, and 5% are determined as highly toxic for the environment (Swedish Chemical Agency 2014). Around 42 million tons of chemicals and one million tons of dyes are used by global fast fashion industry every year (Liu *et al*. 2021).

The result of water utilization during clothes processing stages is a discharge of an equal amount of heavily polluted wastewater, usually in the aquatic environment. Considering the composition and volume of generated wastewater, textile effluent is recognized as the most polluting agent of aquatic resources in the entire industrial sector (Mansour *et al*. 2012). Every year, approximately 53 billion gallons of wastewaters are discharged into aquatic resources from textile operating mills (Chen *et al*. 2006). Various chemicals used in the production stage are transferred into the textile effluent, making it highly toxic for the aquatic receiving environment. Usually, ,,a single European textile-finishing company uses over 466 g of chemicals per kg of textile, including sizing agents, pretreatment auxiliaries, dyestuff, pigments, dyeing auxiliaries, final finishing auxiliaries and basic chemicals" (Niinimäki *et al*. 2020, 193).

Wastewater from textile operations is extremely heterogeneous, as it contains a complex mixture of different chemicals varying in quantity and quality (Madhav *et al*. 2018; Khan and Malik 2014). The composition and toxicity of textile effluent distinctly vary among facilities, depending on which chemicals were utilized during the processing and the adopted processes (Mukherjee 2015; Kishor *et al.* 2021). Usually, textile effluent contains around 72 different types of highly toxic pollutants, of which around 30 pollutants are resistant to microbial degradation, posing serious environmental and health hazards (Khandare 2015). A typical textile facility usually generates around 200-350 cubic meters of wastewater per ton of finished product (Khan and Malik

2014). Wastewaters from textile operations are characterized with high dye content, organic loads, biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), total organic carbon (TOC), ph level and low biodegradability (Kishor *et al*. 2021; Khan and Malik 2014) (table 38). In general, these effluents are very hot and alkaline, with a strong smell and color (Shaikh 2009). They represent a very complex matrix containing a variety of highly toxic and hazardous pollutants such as persistent coloring pollutants (dyes), phosphates, sulfates, sulfides, nitrates, chlorides, formaldehyde, phthalates, phenols, surfactants, perfluorooctanoic acid (PFOA), pentachlorophenol, fats, grease and various heavy metals (Kishor *et al*. 2021; Toprak and Anis 2017). Besides this, such wastewaters also have high loads of salts, alkalis, acids, mordants, binders, dispersants, volatile organic compounds (VOCs), chlorobenzenes, reducing agents, dioxins, detergents, bleaching, fixing, and finishing agents, alongside with high electrical conductivity, turbidity, and alkalinity (Kishor *et al*. 2021). High ph value and level of biological oxygen demand (BOD) and chemical oxygen demand (COD), suspended solids (SS), oils, nitrogen, phosphorus, sulphates, dyes and with them associated heavy metals pose a special concern (Toprak and Anis 2017).

Parameters	Value
pH	5.1-12
TSS	18-270 mg/l
TDS	2100-12260 mg/l
COD	200-3505 mg/l
Conductivity	15.78 mS/cm
Chlorides	1240-3761 mg/l

Table 38 Typical values of textile wastewater (Korbhati *et al*. 2008)

The presence of heavy metals such as chromium (Cr), cadmium (Cd), lead (Pb), antimony (Sb), arsenic (As), copper (Cu), nickel (Ni), zinc (Zn), mercury (Hg), silver (Ag), tin (Sn), titanium (Ti), and cobalt (Co) (Al-Tohamy *et al.* 2022; Chowdhury 2014) makes the effluent highly toxic to aquatic environment and organisms, alongside with other previously mentioned chemicals. Such wastewater requires sufficient treatment before disposal into aquatic environment in order to protect public health and water resources. However, textile effluent is highly challenging to treat due to its heterogeneity, persistence, and low biodegradability. As clothes production is conducted in developing countries, often in small-scale facilities which lack the financial resources to purchase and operate expensive equipment for adequate effluent treatment, it is usually discharged directly into water resources, such as rivers and lakes, polluting and degrading their quality (Madhav et al. 2018). Even when the wastewater is treated and seems clean as hazardous pollutants such as dyes, salts, heavy metals, and other toxic chemicals are removed, another problem is effluent's high temperature, which is extremely damaging for aquatic life (Mukherjee 2015; Kant 2012) as it reduces levels of dissolved oxygen concentrations in the water.

If wastewaters are discharged directly into aquatic resources before their previous treatment, which is usually the case, they can pose a serious environmental threat and largely impact aquatic life and water quality (fig. 83). One of the main problems is the presence of synthetic dyes in effluents associated with dyeing and printing stages. Textile and fast fashion industries utilize around 1.3 million tons of synthetic dyes and pigments (Konwar and Boruah 2020). Estimated show that usually, around 15 % of dyes are expected to vanish in the textile's wastewaters (Sharma *et al.* 2021). However, this is largely impacted by dye class utilization, so depending on which dyes were used in the process, dye losses could range from 2% regarding basic dyes to 50% with reactive dyes (O'Neill et al. 1999). Globally, approximately 280,000 tons of different dyes are discharged into aquatic resources from textile and fast fashion industries (Cao *et al*. 2019). Apart from this, in Europe alone, about 1,000,000 tons of salts are dumped into water bodies every year (Mukherjee 2015). The problem is that due to their high solubility in water, dyes cannot be removed from the effluent by conventional treatment methods (Lellis *et al*. 2019).

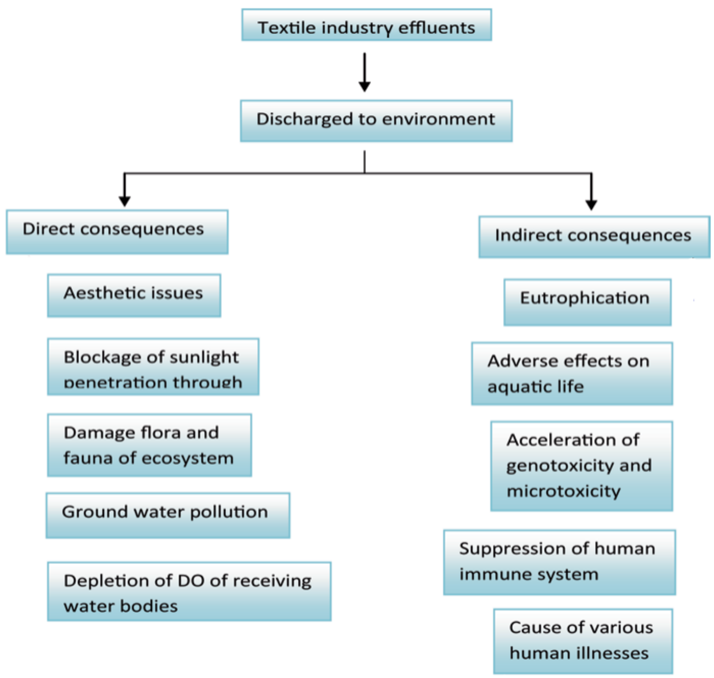


Fig. 83 Direct and indirect consequences of discharge of textile effluent into freshwater resources (Khan and Malik 2014)

„Dyes can be visible in water at concentrations as low as 1 ppm" (Denzil *et al*. 2019). Apart from causing coloration of receiving water bodies and degrading their aesthetic quality, the presence of dyes in water bodies also interferes with light transmission and blocks penetration of sunlight from entering the photic zone of the aquatic environment (Al-Tohamy *et al*. 2022). The consequence is reduced photosynthesis activity of aquatic flora which further disrupts the natural balance, affecting the entire aquatic ecosystem (Al-Tohamy *et al*. 2022). Besides altering the absorption and reflection rate of sunlight, dyes also deplete oxygen concentrations, which is an essential element for aquatic life (Sharma *et al.* 2021; Khan and Malik 2014). Further, dyes have a negative impact on certain parameters of algal growth, including pigment, protein, and other nutrients (Al-Tohamy *et al*. 2022). Microalgae play a significant role as primary producers in the aquatic environment. They are very sensitive to even the slightest environmental changes and pollution, and have a short life span (Sharma *et al.* 2021). The presence of various dyes in the water bodies can obstruct microalgal growth and disturb the trophic transmission of energy and nutrients within aquatic ecosystems (Al-Tohamy *et al*. 2022). Many dyes and their decomposition derivatives are highly toxic to aquatic life (Khan and Malik 2014). Dyes can convert into toxic by-products, usually under anaerobic conditions (Khan and Malik 2014). Dyes have been associated with allergic reactions, carcinogenic, genotoxic, mutagenic, and cytotoxic effects (Khandare and Govindwar 2015). Ingested by fish and other living organisms, dyes convert into toxic intermediates during metabolization, which further has a negative impact on fish, including their predators (Elgarahy *et al.* 2021). Also, intestinal microflora in the human gut converts dyes into toxic amino acids, impacting human health (Al-Tohamy *et al*. 2022). Textile dyes can cause various human diseases, from dermatitis to problems with the central nervous system (Al-Tohamy *et al*. 2022). Due to their persistence and non-degradable nature, dyes tend to accumulate in fish, algae and sediment, providing biomagnification across the entire food chain so that organisms at the higher trophic level show greater concentrations compared with their prey (Lellis *et al.* 2019). Fish and other organisms represent an essential source of protein for humans. However, the pollution of aquatic resources can result in the restriction and decline in available fish stock. Consumption of contaminated fish with dyes can cause symptoms such as cramps, fever, and hypertension (Al-Tohamy *et al*. 2022).

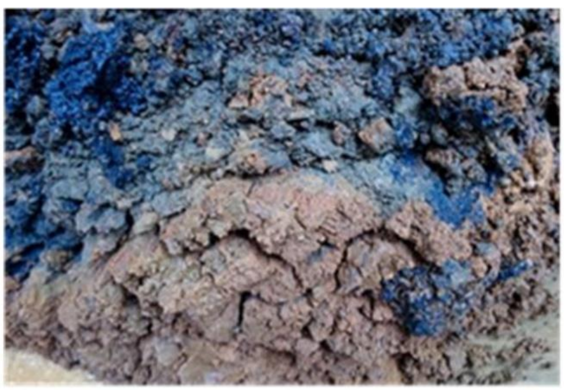


Fig. 84 Textile sluge (Jaiswal 2018)

Fig. 85 Textile wastewater (Sanghavi and Ranga 2019)

Further, organic polluters present in the textile's effluent can be biodegradable or non-biodegradable. Biodegradable organic components deplete oxygen concentrations in water during their degradation, undermining the water quality and disrupting the aquatic organisms (Toprak and Anis 2017). Non-biodegradable pollutants are persistent and can accumulate and enter the food web, which further disturbs the aquatic system and life (Madhav *et al*. 2018). Organic pollutants (POPs) such as additives, detergents, dioxin, phenol, pesticide, surfactants, fasteners, mordants, salts, and formaldehyde are frequently present in textile wastewaters and are reported as harmful substances for human and animal health (Kishor *et al*. 2021). The most common inorganic contaminants in textile effluents are basic and acidic compounds and metallic salts (Madhav *et al*. 2018). As these pollutants go through diverse biochemical interactions, they diminish the quality of the receiving water bodies (Madhav *et al*. 2018). Sulfates pose a special concern because of their ability to form strong acids, which further can change the pH value of water (Chowdhury

2014). Nonylphenol ethoxylates (NPEs) are extensively used as surfactants and detergents in textiles processing (Ellen MacArthur Foundation 2017). They are persistent, toxic, and can accumulate in the food chain and living organisms (Ellen MacArthur Foundation 2017). Further, nonylphenol ethoxylates (NPEs) can break into nonylphenols which have been reported as hormone disruptive substances (Ellen MacArthur Foundation 2017). Also, the presence of phosphates can cause eutrophication (Chowdhury 2014). However, the most attention and concern have been given to the presence of heavy metals in textile effluents. Heavy metals such as chromium (Cr), antimony (Sb), copper (Cu), zinc (Zn), lead (Pb), cadmium (Cd), and nickel (Ni), among others, are often present in textile wastewaters (Kishor *et al.* 2021). They are highly toxic to humans and aquatic life, however, their toxicity largely depends on their physico-chemical form (Shaikh 2009). For example, cadmium (Cd) and lead (Pb) are classified as carcinogens (Chowdhury 2014). Cadmium (Cd) has been banned in Europe for a longer period of time (Chowdhury 2014). Chromium (VI) is usually a by-product of the leather tanning process. Chromium (VI) is also cancerogenic, a skin irritant, and a strong oxidant (Chowdhury 2014). Nickel (Ni) is usually used in the production of clothes accessories such as buttons, zippers, and rivets. Nickel (Ni) can cause serious skin irritation and allergic reactions (Chowdhury 2014). It is estimated that around 300–500 million tons of heavy metals, solvents, and toxic sludge are discharged into water resources worldwide every year (Chowdhury 2014). Heavy metals can affect some plant growth parameters such as seed germination and seedling growth and decrease microbial activity (Kishor *et al.* 2021). As they are non-biodegradable, they can enter the food web and accumulate in different tissues and organs in living organisms, leading to various symptoms and diseases. Their accumulation usually occurs in organs such as liver, kidney, bones, heart, and brain (Khan and Malik 2014). Diseases and symptoms such as diarrhea, neuromuscular, dermatitis, hemorrhage, central nervous system disorder, liver and kidney malfunction can occur due to exposure to heavy metals (Kishor *et al.* 2021).

