



Waste Management in the Textile Industry

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ABSTRACT

In the management system of large companies, environmental protection is increasingly becoming one of the more important subsystems in terms of the generation of industrial waste. In order to manage the impact a factory's production process on the environment as efficiently as possible, it is necessary to control certain quality parameters of emissions into the environment, and activities to minimize the impact of emissions and pollution, from the moment the raw materials arrive until the product leaves the warehouse as a finished product. By analyzing the technological process, the method of waste management is defined, i.e. the types, composition and quantities of waste generated in the textile plants are determined. By constantly analyzing the existing waste management system, the currently implemented measures and possible shortcomings and omissions are constantly reviewed, on the basis of which measures to improve waste management are proposed. The paper describes the impact of waste management in the textile industry on the environment, i.e. examples of the management flow of industrially generated hazardous and non-hazardous waste - characterization of industrial waste, disposal methods and proposals for their reduction.

1. Introduction

According to the provisions of the Waste Management Law (36/2009, 88/2010, 95/2018, 35/2023), waste means any material or object that is present in the current production, service or other activity, objects that are not intended for use, as well as waste material that is present in the consumer and that is part of the production process, i.e. it is consumed for further use and must be rejected.

Therefore, waste is considered to be everything that is thrown away, intended to be thrown away or has to be thrown away.

In accordance with Waste Management Law (36/2009, 88/2010, 95/2018, 35/2023), waste is divided, according to the source, into:

- 1) communal waste (household waste);
- 2) commercial waste; and
- 3) industrial waste.

Waste can be classified according to its composition (waste oils, waste tires, used accumulators and batteries, etc.) or depending on the dangerous characteristics that affect human health and the environment (inert, non-hazardous, and hazardous waste). Some classification systems combine different ways of classifying waste within one system. Industrially generated non-hazardous waste predominates.

Every movement of waste is accompanied by a document on the movement of waste, and its form is prescribed by a special Rulebook (17/2017), and

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consists of four parts:

- Part A - data on waste;
- Part B – data on the waste producer;
- Part C – data on the waste carrier; and
- Part D - data on the recipient of the waste.

Each member of this chain is obliged to guarantee the accuracy of the data by signing and certifying their part and, at the end of the year, the summary report is sent to the Environmental Protection Agency on the specially designed portal of that state institution. Textile wastes arise out of many production processes, such as fiber and filament manufacture, spinning, weaving, knitting, nonwoven, and clothing manufacturing (Bhatia et al., 2014). In this context, textile wastes can be classified as pre-consumer and post-consumer wastes (Chen and Burns, 2006; Damayanti et al., 2021). Pre-consumer textile waste includes manufacturing waste from the processing of fibers, yarn, fabric, and nonwovens and clothing manufacturing (Rani and Jamal, 2018). Pre-consumer textile waste is generally seen as “clean waste” as it is released during the textile production process (Chavan, 2014; Labayen et al., 2022). About a quarter of chemicals produced globally are used in the textile industry (Greenpeace International - Dirty Laundry, 2011). Numerous chemicals are used for textile production, mainly in the wet processing and many of them (nearly 2000 different chemicals), have adverse impacts on health.

Some chemicals evaporate, while others are dissolved in treatment water which ultimately goes back to the environment, and some chemicals remain in the product (Choudhury, 2014).

Producing cellulose-based fibers also necessitates large

amounts of chemicals and some of the chemicals used are sources of concern. Producing the fibers requires using chemicals too, for example for dyes or finishing treatments. This part of the production is estimated to use approximately 43 million tons of chemicals globally (Ellen MacArthur Foundation, 2017).

The waste generated by producing and consuming textiles is major problem. Textile consumption around the world is calculated to be over 100 million tons (Harder, 2019). However, the rate of recycling is rather low: barely 13 % of the total material input is in some way recycled after usage. Of this recycled 13 %, a minuscule part is used to produce new clothing-less than 1 % (Abede, 2021).

The rest is recycled into other, lower-value items such as insulation material, wiping cloths or mattress stuffing (Ellen MacArthur Foundation, 2017). Textile and clothing waste causes environmental problems and deterioration of ecological balance. Unfitting and uncontrolled disposal of waste cause major problems, (Xie et al., 2021).