Fig. 86 and 87 Pollution of aquatic water bodies from the textile industry

Another great problem related with clothes is microplastic pollution of aquatic resources. Fast fashion and textile industries are the major sources of microplastics, which is a growing concern due to their negative environmental and health impacts. Microfibers are usually released during the clothes production and utilization stage and at the end-of-life at the disposal (Liu *et al*. 2021). They originate from clothes made from synthetic fibers such as nylon, acrylic, and polyester (Rukhaya *et al.* 2021). Microplastics are very small pieces of plastic, invisible to human eye (Eder-Hansen *et al*. 2017). There are two types of plastics, primary and secondary. Primary microplastics are the ones directly released into the environment, while secondary microplastics originate from decomposition of primary microplastics and other larger plastic pieces after they enter the aquatic resources (Eder-Hansen *et al*. 2017). Microfibers are tiny pieces of usually synthetic fibers released during clothes washing. It is estimated that only one washing of 6 kg of clothes can result in releasing up to 700,000 fibers (Napper and Thompson 2016). Further, only one person could contribute to a discharge of up to 300 million microfibers per year by washing their clothes (Rukhaya *et al.* 2021). The diameter of microfibers is usually less than 10 µm, and they have a very low density, usually around 0.65 to 1.8 g/cm3, which is lower than soil particles (2.65 g/cm3), making them more transportable (Jerg and Baumann 1990; Brahney *et al.* 2020). It is estimated that synthetic microfibers and nanofibers comprise up to 35% of primary microplastics in the ocean (Liu *et al*. 2021).

Most of released microfibers find their way into the ocean. ,,Each year half a million ton of plastic microfibers, equivalent to 50 billion plastic bottles, are released into the ocean from textile washing activities" (Patwary 2020, 9). Rivers are the main transport pathways of microplastic pollution into the ocean resources. They carry microplastic pollution downstream until its ultimately discharged into the marine environment. ,,Estimates indicate that ten rivers, eight of which are in Asia: the Yangtze, Indus, Yellow, Hai He, Ganges, Pearl, Amur, and Mekong rivers, and the Nile and Niger rivers in Africa, carry more than 90% of the plastic waste" (Liu *et al*. 2021, 11246) delivering all that plastic into the ocean. Apart from ocean pollution, microplastics have been found in other various marine habitats worldwide, such as shorelines, the sea surface, deep-sea sediment, and Arctic sea ice, as well as freshwater habitats and drinking water (Liu *et al*. 2021).

While negative impacts of larger pieces of plastic such as ingestion, injury, entanglement, or suffocation of wildlife are easily noticeable, potential negative impacts of microplastics are still less clear (Ellen MacArthur Foundation 2017). However, there is a general acceptance that microplastics could leave serious environmental consequences. Microplastics pose a special concern for aquatic organisms, as they can be ingested by fish and other living organisms, and therefore enter the food chain (Rukhaya *et al.* 2021). Microplastics can cause starvation and stunted growth in some species (Ellen MacArthur Foundation 2017). Further, their decomposition in the digestive tract could result in the generation of various substances of concern (Ellen MacArthur Foundation 2017). Microplastics have been found in digestive tracts of a wide range of aquatic organisms, seafood, and commercially important fish and shellfish (Liu *et al*. 2021). Thus, mainly through consumption of contaminated sea goods, microplastics, in the end, find their way to reach humans (fig. 88). ,,One study estimates that an average European shellfish consumer eats as many as 11,000 microplastic particles per year through their diet" (Ellen MacArthur Foundation 2017, 67). Apart from this, the surface of microplastics often absorbs various substances, including toxic and hazardous chemicals, which are then ingested alongside with plastics posing a serious health concern (Ellen MacArthur Foundation 2017). Further, as microplastic and microfibers such as polyethylene terephthalate (PET), regenerated cellulose, nylon, and polypropylene, are resistant to biodegradation, they tend to accumulate in the marine environment and terrestrial habits, prevailing there for a very long period of time (Liu *et al*. 2021; Kleinhückelkotten and Neitzke 2020). In the future, microplastic will pose an increasing threat as fast fashion and textile industry will continue to grow. ,,On current trend, the amount of plastic microfibres entering the ocean between 2015 and 2050 could accumulate to an excess of 22 million tonnes" (Ellen MacArthur Foundation 2017, 21). It is estimated that oceans already contain around 1.4 quadrillion microfibres, and by 2050 there could be more plastic than fish (by weight) (Leonard 2016; Ellen MacArthur Foundation 2017). ,,The release of plastic microfibres into the ocean due to the washing of textiles could grow to 0.7 million tonnes per year by 2050" (Ellen MacArthur Foundation 2017, 39). Apart from this, clothes laundering will require additional 20 billion cubic meters of water per year globally (Pakula and Stamminger 2009).

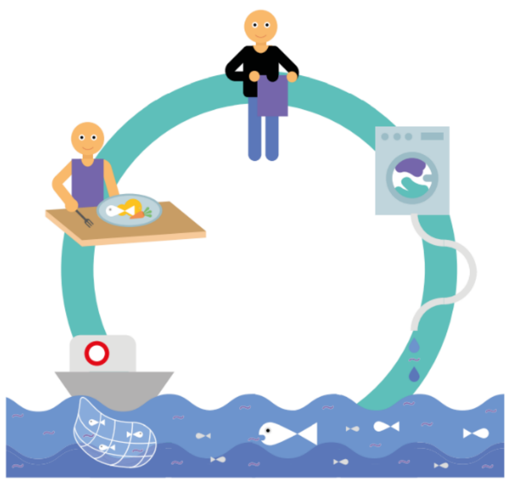


Fig. 88 Microplastics entering the food chain and impact on human (Ellen MacArthur Foundation 2017)

4.2.2 Impact on soil resources

Textile and fast fashion industries are significant sources of soil pollution and degradation. Diverse negative impacts are result of various fast fashion and textile activities such as cotton farming, raising of sheep for wool production, clothes processing and manufacture, but also discharge of various liquid wastes, and use of textile contaminated water for irrigation. Cotton cultivation has recently been recognized as a special concern due to major pollution, degradation, and pressure on soil resources. Cotton farming's extensive use of pesticides and fertilizers leads to soil contamination, which has diverse negative consequences. Of the total amount of pesticides produced globally, 6% is utilized for growing cotton fibers, including 16% insecticides, 4% herbicides, growth regulators, desiccants and defoliants, and 1% of fungicides (Niinimäki *et al*. 2020). Pesticides are considered as hazardous and toxic chemicals, especially in case of inadequate and extensive utilization. They can reduce soil fertility and biodiversity, disturb biological processes, and affect microorganisms, plants and insects (Niinimäki *et al*. 2020). Apart from this, cotton cultivation also accounts for about 4% of nitrogen and phosphorus fertilizer use globally (Ellen MacArthur Foundation 2017). The main problem with fertilizers is that due to their extensive use, they can leach into water bodies, causing eutrophication and oxygen depletion (Ellen MacArthur Foundation 2017). Further, inorganic and organic fertilizers and pesticides often contain heavy metals (Gunalan *et al*. 2018). Fungicides and phosphate fertilizers are especially sources of heavy metals such as cadmium (Cd), chromium (Cr), nickel (Ni), lead (Pb), and zinc (Zn) (Gunalan *et al*. 2018). Fast fashion has the capability to disturb soil, forest resources, and the entire ecosystem (Rukhaya *et al*. 2021). Sheep breeding for wool production also poses a major concern. Due to extensive sheep grazing, soil erosion could occur, which causes soil nutrient losses and erosion. Land degradation can also lead to other negative implications such as loss of valuable plant species and biodiversity, food shortages, and famine (Rukhaya *et al*. 2021). Production of wood-based fibers such as viscose also contributes to soil erosion and deforestation. Thousands of hectares of native forests are replaced and destroyed for growing plants for the production of viscose fibers (Rukhaya *et al*. 2021). Apart from degrading forest resources and initiating soil erosion, this further poses a major threat to global food security and contributes to issue of climate changes (Rukhaya *et al*. 2021).

Another great problem is use of textile wastewaters or already polluted freshwaters by textile industry for irrigation of agricultural land. This is often the case, especially in developing countries and nations with scarce water resources, as growing water crisis has forced farmers to utilize untreated or partially treated textile effluent for irrigation (Imran *et al.* 2015; Pokhriya *et al*. 2020). As mentioned before, textile wastewaters are heavily polluted and contain various hazardous chemicals, including residues of dyes and heavy metals. Apart from this, these waters usually have increased temperature. Irrigation with such water has various negative implications. It affects the growth of crops, soil health, grain quality, fodder quality, and health of consumers (Garg and Kaushik 2008). The pollutants present in the textile effluent can largely alter physical, chemical, and biological properties of the soil (Pokhriya *et al*. 2020). This has negative consequences on crop cultivation, however, effects can vary from crop to crop (Garg and Kaushik 2008). Irrigation with such water can lead to high pollution and changes in soil's macro and micro nutrient content, affecting agricultural production (Kanan *et al*. 2014). Also, such contaminated soil can inhibit plant growth through oxidative stress and reduction of protein content, photosynthesis, and CO2 assimilating rates (Slama *et al*. 2021). Due to high concentrations of bicarbonates (HCO_3) and carbonates (CO_3), textile effluents have high pH values, which promotes alkalinity conditions, further affecting soil permeability and microflora (Kanan *et al*. 2014). Further, this can strengthen sodality of soil and impact crop growth (Kanan *et al*. 2014). Apart from this, due to rich nutrient content and the presence of organic matter, textile wastewaters could increase soil conductivity and salinity (Pokhriya *et al*. 2020). In the long run, the use of textile wastewaters for irrigation deteriorates the soil quality. If the wastewaters are allowed to flow in the fields, they can clog soil pores, leading to losses of soil productivity (Khan and Malik 2014) (fig. 89). Also, effluent, including contaminants, can infiltrate into the soil, thus further polluting and endangering underground water resources (Konwar and Boruah 2020).

Fig. 89 Soil pollution by discharge of textile wastewaters (Chapman 2017)

The presence of dyes in textile wastewater poses a special concern. Dyes could accumulate in the soil, especially near the textile operation mills and soils irrigated with wastewaters containing dyes (Imran *et al*. 2015). The problem is that dyes are usually resistant to aerobic degradation, while under anaerobic conditions, they could break into potentially carcinogenic aromatic amines (Franciscon *et al*. 2009). In general, the presence of dyes in soil could have a negative impact on microbial communities and also plants, as they show phytotoxic effects impacting their germination and growth (Lellis *et al*. 2019; Imran *et al*. 2015). Apart from dyes, textile wastewater could also contain traces of fibers and yarns. They are responsible for pollution of local landfill habitats and agricultural fields. Polyester fibers pose a special concern due to their nondegradable nature. However, the presence of heavy metals in textile effluent represents the greatest concern for the soil and nature in general. They are recognized as one of the major sources of soil pollution (Singh and Kalamdhad 2011). Even though metals are naturally present in the soil, at high concentrations, they can pose a serious threat to the entire ecosystem. Some metals such as cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), and zinc (Zn) are essential micronutrients for plant growth, while heavy metals such as aluminum (Al), arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb), antimony (Sb), and selenium (Se) do not play any relevant role and are rather toxic for plants and other living organisms (Singh and Kalamdhad 2011). Also, essential metals could become toxic at higher concentrations and when they exceed their safe thresholds (Singh and Kalamdhad 2011). Heavy metals usually occur in colloidal, ionic, particulate, and dissolved phases (Abraham and Sonil

2013). In the soil, they could be present ,,as free metal ions, soluble metal complexes, exchangeable metal ions, organically bound metals, precipitated or insoluble compounds like oxides, carbonates, and hydroxides, or a part of silicate materials" (Abraham and Sonil 2013). There are three major concerns associated with heavy metals:

- Loss of soil productivity
- Groundwater pollution due to metal leaching
- Their accumulation in the food chain with associated negative health effects on plants, animals, and humans (Garg and Kaushik 2008).

Due to their nondegradable nature and long biological half-life, soil heavy metal contamination is considered as serious environmental threat (Chaoua *et al*. 2019). In the long run, irrigation of agricultural land with textile wastewaters containing heavy metals leads to their accumulation, as soils act as a heavy metal sink (Garg and Kaushik 2008). The accumulation rate in soil depends on the concentration level of heavy metals in the effluent, as well as the frequency and extent of irrigation with such waters (Bansal *et al*. 1992). ,,As the heavy metals slowly build up their concentrations in the soil to the toxic level, soil functions are severely affected" (Gola *et al.* 2016, 1066). Accumulation of heavy metals could alter physical, chemical, and biological characteristics of soil (Singh and Kalamdhad 2011). Often, soils irrigated with this kind of wastewater are poor in nutrients and microbial diversity (Abraham and Nanda 2013). Further, these waters could deteriorate the quality of soil and limit agricultural production and environmental functions of the soil (Gola *et al.* 2016; Friedlova 2010). Depending on the heavy metal concentrations and their variety in the soil, they can also decrease the rate of soil respiration, a very important soil parameter which indicates the soil's capacity to support life (Gola *et al.* 2016). At very low concentrations, heavy metals usually do not affect the soil respiration rate, however, the conditions are more dangerous if multiple metals are simultaneously present in the soil (Gola *et al.* 2016), which is usually the case.

In their immobilized form, heavy metals can be present for a long period of time, with a very slow leaching rate and high availability for plants and other living organisms (Friedlova 2010; Abraham and Sonil 2013). In case of leaching, they could be transported into aquatic bodies and underground waters, posing a serious environmental threat. Bioavailability of heavy metals largely depends on the pH level of the soil. With increased pH value, heavy metal bioavailability decreases due to precipitation of hydroxides, carbonates or formation of insoluble organic complexes, while lower pH level means their higher bioavailability (Smith and Giller 1992; Lombi *et al*. 2003). Usually, soils polluted with heavy metals are more acidic, with low pH values in comparison with non-contaminated soils (Gola *et al*. 2016). Further, increased conductivity could also enhance the solubility of heavy metals and, therefore, their bioavailability (Chaoua et al. 2019). Root exudates and microorganisms also play an important role in metal mobility and availability (Gunalan *et al*. 2018). Usually, only a fraction of heavy metals are available for plant uptake. The absorption and accumulation of heavy metals largely depend on plant age and species, as some plants are more efficient in absorbing heavy metals than others (Singh and Kalamdhad 2011). Besides soil pH and plant efficiency, other factors such as temperature, moisture, and organic matter affect heavy metal absorption rate (Singh and Kalamdhad 2011). Absorbed heavy metals usually tend to accumulate in plant's roots and leaves (fig. 90). Heavy metals show toxic effects on plants, and their accumulation cloud leads to chlorosis, weaked plant growth, yield depression, reduced nutrient uptake, and disorders in plant metabolism (Guala *et al.* 2010). They can ,,deteriorate the overall quality of the plants in term of germination rate, chlorophyll content, overall biomass and fruit/pod formation" (Gola *et al.* 2016, 1068). Further, heavy metal presence could reduce nitrogen fixation, impacting crop productivity (Chaudhary *et al.* 2004). Uptake of heavy metals by plants and further accumulation is one of the main routes of their entrance into the food chain and exposure to humans (Jordao *et al*. 2006). Heavy metals such as zinc (Zn), cadmium (Cd), lead (Pb), and copper (Cu) were often found in vegetables (Kachenko and Singh 2006). Consummation of such heavy metal contaminated fruits and vegetables poses a serious health hazard to humans. Heavy metals have shown toxic, carcinogenic, and mutagenic effects and can cause various acute and chronic diseases.

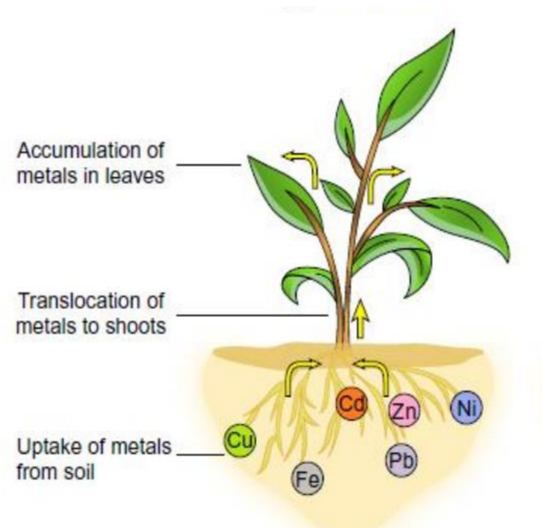


Fig. 90 Accumulation of heavy metals in plants (Ghori *et al.* 2016)

Further, as soils are biologically balanced systems, any major change can alter microbial community structure and biochemical processes (Imran *et al.* 2015). Thus, heavy metals can largely affect bacteria, fungi, actinomycetes, and other microbial population in the soil. These microorganisms play a fundamental role in transformation, recycling and storage of plant nutrients such as carbon (C), nitrogen (N), phosphorus (P), sulfur (S) and other elements, organic matter degradation and mineralization, maintenance of soil structure, detoxification of noxious chemicals, and the control of plant pests (Chu 2018; Friedlova 2010; Singh and Kalamdhad 2011). Soil microbes are involved in all biochemical reactions in the soil (Chu 2018). They ,,can degrade inorganic and organic pollutants, reduce the toxicity of pollutants to plants, and provide a good ecological environment for plant growth" (Chu 2018, 2). However, heavy metals could decrease the number, diversity, and activity of microbial communities in the soil, affecting their quality and quantity (Friedlova 2010). There is a direct link between heavy metal concentration and microbial activities, such as respiration, nitrification, mineralization, intracellular and extracellular enzymatic activities, and microbial community biomass and structure (Abraham and Nanda 2013). Heavy metals can slow down growth and reproduction rate of microorganisms and inhibit the development of specific microbial groups, especially nitrifiers and nitrogen fixers (Friedlova 2010; Abraham and Nanda 2013). Further, heavy metals largely impact enzyme activity by altering the microbial community, which synthesizes enzymes (Shun-hong *et al.* 2009). Due to reduced growth and reproduction rate, the synthesis and metabolism of the microbial enzyme also decline (Chu 2018). Further, as concentrations of heavy metals increases, the enzyme activity decreases due to their interaction with heavy metals (Kuperman and Carreiro 1997). Apart from this, in the long run, heavy metals could increase the tolerance of microbial communities and fungi, which play an important role in the restoration of contaminated ecosystems (Singh and Kalamdhad 2011). More so, heavy metals also show toxic effects towards soil biota. Their presence can kill soil microorganisms necessary for soil activity and fertility. They can decrease bacterial species richness and increase soil actinomycetes (Gunalan *et al*. 2018). The toxicity of heavy metals depends on many factors such as pH, temperature, soil type, quantity of pollutants, water content in soil, inorganic anions and cations, hydrous metal oxides, clay minerals, organic matter form and amount, chemical forms in which metals occurs, among other (Friedlova 2010).

4.2.3 Impact on air quality and GHG emissions

Right after freshwater pollution, gaseous emissions including GHG, have been recognized as the second largest problem in the textile and fast fashion industries. Almost all operations during clothes manufacturing emit various gas emissions and contribute to air pollution. Apart from this, emission of GHG is another significant issue characteristic for the entire textile operation chain and clothes life cycle. ,,Textiles, generate the most greenhouse gases per unit of material" (Niinimäki *et al.* 2020, 192). Depending on the nature of their sources, air emissions can be classified into:

- Point sources such as boilers, ovens, and storage tanks
- Diffusive which include solvent-based, wastewater treatment, warehouses, and spills (Mukherjee 2015).

Air emissions include various pollutants such as dust, lint, acid vapours, oil fumes, solvent mists, odor, and boiler exhausts (Toprak and Anis 2017). They can be divided into:

- ,,primary air pollutants (e.g. VOCs and free gaseous chlorine from aqueous chlorine compounds formed due to use of hypochlorides),
- suspected photochemical precursors (e.g. chlorine radicals formed from chlorine gas molecules),

- other suspected secondary air pollutants formed in the gas phase by the action of the precursors mentioned above (e.g. HCl and halogenated VOCs after a series of radical chain mechanisms which may consist of additions or aromatic substitution reactions in the gas phase)" (Muezzinoglu 1998, 340)

Further, sources of air pollution could be divided into "combustion flue gases" and "process emissions into both indoor and ambient air" (Muezzinoglu 1998). Even though combustion units are predominant sources of air pollution, pollution directly related to production processes is also a major issue. Air pollutants can be divided into suspended particulate matter and organic or inorganic gases and vapors (Muezzinoglu 1998). As already mentioned, initial stages of clothes production such as fiber preparation operations, spinning, and weaving largely undermine the air quality through emission of dust particles. The following operations in the textile industry contribute to air pollution as well. Thus, operations such as dyeing, printing, resin finishing, drying, and wastewater treatment plants are also sources of air emissions (Khan and Malik 2014). Chlorinated organic gases are especially emitted during processes such as desizing, bleaching, and dry cleaning due to utilization of chlorine-based chemicals and old technologies (Muezzinoglu 1998). Wool carbonization generates corrosive acid fumes (Toprak and Anis 2017). Boilers, used for heating the wash water and generation of high pressure steam for printing stage, are great sources of emission of nitrogen and sulfur oxides (Muezzinoglu 1998; Khan and Malik 2014). These oxides can alter the pH of habitats damaging the entire ecosystem (Toprak and Anis 2017). Dyeing and printing stages are a source of solvent vapors which include toxic chemicals such as kerosene or mineral turpentine oil, chlorofluorohydrocarbons, formaldehyde, mono- and dichlorobenzene, hexane, ethyl acetate, styrene, and other (Toprak and Anis 2017). Solvents such as butyl acetate, used for dissolving and thinning dyes, have high vapor pressures and can find their way into the atmosphere if necessary controls are not applied (Muezzinoglu 1998). They continue to evaporate even in further stages such as printing, fixing, and drying (Muezzinoglu 1998). Further, hydrocarbons are usually emitted from drying ovens and mineral oils during high-temperature drying/curing (Khan and Malik 2014). These processes also emit other pollutants such as formaldehyde, acids, softeners, and other volatile compounds (Khan and Malik 2014). VOC (volatile organic compounds) and chlorine have the potential to disturb global atmospheric mechanisms (Muezzinoglu 1998). Other emissions of concern include acetic acid and formaldehyde (Rukhaya *et al*. 2021).

,,Cross linkages between air-borne, water-borne or solid phase pollutants are important, too" (Muezzinoglu 1998, 340). Thus, apart from direct air pollution, indirect pollution must be considered as well. There are two types of indirect air pollution:

- formation of secondary pollutants through gas-phase reactions in the workplace air and outdoor,
- pollutants evaporating from other pollutant streams, especially textile wastewaters and treatment plants (Muezzinoglu 1998).

Open wastewater channels, as well as the first units of the wastewater treatment plants, could become sources of fugitive emissions (Muezzinoglu 1998). Textile wastewater is subject of air emission of hazardous chemicals in case of inadequate and careless handling, treatment, and disposal (Muezzinoglu 1998). Wastewaters emit gases and vapors usually during transportation and treatment (Muezzinoglu 1998). Low boiling organic liquids could form upper layer or foam in the water phase and evaporate into the indoor and outdoor air from waste water channels, aeration units, and equalization basins to create toxic or hazardous VOCs (Muezzinoglu 1998). Apart from this, in the textile wastewater treatment plant, potential sources of emissions and air pollution are also primary sedimentation or biological aeration units, influent channels, pump houses, oil traps, and grit chambers (Muezzinoglu 1998). ,,In many cases solvents as well as chlorine-containing wastewaters continue evaporating at the equalization and neutralization units of the treatment plant" (Muezzinoglu 1998, 343).

More so, fast fashion and textile industries are a major source of GHG emissions, resulting mostly from the usage of non-renewable energy sources. Every year, the fast fashion industry releases millions of tonnes of carbon dioxide, accounting for about 10% of the global carbon footprint (Rukhaya *et al.* 2021). More precisely, fast fashion and textile industries are generating about 2.1 billion tons of CO2 equivalent each year (McKinsey & Company and Global Fashion Agenda 2020). This is a result of various fast fashion operations, from fiber extraction, clothes manufacturing, and transportation, to garment utilization stage and final disposal. In fact, upstream activities such as energy-intensive raw material and clothes production, preparation, and processing account for 70% of the total fast fashion industry's emissions, while the remaining 30% is associated with downstream activities such as packaging, transport, retail operations, the use-phase and end-of-use activities (fig. 91) (McKinsey & Company and Global Fashion Agenda 2020).