Recycling of textile waste and diversifying the content of recycled raw materials could be a way to support the country’s economy. The employment opportunities in the textile sector and in other sectors increase with well-run waste management. The recycling sector is an important supplier to many industries, and wastes are considered to be cheap raw materials (Gizem et al., 2023).

1.1. Treatment of textile industry plants generated waste

In accordance with the Rulebook (56/2010, 93/2019, 39/2021), Table 1 shows an example of waste generated list by the performance of certain business activities of the textile factory work units.

Table 1

Example of a list of waste generated from the textile industry (Alendarević, 2022; Krivokuća, 2022)

| Name of the waste | Note |
|--|--|
| Textile industry waste | |
| Paints and pigments containing hazardous substances | Residues after painting that go into the waste water pool |
| Sludge from wastewater treatment at source | It is possible that sludge will remain after the treatment of waste water, after the reconstruction of the system |
| Waste from processed textile fibers | Whole pieces (white and colored), pieces that are created by cutting off a certain part during the formation of the final product Specific pieces - "laces" (potential official by-product) |
| Waste not otherwise specified | Other textile waste - whole pieces, cutting residues, textile fibers, etc. |
| Wastes from production, formulation, supply and use and removal of paints and varnishes | |
| Waste paint and varnish | Waste soluble powder dyes for the textile industry |
| Waste hydraulic oils | |
| Other hydraulic oils | From cooling compressors, from compressors for compressing air |
| Waste motor oils, gear oils and lubricants | |
| Other waste motor oils, gear oils and lubricants | They do not remain after servicing the vehicle, because the service technician keeps them |

Table 1 continued

Example of a list of waste generated from the textile industry (Alendarević, 2022; Krivokuća, 2022)

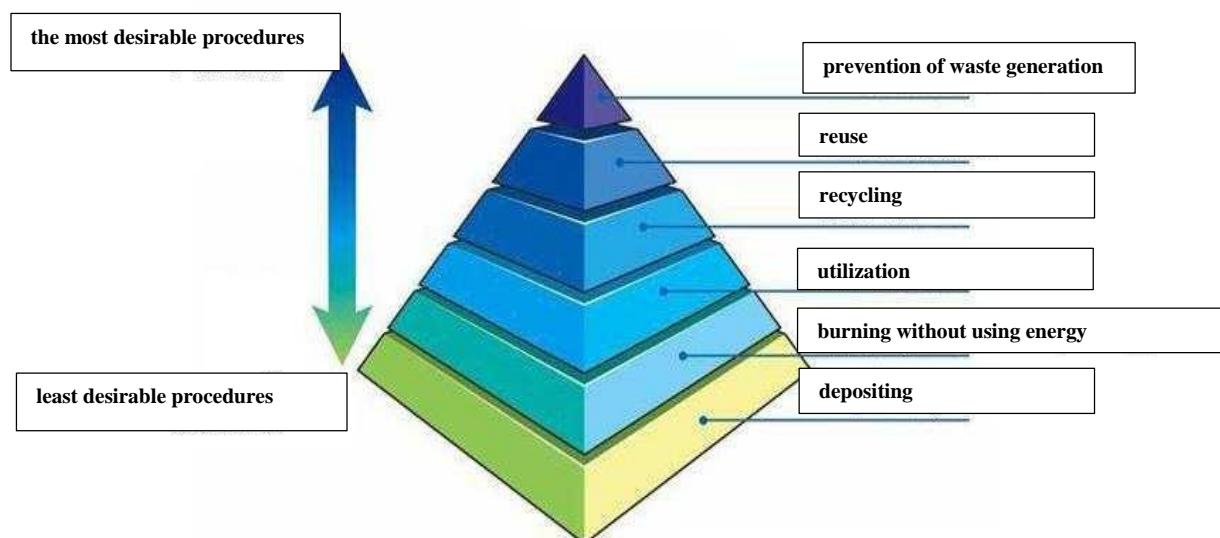
| Name of the waste | Note |
|---|--|
| Packaging (including specially collected packaging in municipal waste) | |
| Paper and cardboard packaging | Cardboard boxes, partitions, Cardboard packaging („hizne“) A. Used polyethylene bags and stretch film, B. stands for packaging („hizne“) made of various materials (polypropylene, polystyrene, colored PET), C. plastic packaging („hizne“, mainly made of polypropylene) D. plastic packaging, barrels of auxiliary substances used in the process of dyeing product, they are made of HDPE – one of the types of polyethylene; F. PE bags for transport various type of products |
| Plastic packaging | |
| Wooden packaging | Broken pallets that are not of EU standards |
| Metals (including their alloys) | |
| Aluminium | Waste from scrapped machines, boiler house overhaul, etc. |
| Iron and steel | Waste from scrapped machines, boiler house overhaul, etc. |