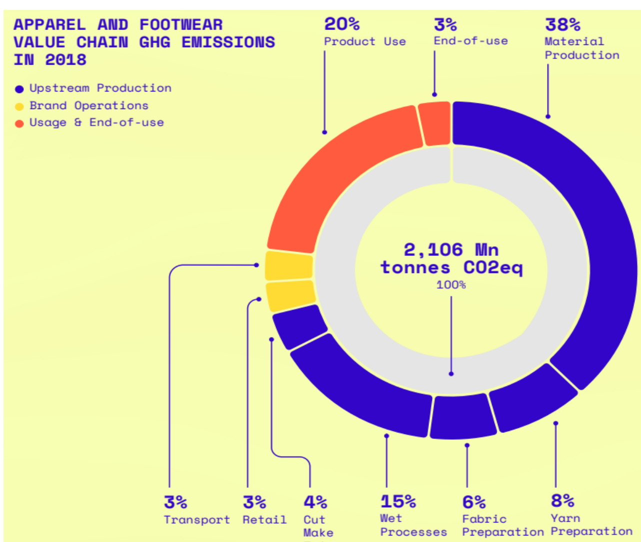


Fig. 91 GHG emission share of upstream and downstream fast fashion activities (McKinsey & Company and Global Fashion Agenda 2020)

Thus fiber production, especially polymer extrusion for synthetic fibers and agriculture for natural fibers, are major sources of GHG emissions (Patwary 2020). Production of polyester and other synthetic fabrics is an energy-intensive process which requires huge amounts of crude oil, resulting in emission of GHG, including other pollutants such as volatile organic compounds, acid gases, and particulate matter (Rukhaya *et al*. 2021). Production of pesticides and fertilizers used for growing cotton also largely contributes to GHG emissions. ,,They account for around 70% of GHG emissions in conventional cotton cultivation" (McKinsey & Company and Global Fashion Agenda 2020, 10). Other natural fibers, such as wool, have a carbon footprint too, especially at the beginning stage due to sheep breeding responsible for the emission of methane gas (Kaikobad *et al*. 2015), which has even stronger greenhouse effect than carbon dioxide. However, the level of emissions mostly depends on the fiber type being processed and applied technology (Rukhaya *et al*. 2021). Each stage of clothes processing requires energy input, usually in the form of thermal energy for heating processes and electricity for operating the machinery and equipment in the textile mills. Given that most of the clothes are being produced in developing countries, heat and electricity are often generated from non-renewable sources such as coal, which leaves an enormous carbon footprint (table 39). Yarn and clothes manufacturing are the main consumers of electric energy, accounting for nearly 3/4 or 4/5 of the total energy requirements in a textile mill, while about 15 to 20% of electric energy is utilized for operating machinery in the wet processing stage (Toprak and Anis 2017). Besides electric energy, thermal energy required for the production of steam for various processes is also usually generated from coal, contributing to GHG emissions. Apart from production, distribution and transportation of clothes also have their share in GHG emissions as they require a significant amount of energy, mostly obtained from non-renewable energy sources. This stage accounts for about 2% of the total climate-change impacts (Eder-Hansen *et al*. 2017). Clothes are usually distributed by container boats, however, in recent years, transportation by air cargo began to increase to save time and due to online shopping (Niinimäki *et al*. 2020). Air cargo has a considerably larger carbon footprint, as moving only 1% of clothes transportation from ship to air cargo could increase carbon emissions by 35% (Quantis 2018).

Production step	Contribution to GHG emissions (%)
Fiber production	30
Yarn production	26
Preparation and bleaching	8
Fabric manufacture	11
Dyeing and finifhing	5
Other raw materials	8
Garment manufacture	3
Packing	7
Transportation	2

Table 39 Contribution of the different production steps of clothing to total greenhouse gas emissions (Business for Social Responsibility 2009)

If the fast fashion industry continues at the current pace, the climate footprint will double, as emissions are projected to increase by 60 %, which is around 2.7 billion tons per year by 2030 (Napier and Sanguineti 2018; McKinsey & Company and Global Fashion Agenda 2020). To reduce climate change footprint, the fast fashion industry needs to lower production volumes and cut down use of non-renewable energy sources, synthetic fiber should be replaced with natural fibers, and sustainable shipping and garment utilization must be considered (Niinimäki *et al.* 2020). However, due to population and consumption growth, the fast fashion industry business will likely continue to increase, and without further abatement action in the next decade, carbon footprint as well, with an annual volume growth rate of 2.7% (McKinsey & Company and Global Fashion Agenda 2020). In order to align with the 1.5-degree pathway in the next decade, fast fashion will need to intensify abatement measures to reduce annual emissions to around 1.1 billion tonnes by 2030, which is around half of today's amounts (fig. 92) (McKinsey & Company and Global Fashion Agenda 2020).

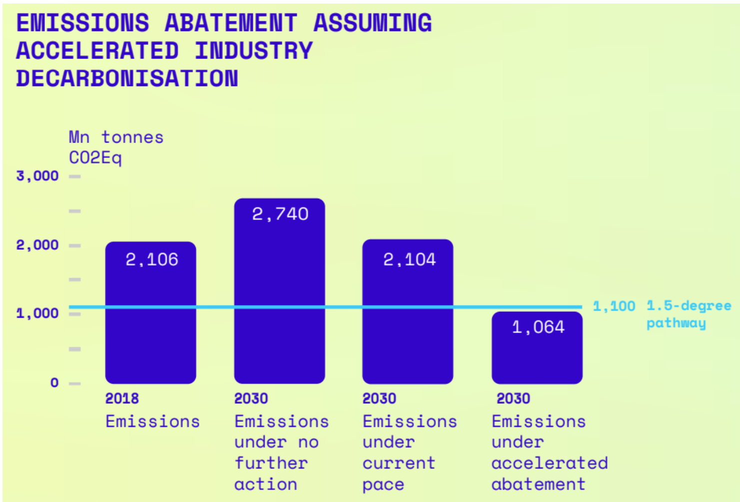


Fig. 92 Fast fashion industry decarbonization under different scenarios (McKinsey & Company and Global Fashion Agenda 2020)

Reduced overproduction plays a vital role in GHG emission reduction and could save about 158 million tonnes by 2030. Apart from this, adoption of circular business approach is a key lever for decarbonization and, by 2030, can save up to 143 million tonnes of GHG emissions, mainly through extension of clothes life, recycling, fashion rentals, re-commerce, repair and refurbishment, and reduced need for new resources input (McKinsey & Company and Global Fashion Agenda 2020). This means that „by 2030 we need to live in a world in which one in five garments are traded through circular business models" (McKinsey & Company and Global Fashion Agenda 2020, 14). The focus of abatement measures should be on upstream operations, as the potential of 60% emission savings lies in decarbonizing this stage, while 20% in retailor operations and 20% in encouraging sustainable consumers behavior (fig. 93) (McKinsey & Company and Global Fashion Agenda 2020). However, with current abatement measures in place and no further action, by 2030, the fast fashion industry will maintain GHG emissions at 2.1 billion tonnes, representing a loss of potentially saved 1.676 million tonnes (McKinsey & Company and

Global Fashion Agenda 2020). Around 45% of that potential lies in decarbonizing the production and improving process efficiency, such as spinning, weaving, and knitting and shifting from wet towards dry processing, 39% in transition from coal to renewable energy, and 16% in switching from coal energy boilers to electric boilers, across the production chain (fig. 94) (McKinsey & Company and Global Fashion Agenda 2020).

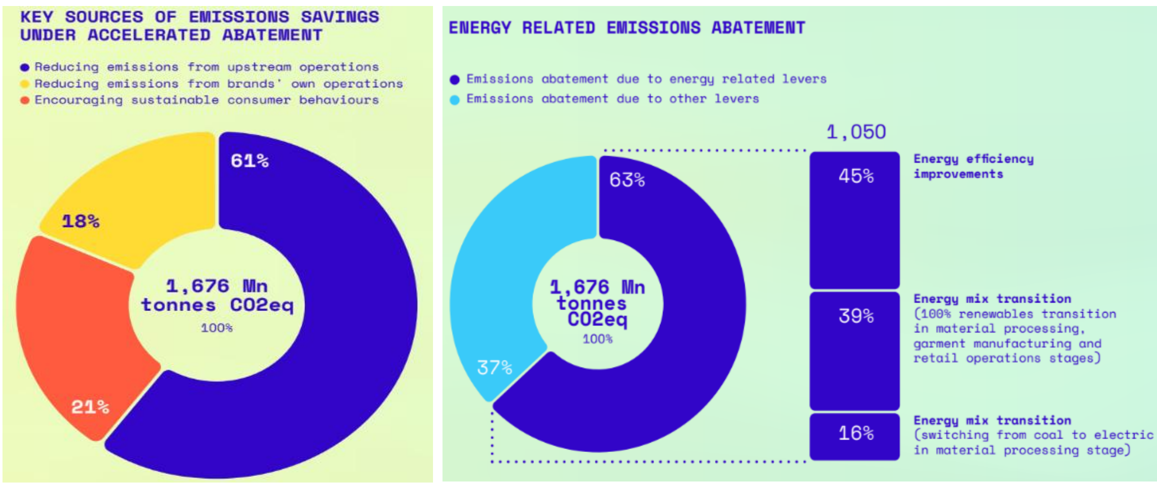


Fig. 93 and 94 GHG emission savings in the fast fashion industry
(McKinsey & Company and Global Fashion Agenda 2020)

The fast fashion industry has to identify energy-intensive hotspots throughout the clothing supply chain and make an effort to switch to renewable energy (Patwary 2020). Here, fast fashion brands and retailers play a vital role in decarbonization of upstream activities and transition towards renewable energy sources. Assuming that the fast fashion industry can quickly achieve a global target of 40% renewable energy share would mean saving around 200 million tons of CO2 emissions, equivalent to 7% of global annual emissions in 2030 (Eder-Hansen *et al*. 2017). Decarbonised fiber production could save around 205 million tonnes of GHG emissions annually, with 20% of energy efficiency improvements in polyester production and 40% reduction in fertilizer and pesticide usage in cotton cultivation (McKinsey & Company and Global Fashion Agenda 2020). Further, decarbonized fiber processing could reduce GHG emissions for 703 million tonnes, with a transition to renewable energy and efficiency improvements in spinning, weaving, knitting, and shift from wet to dry processing (McKinsey & Company and Global Fashion Agenda 2020). Minimised production and manufacturing wastage could save up to 24 million tonnes of GHG emissions (McKinsey & Company and Global Fashion Agenda 2020). This requires improvments in processing fibers into textiles and reduction of waste generated during grament construction through better design and cutting techniques (McKinsey & Company and Global Fashion Agenda 2020). Lastly, decarbonizing garment construction and manufacturing could deliver around 90 million tonnes of GHG emissions savings, with 30 % improvements in energy efficiency across heating, ventilation, and air conditioning-related equipment and 20 % efficiency of sewing machines (fig. 95) (McKinsey & Company and Global Fashion Agenda 2020).

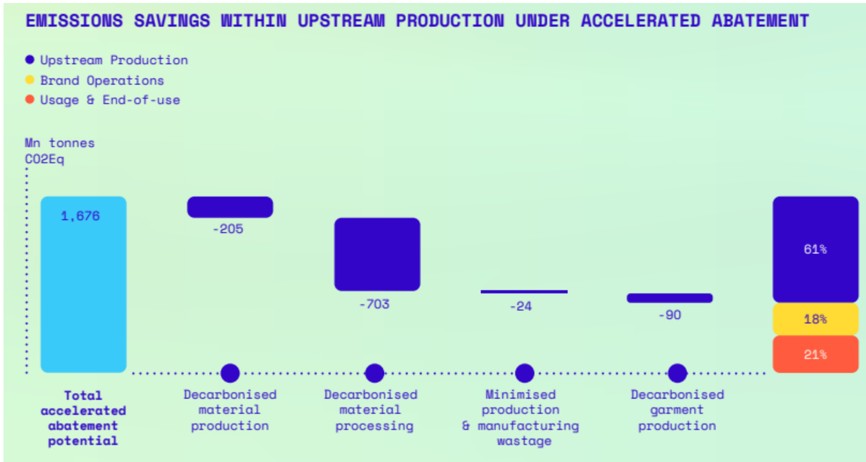


Fig. 95 Decarbonization of upstream production stage
(McKinsey & Company and Global Fashion Agenda 2020)

Apart from this, as oil-based synthetic fibers such as polyester, nylon, and others have a higher carbon footprint, their replacement with renewable plant-based fibers must take place in the future. Increasment of material mixed fibers (natural and synthetic) in clothes production could save up to 41 million tonnes of GHG emissions (McKinsey & Company and Global Fashion Agenda 2020). This means adoption of 20% of recycled polyester (PET) usage and 11% of alternative fibers such as organic, recycled, or biobased textiles (McKinsey & Company and Global Fashion Agenda 2020). Further, transition to sustainable transport could save around 39 million tonnes of GHG emissions. To achieve that, the fast fashion industry has to increase sea transportation to up to 90% and maintain air transportation at around 10%, compared to today's share of 83% sea transport and 17% air transport (McKinsey & Company and Global Fashion Agenda 2020). Improved packing could reduce GHG emissions for about 5 million tonnes, while decarbonization of retail operations would deliver 52 million tonnes of GHG emissions savings (fig. 96) (McKinsey & Company and Global Fashion Agenda 2020). Consumer behavior also has a vital role in reducing carbon footprint, as around 186 million tonnes of GHG emissions could be saved with reduced washing and drying (fig. 97) (McKinsey & Company and Global Fashion Agenda 2020). Finally, increased recycling and collection rates would decrease annual GHG emissions for around 18 million tonnes (McKinsey & Company and Global Fashion Agenda 2020). This would further reduce the need for incineration and landfill.

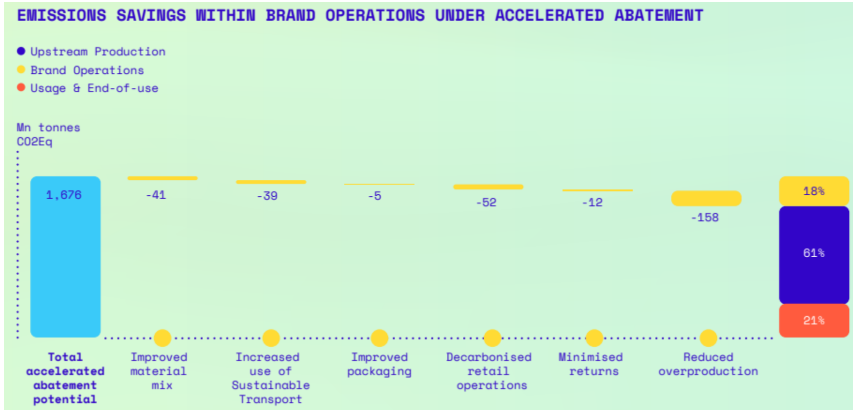


Fig. 96 Decarbonization of brand operations
(McKinsey & Company and Global Fashion Agenda 2020)

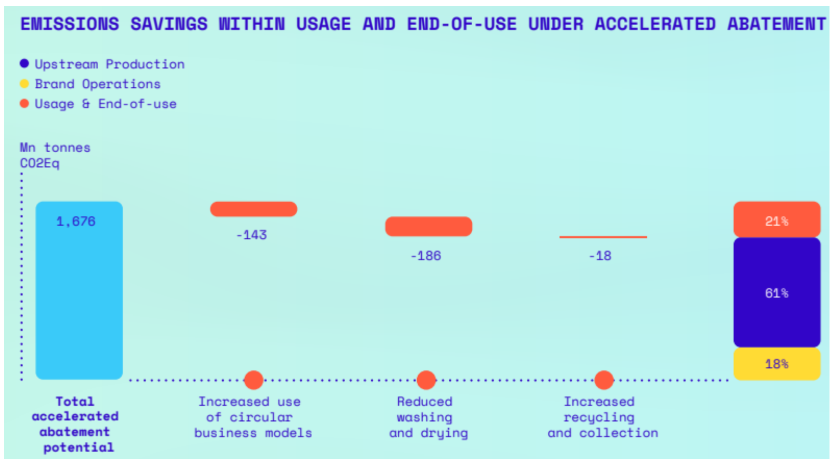


Fig. 97 Decarbonization of usage and end-of-use stages
(McKinsey & Company and Global Fashion Agenda 2020)

4.2.4 Waste generation

Fast fashion business model is responsible for generation of millions of tonnes of textile waste. As mentioned before, it thrives on fast production of vast amounts of cheap clothes, with frequent introduction of new trends encouraging consumerism and disposal behavior. Fast fashion has to manufacture clothes expeditiously in order to keep up with the fast changing trends. „It is a fast-response system that encourages disposability" (Ting and Stagner 2021, 2). Chep price and availability of clothes have shifted the paradigm of people's purchasing and disposal habits towards unsustainable behavior. Today, people are more frequently purchasing higher volumes of lower quality clothes and disposing them after a few wears (Horton 2018). Due to population growth, rise of middle class, improved incomes, and living standards across the globe, the production and consumption rates of clothes significantly increased (Shirvanimoghaddam *et al.* 2020), resulting in generation of vast amounts of textile waste with associated environmental problems. In the last two decades, the global annual consumption of textiles has increased from 7 to 13 kg per person (Shirvanimoghaddam *et al.* 2020). Fast fashion industry is now producing twice the amount of clothing compared to the year before 2000, with the increasement in clothing production rate of 2% per year (Niinimäki et al. 2020). Consumers are over consuming and liberally disposing clothing, promoting the fast fashion business model (Liang and Xu 2018), not aware of the environmental consequences of such behavior. From 1994 to 2014, clothes production has increased by 400%, so today, the global fast fashion industry is producing around 80-100 billion pieces of clothing each year, which is around 1.2 trillion dollars of annual sales (Garg 2019; Patwary 2020; Bick *et al*. 2018). It uses an enormous amount of natural resources, leaving a high pressure and degrading the environment to produce clothes which will be in use just for a short period of time. As clothes purchase and disposal rates have dramatically increased, the life cycle of garments (e.g. T-shirts) has become tremendously shortened (Claudio 2007). In the last 15 years, the average time of garment utilization has decreased by 36% (Morlet *et al.* 2017). For instance, in the US, clothes are utilized for only about a quarter of the global average time (Ellen MacArthur Foundation 2017). In China situation is becoming similar, as, in the last 15 years, clothes use time has decreased by 70% (Ellen MacArthur Foundation 2017). Estimates show that more than half of the fast fashion clothes are disposed under a year (McKinsey & Company 2016). ,,The use lives of three garment types (T-shirts, knit collared shirts and woven pants) in six countries (China, Germany, Italy, Japan, the UK and the USA) averaged only 3.1 to 3.5 years per garment" (Niinimäki *et al.* 2020, 195). These dramatic increases in fast fashion production and consumption rates, along with reduction of clothes service time and throwaway culture, have resulted in generation of tremendous amounts of textile waste leaving social, economic, and environmental consequences across the globe (Niinimäki *et al.* 2020; Shirvanimoghaddam *et al.* 2020). More precisely the global fast fashion and textile industries are producing about 92 million tonnes of textile waste every year (Rukhaya *et al*. 2021), which is 17.5 kg per person annually (Moazzem *et al*. 2021). According to Ellen MacArthur Foundation (2017, 37), ,,one garbage truck of textiles is landfilled or incinerated every second". Americans are producing the highest amounts of textile waste with 32 kg/per person annually, followed by the UK with 30 kg, Australia 27 kg, while in Finland waste generation per person accounts for 13 kg, and Denmark 16 kg annually (Blackburn 2015; Niinimäki *et al.* 2020). At their end of life, clothes are incinerated, landfilleded or transported to developing countries, which is usually the case, and are rarely recycled (Niinimäki *et al.* 2020). Developed nations usually handle their textile waste by exportation to developing countries, especially Africa (Rukhaya *et al*. 2021). Second-hand clothing is sold in more than 100 countries (Claudio 2007). However, this cannot be a long-term solution as developing countries are already facing with unbearable pressure from extensive amounts of textile waste. ,,In Uganda, for example, second-hand garments already account for

81% of all clothing purchases” (Ellen MacArthur Foundation 2017, 205). Many of them (e.g. Turkey and China) have banned further imports of textiles due to oversaturation of local markets and in order to protect domestic textile industry as second-hand clothes have replaced local textile production (Niinimäki *et al.* 2020; Rukhaya *et al*. 2021).

There are two types of textile waste: pre-consumer and post-consumer (Chen and Burns 2006). Pre-consumer waste is generated during the clothes production stage, and as previously explained, it originates from mistakes made in garment construction and cutting. It mainly consists of wasted fibers, yarn, and fabrics (Chen and Burns 2006). This waste is responsible for around 20% of the industry's fabric waste (Šajn 2019). Enhancing communication between designers and manufacturing staff could minimize generation of this type of waste through improved production accuracy and avoidance of mistakes (Niinimäki *et al.* 2020). Every year around 750,000 tons of this waste is recycled into new raw materials for industries such as automotive, paper, mattress, home furnishings, furniture, and others (Chen and Burns 2006). Thus, around 75% of pre-consumer waste is kept out from landfills and recycled (Chen and Burns 2006). Apart from this, pre-consumer waste also includes waste called deadstock, which is returned or unsold new and unworn clothes (Niinimäki *et al.* 2020). In recent years, increasing attention has been given to this type of waste due to vast amounts. For instance, in 2016, from the total amount of imported clothes in the EU, only a third was sold at full retail price, a third was sold at a discounted price, and a third was not sold at all (Mathews 2016). Many fast fashion retailers are dealing with this issue. For example, famous Swedish fast-fashion retailer H & M reported that it holds around 4.3 billion dollars worth of unsold inventory in their warehouses (Paton 2018). The brand is incinerating around 12 tonnes of unsold garments every year in Denmark plants (Hendriksz 2017). Similarly, British luxury brand Burberry reporeted that it incinerated £90 million worth of unsold inventory over the last five years (Reints 2018). In fact, incineration of this type of waste by fast fashion retailers is a very common practice. Thus, famous fast fashion brands such as Zara, Gap, H & M, and others are often incinerating their deadstock mainly for two reasons:

- The merchandisers do not accurately predict the amount of shopping the consumers will do, and there is too much clothing.
- Clothes production has to be done in a short period of time in order to keep up with constantly and rapidly changing trends (Napier and Sanguineti 2018).

Although the incineration of this waste can recover some of the energy from the products, it also contributes to air pollution, even more so than reuse and recycling (Niinimäki *et al.* 2020). On the other hand, post-consumer waste is generated after clothes utilization, when consumers decide to discharge apparel after a certain amount of time. The post-consumer waste consists of usually various used clothing items and household textile articles (Chen and Burns 2006). About 75 % of clothing is discharged due to fitting, choice, and need issues, and some of them are hardly worn (WRAP 2017). Further, most consumers tend to keep their old or clothes that they do not wear in their wardrobes. „Once bought, an estimated 21% of annual clothing purchases stay in the home, increasing the stocks of clothing and other textiles” (Mukherjee 2015, 28). This stockpiling leads to an increase of the "national wardrobe", a potentially vast amount of latent waste which will eventually enter the waste stream (Mukherjee 2015). Clothing consumption is the highest in the US with 37 kg per capita/year, followed by Australia with 27 kg, Western Europe 22 kg, and developing countries in Africa and Asia with only 5 kg (Milburn 2016b). The global average annual clothes consumption is 11.4 kg per person (Quantis 2018). Consumers in the US purchase one item of clothing every 5.5 days, while in Europe, clothes purchases increased by 40% from 1996-2012 (Niinimäki *et al.* 2020). Thus, in European countries such as Italy, clothes consumption is 14.5 kg per person, Germany 16.7 kg, the UK 26.7 kg, and Denmark, Sweden, Norway, and Finland between 13 kg and 17 kg (Niinimäki *et al.* 2020). In the EU, about 5 % of household expenditure is spent on clothing and footwear, of which about 80 % on clothes and 20 % on footwear (Šajn 2019). By 2030 the global apparel consumption is projected to increase by 63 %, which will bring additional 57 million tonnes of textile waste, thus, the total amount of textile waste will account for 148 million tonnes each year (Eder-Hansen *et al*. 2017). By 2050 total clothing sales could reach 160 million tonnes, driven especially by emerging markets such as Asia and Africa, which will be more than three times of today's amount (Ellen MacArthur Foundation 2017).

Two main approaches can be implemented in order to prevent generation of textile waste and set a track toward more sustainable fashion and textile industries:

- Proactive, which includes waste prevention and reduction;
- Reactive include reuse, recycling, incineration, and disposal (Niinimäki *et al.* 2020).

Proactive measures are preferable compared to reactive as they are the first line of prevention of textile waste generation, unlike reactive when the waste is already generated, and the fast fashion industry has to find ways to handle it. One of the main problems is that clothes design and manufacturing are not performed in the same place due to the shift of clothes production towards developing countries and stretched supply chain. Thus, while clothes design is performed at the headquarters of the fast fashion brands in usually developed countries of the Global North, the clothes production is done in the Global South due to cheap labor, weak laws, and legislation. This creates a void and miscommunication between clothes design and manufacturing, inhibiting waste reduction and, on the contrary, contributing to generation of waste. This issue could be overcome through improved communication between designers and manufacturing facilities. Further, proactive methods could be implemented in garment design phase, which will minimize the generation of cut waste and enable their reuse in production (Niinimäki *et al.* 2020). This could include „invisible remanufacturing, where fabrics are placed in invisible sections of the garment; visible remanufacturing, where they are placed in external visible places; and design-led manufacturing, where offcuts are used creatively to decorate the garment" (Niinimäki *et al.* 2020, 198). This approach could save up to 17% of virgin material and reduce GHG emissions by 7,927 kg during the production of 10,000 garments (Runnel *et al*. 2017). Regarding reactive measures, reuse is the most desirable strategy, followed by recycling and incineration, while disposal should be the last preferable solution in the waste management hierarchy (fig. 98).

Fig. 98 Waste hierarchy (Mukherjee 2015)

Reuse is the best option due to energy savings as it does not require additional material processing compared to recycling (Munasinghe *et al*. 2021). More so, reuse and recycling have negative GHG emissions, which means that they avoid more GHG emissions than they emit (Munasinghe *et al*. 2021; Erbach 2015). Even though recycling has lower GHG emissions than gasification and incineration, it has high energy consumption (Munasinghe *et al*. 2021). ,,Incineration and gasification are used as energy recovery methods but are least preferred from the resource recovery perspective" (Munasinghe *et al*. 2021, 4). Clothes disposal to landfills is considered as the worst option regarding economy and environment (fig. 99 and 100).