Due to its specificities, the complete treatment of waste in manufacturing textile plants is defined on the basis of signed contracts only with companies that are authorized and registered for the circulation and processing of waste which have all the necessary documentation on the fulfillment of the conditions in terms of environmental protection. All necessary conditions for its management are prescribed for each type of waste. Also, the method of disposal of waste, i.e., its final disposition, is recorded and operational instructions are drawn up (within job descriptions, work methods, etc.) by workplace or for a group of jobs. These operating instructions represent binding activities for all employees in textile manufacturing plants.

The locations of collecting places, labeling and sorting waste materials in manufacturing textile plants are

defined according to the place of their origin within the organizational unit. Places of temporary storage can be located outside the production or warehouse areas (concrete plateau) within the factory area. Any generated waste is disposed of, i.e. handed over to operators who have the appropriate permit. Each type of generated waste is assigned a waste index number through characterization in an accredited laboratory. The basic principles of the waste management hierarchy are shown in Figure 1.

The resulting waste is handed over to the authorized operator with the document on the movement of waste, who closes the document on the movement of waste within the legal term, i.e. submits information on the recipient of waste (storage, exporter, recycler, and co-incinerator).

**Figure 1.** Hierarchy of waste management (Metaling p.u.t. <https://www.metaling.rs/karakteristike-odrzivog-upravljanja-otpadom.html>)

2. Material and Methods

2.1. Method of storage, treatment and disposal of waste

The production process in textile plants results in the generation of certain types of waste materials, which are deposited in sacks, boxes, wooden boxes, or containers designated for that purpose, placed within the work unit framework whose activities generate the type of waste according to the type of technological/production process. Although there are several methods for disposing of clothing waste, the most effective methods are recycling and reuse. The assessment of waste clothing is very complex because clothing is made from different raw materials and may contain different additives (Risteski et al., 2020). Garments can have many components such as labels, sewing thread, buttons, zippers, and interlining, and these components make the separation process difficult. Clothing recycling and textile recycling are two independent topics that are needed to be considered separately (Xie et al., 2021).

Places for the disposal of certain waste are marked with signs on which there are inscriptions about the name of the waste. Figure 2 shows an example of marking the storage area in a textile manufacturing plant. Signs for waste marking are placed at locations intended for proper and orderly storage of waste within the company.



Figure 2. Marking of waste collection locations (Alendarević, 2022; Krivokuća, 2022)

3. Results and Discussions

Packaging is an important element of the industry providing protection, handling, marketing promotion, and other functions. The common packaging materials used in the industry are plastics and paper-based.

However, textile packaging contributes a significant amount of solid waste that damages the environment. The industry has responded in different ways to reduce the waste generation by promoting recycling, reuse, energy recovery, minimization, and using novel compostable

polymers. This management of packaging waste is being adopted by large retailers and brands in their effort to promote sustainability (Doice, 2021). Solid waste dumping is a crucial risk, especially for developing countries. Insufficient collection and thoughtless disposal of solid waste causes land and air pollution and creates risks to human health and the environment. Thus, the management of textile waste has gained importance, and developing nations should spend a major part of their municipal revenues on waste management.

3.1. Packaging waste management flow: recyclable plastic, cardboard and wooden pallets

Recyclable plastic mostly comes from tertiary packaging, i.e. stretch film that wraps the pallet with goods during transport, plastic packaging (sleeves) on which the yarn arrives, from the stand and bumper on which the sleeves arrive together with the yarn, from discarded PE bags used to transport textile products in various stages of production, as well as empty packaging from products that are not considered hazardous materials. Recyclable cardboard/paper comes from cardboard boxes, i.e. secondary packaging in which many products of raw materials are packed. This also includes the paper wrapper in which the packaging for packaging textile products arrives and cardboard sleeves that serve as yarn carriers.