Fig. 99 Clothes landfill (Marshall 2018)

Fig. 100 Clothes landfill (Mowbray 2018)

,,Around 90–100% of the discarded textiles for landfill could be recovered through reuse or recycling" (Moazzem *et al*. 2021). Further, textile waste contains valuable resources, which are unfortunately lost through their disposal to landfills (Moazzem *et al*. 2021). Disposed natural and bio-based textiles during decomposition emit harmful ammonia, methane, and carbon dioxide (Moazzem *et al*. 2021), contributing to climate changes, while synthetic fabrics can remain in the soil for a very long period. Their degradation can take up to 200 years (Shirvanimoghaddam *et* *al.* 2020). Harmful substances used during clothes production, such as dyes, can leak out as clothes dispose and degrade the environment. Estimates show that textile degradation in landfills can release up to 2,000 tonnes of hazardous colorants in the EU each year (Ellen MacArthur Foundation 2017). Besides, textile waste disposal is associated with high costs. For instance, clothes disposal costs the UK economy around £82 million each year (WRAP 2014). However, unfortunately, most of the global clothing waste ends up in landfill. Globally, around 80% of clothing is landfilleded and incinerated, while only 20% is collected for reuse and recycling (fig. 101) (Eder-Hansen *et al*. 2017). Around 400 billion dollars worth of clothing is wasted each year (Drew and Reichart 2019). From the collected clothing and textiles, 10% is lost, 40% is reused, accounting for 8% of the total textile waste, and 50% is recycled, which is 10% of the total waste amount (Eder-Hansen *et al*. 2017). From the remaining 80% of textile waste, 30% is incinerated, and 70% is disposed (Eder-Hansen *et al*. 2017). The collection rate varies considerably between different countries and regions across the world. Thus, for example, in Germany, discharged apparel collection accounts for up to 75%, in Italy 11%, while in the US and China, collection rates are between 10% and 15% (Ellen MacArthur Foundation 2017). With a collection rate of 11 kg per capita, the UK is second to Germany (Niinimäki *et al.* 2020). However, some countries and regions, especially developing countries in Asia and Africa, do not have a collection infrastructure at all (Ellen MacArthur Foundation 2017). Actually, collected clothes from high-income countries are mostly exported to these poor regions. If the collection rate for clothes reuse and recycling would triple, from today’s 20% to 60% by 2030, fast fashion industry could save up to 4 billion dollars to the world economy (Eder-Hansen *et al*. 2017). Fast fashion brands could play a major role in increasing future collection rates, as they could set up collection programs for used clothing in their own fashion stores. Consumers could be awarded with store credits or discounts for returning the used clothing, however, this could also encourage consumers to purchase more clothes (Liu *et al*. 2021). „A policy of extended producer responsibility will exert stronger pressure on businesses and ensure that all apparel items are collected and put back into the system, closing the material loop” (Niinimäki *et al.* 2020, 197). Fast fashion brands have to accept and understand that waste is a part of the fashion business model and take responsibility for it (Niinimäki *et al.* 2020). Some famous fast fashion brands, such as Patagonia, Zara, and H & M, and others have already introduced such take-back schemes in their stores (Ellen MacArthur Foundation 2017). For instance, H & M launched a program „Recycle Your Clothes” in 2013 and, so far, collected around 45,000 tonnes of clothes while setting up a future target of scaling up the clothes collection rate to 25,000 tonnes annually by 2020 (Ellen MacArthur Foundation 2017).

Fig. 101 Global clothes and textile waste management (Eder-Hansen *et al*. 2017)

Regarding clothes and textile reuse, it refers to transferring products towards new owner through a donation to charity or second-hand shops, inheriting, renting, swapping, trading, and borrowing (Shirvanimoghaddam *et al*. 2020). Reuse can be formal or informal (Moazzem *et al.* 2021). Formal reuse includes apparel and textile donation to second-hand shops, online selling, or export overseas, while informal refers to clothes sharing among siblings, friends, and reuse in households (Moazzem *et al.* 2021). Another option is repairing and reconditioning the products to keep them in use for a longer period (Moazzem *et al.* 2021). „Product longevity and a longer use of fashion clothing items can reduce environmental impact significantly" (Patwary 2020, 8). For instance, extending the average clothing life for 3 years could reduce waste generation, carbon, and water footprint by 5-10% (Leblanc 2018). „Estimates show that if the number of times a garment is worn is doubled on average, the GHG emissions would be 44% lower" (Šajn 2019, 5). Further, if reuse of second-hand clothes would replace 1 kg of virgin cotton, that could save up to 64,951 kWh of energy input, while reuse of 1 kg of polyester 89,811 kWh (Woolridge *et al*. 2006). However, extended utilization of garments is in direct conflict with very idea of fast fashion, which promotes throwaway culture (Patwary 2020). Therefore, driving the consumers to use their clothing for longer period requires a major cultural, habitual, behavioral and economic shift (Patwary 2020). Unfortunately, 90 % of consumers in EU countries stated that they do not consider buying secondhand clothing at all (WRAP 2016). On the contrary, wealthy countries such as the US, Australia, the UK, and the EU are the main exporters of second-hand clothing to developing parts of the world. The UK exports around half of collected discarded clothes, mainly to sub-Saharan Africa and Eastern Europe for resale (Moazzem *et al.* 2021). „Australia has a big secondhand clothing market locally and overseas" (Moazzem *et al.* 2021). In Europe, around 70 % of collected clothes are reusable, however, only 20 % are resold in domestic markets, while the rest are sold to textile merchants who sort and ship them overseas, and, of these, about 70% are actually reused (Ellen MacArthur Foundation 2017). The US is a major exporter as exports of secondhand clothing, for the period from 1989 to 2003, more than tripled to nearly 7 billion pounds per year (Claudio 2007). Unsold used clothes are usually compressed into 1000-pound bales and shipped overseas to be “graded” (sorted, categorized, and re-baled) by low-wage workers in low- and middle-income countries and resold as secondhand clothes at local markets (fig. 102) (Bick *et al*. 2018). Clothes that are not sold at local markets become waste, ending up in rivers, greenways, and parks as these countries lack efficient municipal waste systems (Bick *et al.* 2018). Unfortunately, most of the clothes given to nonprofit organizations end up in landfills (Chen and Burns 2006), and only about one-fifth are directly reused or sold in their thrift shops (Claudio 2007). This trend of increasing exports of used clothing to developing countries will continue to accelerate due to rise of consumerism in the US and Europe and the falling prices of new clothing (Claudio 2007).

Fig. 102 A woman shops at a mitumba (Swahili for “secondhand”) market in Nairobi, Kenya (Claudio 2007)

Textile recycling refers to reprocessing preconsumer and postconsumer clothing and textile waste for further use in new textile or non-textile products (Sandin and Peters 2018). Textile recycling can be categorized into:

- Based on nature of process to mechanical, chemical, and thermal;
- The level of disassembly of the recovered material;
- Down cycling, in which textiles are recycled into products of lower quality, or upcycling, where textiles are recycled into higher quality products;
- Open-loop is a process in which recycled materials are used for the production of identical products, or closed-loop/cascading, the process in which recycled materials are used for the production of another product (Shirvanimoghaddam *et al*. 2020).

There are various different reasons for clothes recycling and reusing:

- Textile waste is valuable and convenient for reuse and recycling;

- It saves raw materials, water, and energy required for the production of new clothes and textiles;
- It reduces the carbon footprint and GHG emissions associated with the production of new clothes;
- Reduces generation of waste and disposal to landfills;
- Nurtures a more sustainable society in which individuals are responsible for the conservation of their environment;
- Provides employment and economic development as waste management and recycling are highly labor-intensive processes (Shirvanimoghaddam *et al*. 2020).

However, textile recycling is still at a very early stage and low rate globally. It faces various barriers such as financial, technological, infrastructural, educational, legal, and cost-effectiveness of the process (Shirvanimoghaddam *et al*. 2020). Further, the potential recyclability of various textiles differs due to diverse chemicals used in the manufacturing process (Shirvanimoghaddam *et al*. 2020). The textile industry has done a great job in recycling pre-consumer waste, however, post-consumer waste still poses a major difficulty (Chen and Burns 2006). Post-consumer waste is challenging to recycle due to high heterogeneity as it includes different blends of textiles, chemicals such as dyes, and auxiliary materials, like buttons and zips (Chen and Burns 2006; Moazzem *et al.* 2021). Further, it requires collection from communities, sorting, cleaning, and separation of different textile materials (Moazzem *et al.* 2021). Preconsumer waste is more convenient to recycle due to its homogeneity and easy collection (Moazzem *et al.* 2021). This reflects the lack of technologies for clothes sorting, separating blended fibers, and removal of chemicals such as color from the fabrics (Šajn 2019). Therefore, considering the above mentioned challenges, clothes recycling should be done in different stages of clothes lifecycle, e.g., manufacturing, consumption, and postconsumer waste (Shirvanimoghaddam *et al*. 2020). Most clothes are recycled mechanically, especially ones made from natural materials such as cotton. In mechanical recycling, clothes are first sorted into more than 400 grades depending on their type and quality (Blackburn 2015). Usually clothes pass through two levels of sorting, first, in which home textiles are separated from clothes and second, in which clothes are separated according to their quality, condition, brands, and fiber type (Moazzem *et al.* 2021). One of the promising technologies for clothes sorting is Near Infrared (NIR) technologies such as hyperspectral imaging and visual spectroscopy (VIS), which will enable fast sorting of clothes by color and material type (Ellen MacArthur Foundation 2017). This technology can reach sorting speeds of up to one garment per second, however, multicolored garments could still pose a difficulty (Ellen MacArthur Foundation 2017). Further, sorted clothes pass through several mechanical processes such as cutting, shredding, and carding (Moazzem *et al.* 2021). The cut and shredded materials are then passed through a fiber separation drum to obtain fine flet (Moazzem *et al.* 2021). The following treatments eliminate short fibers and dust, providing the desired quality (Moazzem *et al.* 2021). Obtained materials are further used for the production of new products. However, mechanical recycling lowers the quality of fibers, as they are shortened they lose about 75 % of their original value (Šajn 2019). Thus, they are often blended with longer fibers such as virgin cotton or polyester in order to regain the original quality (Ellen MacArthur Foundation 2017). The necessary input of virgin polyester and cotton fibers should come from renewable resources (Ellen MacArthur Foundation 2017). Usually, „a maximum of 20% post-consumer mechanically recovered cotton fibers can be blended with virgin cotton before strength is compromised" (Niinimäki *et al.* 2020, 197). Due to this quality loss, obtained recycled materials are usually down-cycled and used for manufacturing lower-quality products such as insulation material, wiping cloths, mattress stuffing, carpet underlay, furniture removal felt, or weed suppression (Šajn 2019; Moazzem *et al.* 2021). High-quality discarded clothing could be used for remanufacturing another product such as napkins, wallets, and slippers (Moazzem *et al.* 2021). Recycling cotton could save up to 20,000 liters of water per kilogram, as cotton is a water-intensive crop, and its cultivation requires enormous amounts of water (Claudio 2007). Other recycling methods, such as chemical or thermal, are more efficient compared to mechanical recycling. Chemical recycling is usually used for synthetic fibers such as polyester, nylon or polypropylene, and cellulose fibers (Ellen MacArthur Foundation 2017; Moazzem *et al.* 2021). Recently, chemical recycling has been available for also cotton fabrics, while for blends is still being developed (Ellen MacArthur Foundation 2017). In chemical polymer recycling, chemicals are applied to dissolve textiles into polymer level after the garments have been de-buttoned, de-zipped, de-colored, and shredded into small granules (Ellen MacArthur Foundation 2017). Unlike mechanical recycling, chemical recycling has a greater fiber preservation rate, which enables the production of new products with higher participation of recycled fibers, promoting upcycling (Niinimäki *et al.* 2020). In this way, up to 100% recycled yarn can be produced (Heikkilä 2019). However, the quality of recycled polyester may still not be as good as virgin polyester (Kadolph 2007). Nevertheless, chemical recycling can save up to 76% of energy and 71% of CO2 emissions compared to the production of virgin polyester (Fletcher 2014). One study shows that chemical recycling of one tonne of textile waste could save around 10 tonnes of CO2eq and 169 GJ of energy compared to incineration (Zamani *et al*. 2015). Further, as synthetic clothes can be produced from recycled plastic bottles, recycling would keep them from entering aquatic resources and ocean. For example, estimates show that around 2.4 billion plastic bottles are kept from reaching landfills each year in the US through the manufacturing of 100% recycled polyester fibers (Rudie 1994). Unfortunately, recycled polyester still accounts for only 14 % of the total polyester market share (Niinimäki *et al.* 2020). Thermal recycling is usually used for thermoplastics, such as polyester, and in this process, fibers are melted and spun into new yarn for further production of new products (Heikkilä 2019). Increased recycling represents an opportunity for the industry to capture a value of more than USD 100 billion worth of materials and to reduce the negative impacts of their disposal (Ellen MacArthur Foundation 2017). The EU set a goal to collect, sort, and recycle all generated textile waste in each member state by 2025 (Šajn 2019).

Regarding textile incineration, it involves burning textile waste under controlled conditions for energy recovery (Moazzem *et al.* 2021). Incineration can be divided into thermal waste treatment without heat generation and treatment with heat production (Moazzem *et al.* 2021), further used as fuel for other purposes such as electricity generation. The main advantage of incineration is that collected waste does not require separation and can be directly transported and treated (Moazzem *et al.* 2021). However, it produces a lower amount of recoverable energy and generates ash and emissions of concern without proper controlling measures (Muthu 2020; Ellen MacArthur Foundation 2017). In some cases, as textile waste can include chemicals that are not recyclable or recycling is not possible, textile incineration with energy recovery can be more sustainable than recycling materials (Niinimäki *et al.* 2020).

5. Recommendations

5.1 Circular economy approach in the fast fashion industry

Currently, fast fashion and textile industries are relying and operating on a completely unsustainable and linear clothes production, distribution, and utilization economic model. It rests on take-make-dispose patterns, which leave valuable economic opportunities untapped, degrade and pollute the environment at local, regional, and global scales, create significant negative social impacts and pose severe pressure on already scarce natural resources. Fast fashion business logic thrives on ever-growing production and sales, fast clothes manufacturing, low clothes quality, and short life cycles, ignoring the finiteness of natural resources while leading to problems such as unsustainable consumption, fast material throughput, substantial waste generation, and other various environmental and social consequences (Niinimäki *et al*. 2020). However, in recent years there has been a growing social, academic, and governmental concern about such unsustainable linear production and consumption economic model (Ostermann *et al.* 2021). It is becoming clear that fast fashion and textile industries can no longer ignore the fact that the present economic linear model (take-make-dispose) is dysfunctional, with slim chances of effectively adopting sustainable development principles (Koszewska 2018). This calls for radical changes of the entire system and in both current production and consumption patterns. Thus, a circular economy has been recognized as key leverage which could enable such changes and transition toward a more sustainable economic system. Therefore, in recent years, the circular approach has attracted greater attention worldwide from individuals, the business sector, industries, governments, scientists, and academia (Abdelmeguid *et al*. 2022; Koszewska 2018). "It is an economic model that seeks to reorganize the relationship between human economic activities and the environment, proposing a circularity logic in opposition to the current economic model" (Ostermann *et al*. 2021, 224). "It emerges as a new paradigm in systems, economics, value, production and consumption"

(Ostermann *et al*. 2021, 225) and as an alternative to a traditional economy, in which resources are kept in the loop for as much time as possible, with the high maintenance of their original value, and repurpose through generation of new products at the end of utilization through reuse and recycling (Shirvanimoghaddam *et al*. 2020) (fig. 103). While in a linear economy, the main business strategies are fast replacement of products, production optimization, and economies of large scale, a circular economy represents a new economic order which focuses on the recovery of material flows and decoupling of wealth and welfare from resource consumption (Stahel 1986; Stahel 2013). It aims to achieve the decoupling of economic growth from natural resource depletion and environmental degradation (Cooper 1999; Murray *et al*. 2015). Resource flows are optimized and used in a closed loop over and over again, reducing the virgin material and resource inputs (Dissanayake and Weerasinghe 2022). Thus, the circular economy is "a regenerative system in which the entry of resources and waste, emission and loss of energy is minimized by the deceleration, closing and narrowing of material and energy circuits" (Geissdoerfer *et al*. 2017, 766). In other words, the circular economy rests on three key strategies to achieve circularity, defined as slowing, narrowing, and closing the resource loops (Dissanayake and Weerasinghe 2022). Slowing resource loops refer to the extension and intensification of product's use phase, mainly through the production and design of higher quality and long-life goods (Bocken *et al*. 2016). Narrowing loops focuses on reducing the resource inputs during product manufacturing (Bocken *et al*. 2016). Finally, closing the loops relies on reuse and recycling (Bocken *et al*. 2016).

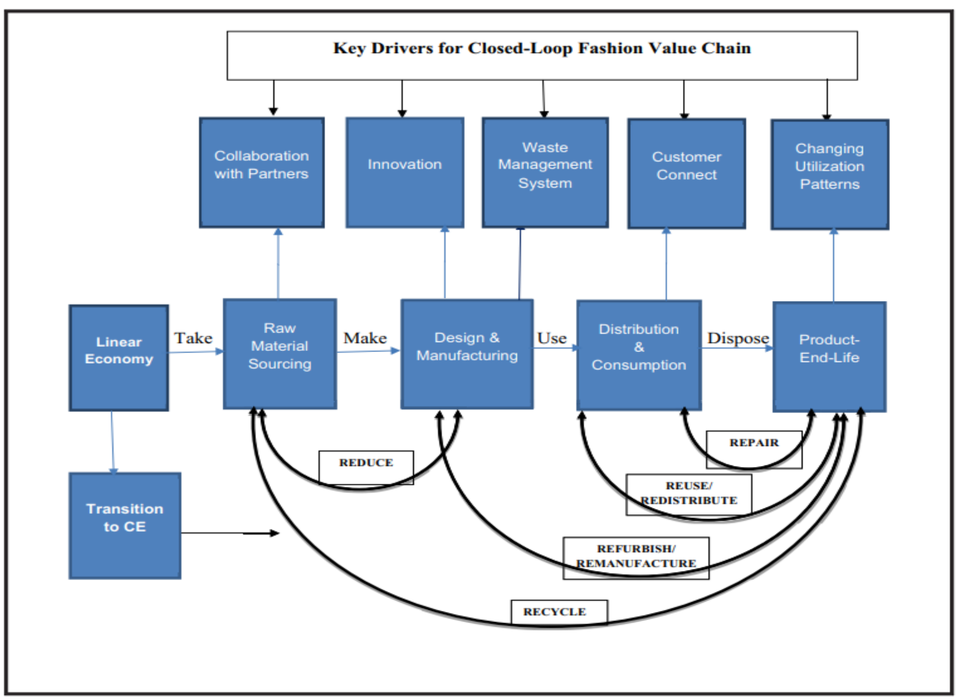


Fig. 103 Transition towards circular economy (Mishra *et al*. 2020)

The circular economy sees waste as a valuable resource. Its framework is shaped by 3R (reduce, reuse, recycle) principles, which must be applied throughout the whole cycle of production, consumption, and return of resources (Koszewska 2018). Thus, circular economy refers to moving away from the linear approach and landfills towards circularity through reuse and recycling. Apart from this, other relevant principles for achieving circularity include sustainable design, zero-waste design, product-life extension, resource recovery, repair, and remanufacture (Koszewska 2018). Sustainable clothes design is crucial for achieving circularity in the fast fashion industry. More than 80% of the environmental impacts of products are pre-determined during the product design stage (European Commission 2014). Thus, designers play a vital role in changing the current paradigm toward a more sustainable fashion and circular approach. They decide which materials are going to be used, how long the products will last and how emotionally attached consumers will be to apparel (Patwary 2020). "In the future, garments must be designed to be suitable for recycling and closing the material loop must be the norm, requiring systematic changes in the industry." (Rukhaya et al. 2021, 520). However, the responsibility should not only lie with the designers, instead, it should involve all parties along the supply chain (Moorhouse 2020). Thus, the producers, retailers as well as consumers represent crucial links in achieving a holistic approach toward fashion circularity and sustainability. One of the approaches to force producers and retailers to take responsibility is through "extended producer responsibility". This ensures that all used clothes are collected, reused, and recycled either through companies setting up their own clothes collection schemes or through financing accredited collectively responsible organizations (Šajn 2019). Apart from this, another approach to circularity includes an extension of the garment lifetime through clothes repair and maintenance practices. Again, retailers can organize repair and maintenance schemes in their stores.[3] This would enable the extension of clothes service time while creating long-lasting relationships with the customer and additional revenue streams for the retailer (Dissanayake and Weerasinghe 2022). Other emerging circular approaches are subscription models, which allow consumers to pay a flat fee to rent or lease a certain number of clothing items (Dissanayake and Weerasinghe 2022). Some brands have already offered clothes as a service, leasing clothes instead of selling them (Šajn 2019). These models are ideal for fashion-minded consumers who frequently change their outfits (Dissanayake and Weerasinghe 2022).

Apart from circular fashion, another model opposing fast fashion is sustainable fashion. It refers to clothes manufacturing by ethical means (Rukhaya *et al.* 2021). Sustainable approaches must be adopted throughout the whole supply chain, from designing, manufacturing, and retailing, and in such a manner that will maximize benefits for people and communities while at the same time minimizing negative environmental impacts (Rukhaya *et al.* 2021). Sustainable fashion is part of the circular economy and includes several terms such as eco-fashion, ethical fashion, and slow fashion (Matušovičová 2020) (fig. 104). Eco-fashion emphasizes the quality of materials and clothes production with minimal environmental impact (Matušovičová 2020). Ethical fashion involves the same approach as eco-fashion, but in addition, it integrates social issues into the

[3] For example: In 2005, Patagonia introduced a policy to repair consumer's clothing without any charge (Moazzem *et al*. 2021).

approach (Matušovičová 2020). Its concern goes beyond poor working conditions within the fast fashion industry, also integrating the industry's negative impacts on the consumer's health (Matušovičová 2020). Slow fashion includes all components, from fashion designers to material suppliers, producers, distributors, and end customers (Matušovičová 2020). Lately, "slow fashion is becoming an important part of the new concept of circular economy, where the product and material are part of the cycle for as long as possible, thus reducing the amount of waste generated" (Matušovičová 2020, 215). In contrast to fast fashion, it focuses on and prioritizes clothes quality over quantity (Matušovičová 2020). Slow fashion recognizes completely different patterns of clothes production and consumption. It incorporates conscious clothes consumption with a holistic view to the issue (Matušovičová 2020). Its aim is not to stop clothes production but rather to slow it down, emphasizing product longevity and quality, and not quantity and rapidly changing trends as fast fashion (Ting and Stagner 2021; Matušovičová 2020). Its goals are to increase clothes life span, slow production and consumption rates, and fast changing seasons and trends (Kongelf and Camacho-Otero 2020). There are five dimensions of slow fashion (Jung and Jin 2014). The first one refers to equality and justice, especially in the area of clothes manufacturing and the improvement of working conditions (Jung and Jin 2014). The second one is authenticity which recognizes traditional techniques and crafts to make unique products (Jung and Jin 2014). Functionality focuses on product's maximum use, usefulness, and versatility (Jung and Jin 2014). Another dimension emphasizes locality through use of local raw materials and local production (Jung and Jin 2014). Lastly, exclusivity focuses on unique pieces of clothing through which consumers will be able to express their personalities (Jung and Jin 2014).

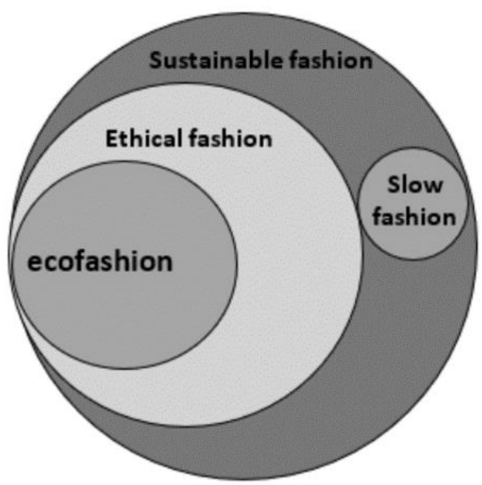


Fig. 104 Categories of sustainable fashion (Matušovičová 2020)