Packaging waste is collected separately at the point of generation, separately by type of material and handed over to an authorized operator for the collection and transport of packaging waste. Disposal of cardboard waste, pallets, metal waste, and plastic is shown in Figures 3 (a-c).



a)



b)



Figure 3. (a-c) Disposal of old paper and cardboard waste
(Alendarević, 2022; Krivokuća, 2022)

All plastic and metal sleeves (yarn carriers) on which the polyamide fiber is delivered are returned to the supplier - as returnable packaging, which reduces the amount of generated industrial waste, Figure 4a and 4b.



a)



b)

Figure 4. Plastic and metal sleeves - reuse (Alendarević, 2022; Krivokuća, 2022)

Cardboard sleeves on which polyamide fibers are wound have represented a problem for disposal for a long time. Although they have the character of non-hazardous waste, they are difficult to cut, soften and shred, i.e. they are prepared for recycling due to their high hardness and glue in them, Figure 5a and 5b.



a)



b)

Figure 5. Storage of non- returnable cardboard boxes - a) before and b) after reorganization (Alendarević, 2022; Krivokuća, 2022)

After handing over to an authorized local non-hazardous waste collector/storer, with whom a contract must be signed, the cardboard boxes are shredded by mechanical treatment (Figure 6), ground and baled in a waste warehouse with valid permits for mechanical treatment, and then handed over to a larger legal entity that collects them along with waste cardboard for recycling (Packaging Law 36/2009, 95/2018).



Figure 6. Shredded cardboard boxes, ready for baling
(Alendarević, 2022; Krivokuća, 2022)

Hard plastic packaging, HDPE barrels of auxiliaries for dyeing textile products, which are used in the production process, are rinsed with water immediately after

emptying in the process of preparing the dyeing solution. Washed packaging has the character of non-hazardous waste. All plastic waste is temporarily stored on pallets on a concrete platform within the factory circle, marked and fenced, Figures 7-11.



Figure 7. Hard recyclable plastic disposal site (Alendarević, 2022; Krivokuća, 2022)



Figure 8. Formed mini eco – island: a) for the disposal of recyclable paper/cardboard sleeves and b) soft plastic (foil) within the factory (Alendarević, 2022; Krivokuća, 2022)



Figure 9. Collection of waste cardboard and cardboard sleeves (Alendarević, 2022; Krivokuća, 2022)

Wooden packaging waste pallets are used to transport products. As long as they are usable, they are used for repacking goods in the warehouse area. When they break, they become packaging wood waste.



Figure 10. Wood waste storage a) before and b) after reorganization (Krivokuća, 2022; Alendarević, 2022)



Figure 11. Wooden packaging – pallets that are returned to the supplier (Krivokuća, 2022; Alendarević, 2022)

In order to reduce the amount of waste generated, the following measures are taken:

- plastic and metal sleeves (yarn carriers) are returned to the yarn manufacturer as returnable packaging - reuse, Figure 11.;
- wooden pallets that are returned to the yarn producer - reuse;
- part of the hard plastic used to stabilize the polyamide yarn during transport is returned to the supplier - reuse;
- part of the hard plastic (HDPE barrels) from auxiliaries for textile dyeing are returned to the supplier - reuse;

- waste generated after the servicing of a device, machine or vehicle by contract remains with the servicer and the servicer has the obligation to dispose of that type of waste;
- slag (potential by-product) that remains after thermal combustion of coal can be used as an alternative building material for construction work within the factory, for the construction of embankments, and local roads to waste water treatment system - potential registered by-product;
- specific textile remnants - "laces" (potential by-product) produced in the finishing work unit are used for horticultural purposes for tying young shoots of raspberry fruit - a potential registered by-product, Figure12. (Alendarević, 2022; Krivokuća, 2022)

3.2. Non-hazardous textile waste management flow

Undyed textile waste originates from the working unit of knitting - whole scrap products, threads (fibers) of yarn left behind during knitting in machines and on spools (sleeves) - knitting phase; and whole scrap products, parts of products that fall off during cutting and sewing - finishing stage (assembly). One part that is discarded during the finishing work is the textile remains, the so-called "noodles" - it has a further use value, for example, in agriculture, for tying young fruit shoots, Figure 12.