Conclusion

Since the industrial revolution, the textile and fashion industries have leaned on a linear economic model. Our consumerism and disposal behavior have turned the planet into a take-make-dispose world with negligence of finite natural resources, as well as social and environmental consequences. The transition towards a circular economy will require a paradigm shift and moving away from such take-make-dispose model, with major changes in current production and consumption patterns. This new economic order rests on the replacement of the current end-of-life concept, the increasment of renewable energy input, elimination of toxic chemicals and waste through superior product design and business models in general (Koszewska 2018). The transition to a circular economy not only solves environmental and social problems but also builds and creates a system with long-term resilience, generating new business and economic opportunities with environmental and societal benefits (Ellen MacArthur Foundation 2017). Major cultural and economic changes with large scale global collaboration are paramount for its success. There is no standardized approach for achieving circularity (Koszewska 2018). The speed and extent of transition towards a circular economic model will largely depend on the level of awareness, knowledge, and engagement of all fashion industry participants (Koszewska 2018). One of the biggest challenges for successful circular approach implementation is the highly globalized, complex, and fragmented fashion supply chain which includes many stakeholders (Dissanayake and Weerasinghe 2022). This will require creativity and close collaboration between designers, manufacturers, retailers, various stakeholders, governments, and consumers (Rukhaya *et al*. 2021). Both the supply and the demand sides of the fashion supply chain have to take responsibility for their sustainable actions (Patwary 2020). Brands and retailers must push the suppliers to carry on their operations more sustainably (Patwary 2020). On the other hand, local governments have to ensure that suppliers conduct their business in accordance with sustainability guidelines, while the local governments have to be guided by international bodies in order to align their environmental regulations with global sustainable targets (Patwary 2020). Also, a central governing and monitoring body at the global level is imperative, which will ensure, monitor, and encourage the fashion industry to hit the set global targets (Patwary 2020). Apart from this, designers play a vital role in achieving circularity and are at the front line of the sustainable fashion model. They must keep in mind the environmental consequences of their decisions and the environmental footprint of their product design. They have to be pro-environmental and oriented towards sustainability with a circular fashion mindset. The clothes must be more durable, resilient with longer service time, made from recyclable and biodegradable materials with lower environmental footprint. Even though it is almost impossible to produce a hundred percent clean and green clothing item (Patwary 2020), the designers and fashion industry must make an effort to make clothes more sustainable. Unfortunately, due to highly competitive fast fashion market and organizational target profits, designers are under constant pressure to design cheap, disposable, and fashionable clothes as quickly as possible, leaving small chances to truly implement and follow sustainable agenda. Suppliers and fashion retailers have to take responsibility for generated waste streams. Here, the governments could play a vital role by introducing the extended producer responsibility schemes for the textile and fashion industries (Liu *et al*. 2021). Collection and recycling of textile waste must be performed on a large scale, closing the loop at the global level. Introduced governmental policies and regulations will be the most effective tools for achieving large-scale changes, forcing the fashion industry to take action and responsibility for generated textile waste streams across the entire supply chain. Unfortunately, many fast fashion companies are unwilling to use recycled materials due to their lower quality (Dissanayake and Weerasinghe 2022). In some cases, recycling can be more expensive than purchasing virgin materials due to lack of technology for adequate textile waste collection, sorting, and recycling (Dissanayake and Weerasinghe 2022). Thus, many fashion companies do not see waste as a valuable resource, but as a cost, which creates barriers for transition to a circular model and closing the loop (Dissanayake and Weerasinghe 2022). Besides, recycling, remanufacturing and packaging regulations and legislations, the governments can also enforce more sustainable manufacture practices across the entire fashion supply chain (Jia *et al*. 2020). Apart from managing already generated waste, waste prevention will be one of the main challenges the textile and fast fashion industries will face while transitioning to the circular economy (Koszewska 2018). Its success will largely depend on how products are designed, produced and consumed (Koszewska 2018). Closer collaboration between designers and producers could play a vital role, in creating a new kind of low waste-driven sustainable design-manufacturing-consumption model (Rukhaya *et al*. 2021). However, circularity alone will not be enough if the fashion industry does not switch to renewable energy and change consumption patterns (Patwary 2020). Textile and fast fashion industries must identify energy-intensive hotspots along the fashion supply chain and make the transition toward renewable energy. Further, current oil-based synthetic fibers must be replaced with plant-based sustainable fibers with a lower carbon footprint. Unfortunately, the circular economy model and its application are still relatively low and unexplored by the fashion industry, mainly due to market competition and profit. Further, the lack of consumer's consciousness, willingness, and limited knowledge have been highlighted as major barriers for the transition toward a circular economy (Dissanayake and Weerasinghe 2022). Consumers must dismiss their current mindset in which fashion is seen as a form of entertainment. They need to understand clothes more as functional products, consume more consciously, and be willing to pay higher prices for environmentally friendlier clothes (Rukhaya *et al*. 2021). Awareness and knowledge about the impact of their actions are the key factors that can lead to higher understanding, taking proper action, behavior, and cultural shift. Consumers must consume clothes more reasonably, give advantage to durable apparels, care for the apparels consciously and dispose them in an appropriate way (Patwary 2020). They can choose slow fashion instead of fast fashion, buying less, second-hand, recycled, or higher quality clothes (Ting and Stagner 2021). However, unfortunately, some consumers do not consider these options at all, as they see second-hand and recycled clothes as lower quality products. Also, due to limited or low purchasing power, some consumers are unwilling to pay extra money for environmentally friendlier or higher quality clothes. Further, clothes service time has to be extended through proper care, repairing, or further utilization for other purposes. New models, such as clothes renting and swapping, offer consumers more opportunities to reuse clothing. Returning used clothes back to the producer will require high consumer commitment and a new level of relationship between consumers and producers (Dissanayake and Weerasinghe 2022). Further, both manufacturers and consumers must value the higher quality and durability of clothing (Ting and Stagner 2021). Brands and retailers are in a unique position as they are the ones who design and sell clothes and introduce new seasons, trends, and styles. Thus, they have the power to influence and change purchasing behavior through different value propositions, changes in the pace of seasons, trends and product offerings, and marketing expertise (Patwary 2020). Apart from this, local governments, media (traditional and social media), NGOs, non-profit and international organizations play a vital role in disseminating relevant information and enhancing awareness (Patwary 2020). Thus, consumers will have a major role in making the fashion industry sustainable. However, instead of waiting for the fashion industry to solve global environmental and social problems, it is everyone's duty to take further action to do their part in the transition towards a more sustainable fashion industry and take responsibility for the impacts of their purchases decisions on the environment, locally and globally.

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Appendices

Survey (original version in English)

1. How old are you?

____

2. Gender:

- Male
- Female

3. Level of education:

- Elementary school
- High school
- Bachelor
- Master
- Ph.D.

4. What is your occupation?

____

5. What is your social status?

- Upper class
- Upper-middle-class
- Middle class
- Working-class
- Poor

6. How much is your monthly income?

- I do not have an income (student, unemployed, retiree)
- Minimum wage 35.000 RSD (300 EUR)
- 35.000-50.000 RSD (300 EUR- 425 EUR)
- 50.000-100.000 RSD (425 EUR- 850 EUR)
- Above 100.000 RSD (850 EUR)

7. Are you familiar with the concept of fast fashion?

- Yes, I know well what is fast fashion
- I heard about it, but I do not know exactly what is fast fashion
- No, I am not

8. Are you familiar with the concept of slow fashion?

- Yes, I know well what is slow fashion
- I heard about it, but I do not know exactly what is slow fashion
- No, I am not

9. Did you know that fast fashion is the second polluting industry, right after the oil industry?

- Yes, I am familiar with that
- No, did not know that

10. Are you aware of environmental problems associated with the fast fashion industry, such as resource depletion, intense water and chemical utilization, discharge of heavily polluted wastewaters and freshwater pollution, and GHG emissions?

- Yes, I am familiar with that
- No, I did not know that

11. Are you familiar with poor working conditions (low wages, unsafe environment, abuse, sexual harassment, child labor) which workers face in the fast fashion industry?

- Yes, I am familiar with that
- No, I did not know that

12. Do you follow fast fashion seasons and trends?

- Yes, I follow every new style, trend, and season
- I follow only sometimes if I like the trend
- I very rarely follow fashion trends
- No, I do not follow fast fashion at all

13. Do you purchase clothes in fast fashion stores such as H&M, Zara, Stradivarius, Bershka, and other fast fashion stores?

- Yes, I always purchase my clothes in fast fashion stores
- I purchase clothes in fast fashion stores occasionally
- I very rarely purchase clothes in fast fashion stores
- No, I do not purchase my clothes in fast fashion stores at all

14. Do you purchase clothes in second-hand stores?

- Yes, I always purchase my clothes in second-hand stores
- I purchase clothes in second-hand stores occasionally
- I very rarely purchase clothes in second-hand stores
- No, I do not purchase my clothes in second-hand stores at all

15. Are you aware that purchasing clothes in second-hand stores is more environmentally friendly than in fast fashion stores?

- Yes, I am very aware of that
- Yes, I hear about it, but I am not familiar why
- No, I do not know that

16. What is the most important factor for you when purchasing clothes?

- Price of clothes
- Quality of clothes
- Trends and style
- Composition of clothes
- Environmental aspect of clothes

17. Do you pay attention to clothes composition while purchasing?

- Yes, I always pay attention to clothes composition
- Sometimes I am interested in checking clothes composition
- I rarely check the clothes composition
- No, that is not important to me at all

18. Of these fibers, which one is the most environmentally friendly in your opinion?

- Cotton
- Synthetic fibers
- Wool
- Hemp

19. Would you give more money for clothes that is environmentally friendlier?

- Yes
- No

20. How many clothes do you purchase per year in kg (without footwear)?
    ____

21. How many pieces of clothing do you usually purchase per year (without footwear)?
    ____

22. How much income do you usually spend on clothes per year (without footwear)?
    ____

23. How long do you usually utilize the clothes such as t-shirts, jeans, dresses, and other, before disposal?

- Less than a month
- Less than 6 month
- Less than a year
- 1-2 years
- 3-4 years
- 5 years or more

24. What do you usually do with clothes that you do not need anymore?

- I usually give them away to someone else (friends, family members)
- I give them to charity
- I just keep them in my closet
- I repair them or find a way to use them for something else
- I toss them away
- Something else

Anketa (survey translated into Serbian language)

1) Koliko imate godina?

____

2) Pol:

- Muški
- Ženski

3) Level edukacije:

- Osnovna škola
- Srednja škola
- Fakultet
- Master studije
- Doktorske studije

4) Čime se bavite?

____

5) Koji je Vaš socijalni status?

- Viša klasa
- Viša-Srednja-klasa
- Srednja klasa
- Niža-radna klasa
- Najniža klasa

6) Kolika su Vaša mesečna primanja?

- Nemam primanja (student, nezaposlen, penzioner)
- Minimalna plata 35.000 RSD (300 EUR)

- 35.000-50.000 RSD (300 EUR- 425 EUR)
- 50.000-100.000 RSD (425 EUR- 850 EUR)
- Iznad 100.000 RSD (850 EUR)

7) Da li ste upoznati sa konceptom brze mode?

- Da, veoma dobro znam šta je brza moda
- Čula sam o tome, ali ne znam tačno šta je brza moda
- Ne, nisam

8) Da li ste upoznati sa konceptom spore mode?

- Da, veoma dobro znam šta je spora moda
- Čula sam o tome, ali ne znam tačno šta je spora moda
- Ne, nisam

9) Da li ste znali da je industrija brze mode drugi najveći zagadjivač odmah posle naftne industrije?

- Da, upoznat/a sam sa tim
- Ne, nisam to znao/znala

10) Da li ste svesni ekoloških problema povezanih sa konceptom brze mode kao što su degradacija i trošenje prirodnih resursa, intezivno korišćenje vode i hemikalija, ispuštanje teško zagađenih otpadnih voda i zagađenje vodnih resursa i emisija gasova sa efektom staklene baste?

- Da, upoznata sam sa tim
- Ne, nisam to znao/znala

11) Da li ste upoznati sa lošim radnim uslovima (niske plate, rizična radna sredina, mobing, seksualno uznemiravanje, rad dece) sa kojima se radnici susreću u tekstiloj i industriji brze mode?

- Da, upoznata sam sa tim
- Ne, nisam to znao/znala

12) Da li pratite sezone i trendove brze mode?

- Da, stalno pratim svaki novi stil, trend i sezonu
- Pratim samo ponekad ako mi se sviđa trend
- Veoma retko pratim modne trendove
- Ne, uopšte ne pratim trendove brze mode

13) Da li kupujete odeću u prodavnicama brze mode kao što su H & M, Zara, Stradivarius, Bershka i drugim radnjama brze mode?

- Da, uvek kupujem odeću u prodavnicama brze mode
- Kupujem odeću u prodavnicama brze mode samo ponekad
- Veoma retko kupujem odeću u prodavnicama brze mode
- Ne, uopšte ne kupujem odeću u prodavnicama brze mode

14) Da li kupujete odeću u second-hand prodavnicama?

- Da, uvek kupujem odeću u second-hand prodavnicama
- Kupujem odeću u second-hand prodavnicama samo ponekad
- Veoma retko kupujem odeću u second-hand prodavnicama
- Ne, uopšte ne kupujem odeću u second-hand prodavnicama

15) Da li ste svesni da je kupovina odeće u second-hand prodavnicama ekološki prihvatljivija nego u prodavnicama brze mode?

- Da, veoma sam svestan/a toga
- Da, čuo/čula sam o tome, ali nisam siguran/a zašto
- Ne, nisam to znao/znala

16) Koji je najvažniji i odlučujući faktor za Vas prilikom kupovine odeće?

- Cena odeće
- Kvalitet odeće
- Trendovi i stil
- Sastav odeće
- Ekološki aspekt odeće

17) Da li obraćate pažnju na sastav odeće prilikom kupovine?

- Da, uvek obraćam pažnju na sastav odeće
- Ponekad sam zainteresovan da proverim sastav odeće
- Veoma retko proveravam sastav odeće
- Ne, to mi uopšte nije važno

18) Od ponuđenih vlakana, koji po Vašem mišljenju ima najmanji uticaj na životnu sredinu?

- Pamuk
- Sintetička vlakna
- Vuna
- Konoplja

19) Da li biste dali više novca za odeću koja ima manji uticaj na životnu sredinu i ekološki je prihvatljivija?

- Da
- Ne

20) Koliko prosečno odeće kupite u kg za godinu dana (bez obuće)?

____

21) Koliko komada odeće uglavnom kupite tokom godinu dana (bez obuće)?

22) Koliko prosečno primanja potrošite na odeću tokom godinu dana (bez obuće)?

23) Koliko dugo koristite odeću kao što su majice, farmerice, haljine i drugo, pre nego što ih odbacite?

- Manje od mesec dana
- Manje od 6 meseci
- Manje od godinu dana
- 1-2 godine
- 3-4 godine
- 5 godina i više

24) Šta uglavnom radite sa odećom koju više ne koristite?

- Uglavnom poklanjam nekom drugom (prijateljima, porodici)
- Doniram u dobrotvorne svrhe (crveni krst i dr.)
- Držim odeću u ormaru
- Popravljam ili nalazim način da koristim za neke druge svrhe
- Bacam
- Nešto drugo