a) „bater“ and „strips“



b) „pucval“



c) SULZER edges

Figure 12. Examples of waste from textile fibres processed
(Alendarević, 2022; Krivokuća, 2022)

Colored textile waste is whole scrap products from the working units of dyers and in packages, without yarn and offcuts. One of the solutions for the disposal and textile waste treatment is the takeover by an authorized operator, which has permits for transport, storage, treatment and export for the treatment of textile waste. According to the results of the analysis, the subject waste is satisfactory in terms of use for thermal treatment and can be used for the same according to the Rulebook) 56/2010, 93/2019, 39/2021), Figure 13.

Particular attention should be paid to the recycling of polyamide, because the fibers are mixed and contain polyamide and lycra in the ratio 85-94 % : 6-15 %. Lycra is cross-linked into the polyamide structure and cannot be technically separated from the polyamide, which creates problems in the later stages of recycling.



a)



b)



c)

Figure 13. Textil waste disposal location a) before and b,c) after reorganization (Alendarević, 2022; Krivokuća, 2022)

The Waste Management Law (36/2009, 88/2010, 95/2018 - other laws, 35/2023) mandates that the hierarchy of waste management be respected and that waste be recycled if possible. If there are no recyclers, one of the solutions is to give the waste to be used by cement plants, which have a permit for co-incineration of this type of waste. Although the situation with companies that have a permit for the transport and storage and/or treatment of waste is very specific, because there are only a few companies that operate and receive textile cotton and polyamide waste, the policy of each company should be to dispose of waste in a legal way, with the respect to hierarchy, so treatment always precedes burning in that order of priority.

4. Conclusions

In the production facilities of the textile industry waste should be handled in a way that ensures the reduction of the harmful impact of waste and the protection of the environment. In every production textile plant, there is an organized collection and temporary storage of waste, for further treatment, where it has a useful value, as well as efficient removal and handing over to the authorized operators for waste management.

Special attention should be paid to strengthening the existing and developing new measures for the establishment of an efficient waste management system based on a well-written waste management plan, which would provide and elaborate all mechanisms for the most rational and sustainable waste management, with clear management plans for special waste flows (hazardous waste, packaging, non-hazardous, communal), with consistent respect for the hierarchy of waste management. Reduction of waste at the source, reuse, recycling of waste, all as a solution before final disposal.

In order to reduce the harmful impact of the textile industry on the environment, it is necessary to work on the development of the awareness of textile producers and users themselves, to give priority to the use of

materials that have the possibility of recycling compared to synthetic materials, to reduce the use of chemicals during the processing and dyeing of fabric, and to switch to the production of clothes that would have a longer shelf life.

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Upravljanje otpadom u tekstilnoj industriji

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INFORMACIJE O RADU

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Ključne reči:
Upravljanje otpadom
Tekstilna industrija
Industrijski otpad
Opasan otpad
Neopasan otpad

I Z V O D

U sistemu upravljanja velikim privrednim subjektima, zaštita životne sredine, sa aspekta stvaranja industrijskog otpada, sve je više jedan od njegovih važnijih podsistema. Da bi se što efikasnije upravljalo uticajem proizvodnog procesa jedne fabrike na životnu sredinu, neophodno je kontrolisati određene parametre kvaliteta emisija u životnu sredinu, kao i aktivnosti na minimiziranju efekata emisija i zagadenja, od momenta prijema sirovina do trenutka kada proizvod napušta skladište gotovog proizvoda. Analizom tehnološkog procesa definiše se način upravljanja otpadom, odnosno definišu se vrste, sastav i količine otpada koji nastaje u tekstilnim pogonima. Kroz stalnu analizu postojećeg sistema upravljanja otpadom, sagledavaju se mere koje se trenutno sprovode, kao i eventualni nedostaci i propusti, na osnovu kojih se predlažu mere za unapređenje upravljanja otpadom. U radu je opisan uticaj upravljanja otpadom u tekstilnoj industriji na životnu sredinu, odnosno primjeri toka upravljanja industrijski nastalim opasnim i neopasnim otpadom - karakterizacija industrijskog otpada, načini odlaganja i predlozi za njegovo smanjenje.