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Green textile materials and techniques for water resource protection

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ABSTRACT

This paper attempts to create a panorama of the green materials and techniques in the textile industry, especially those for water resource protection. For this purpose, the green raw materials in the textile industry were categorized, enumerated and analyzed. Typical examples include banana fibre, Sorona, polylactic acid, etc. Then, the green production techniques were reviewed one by one, including but not limited to green slurry, green surfactants and green dyes. On this basis, the prospects of these new materials and techniques were discussed in details. The research findings shed new light on the application and promotion of green textile methods against water pollution.

Keywords: Green raw materials; Water pollution; Textile industry; Sustainable development

1. Introduction

Toxic discharge is common place in textile industry. The danger of the toxic effluent has been widely recognized in most developed countries. Many measures have been laid down in these countries to reduce the use of toxic raw materials. Meanwhile, the progress of toxic discharge control is slow in developing countries, despite the huge efforts and investments being made. There are still many loopholes in their laws and regulations against the use of toxic raw materials. Overall, it is relatively cheap to manufacture non-green textile products in the developing world. As a result, textile manufacturing across the globe is seeking excessive profits by setting up production bases or purchasing textile products from developing countries [1,2].

Textile manufacturing uses and discharges a variety of chemicals to the water system. Among them, persistent substances such as heavy metals and toxic organics are of particular concern [3]. These substances pose serious threats to health and environment in that they accumulate in the organism through the food chain rather than degrade naturally in the environment. Some of these substances can undermine the endocrine system of man and animals, even at very low levels, and some are even carcinogenic or reproductive toxic. The impact of these persistent and bio-accumulative substances does not stop in the source region. Instead, many substances are carried away to distant places by food chain, ocean currents and atmospheric sedimentation. Thus, the toxic emissions of the textile industry are a global issue.

The current pollution control measures such as sewage treatment cannot effectively prevent the water pollution by the toxic effluent. In sewage treatment plants, the toxic sewage is usually converted to other substances and accumulated in sludge. However, not all toxic substances in the effluent can be removed through the treatment process [4,5]. It is not surprising that the ecosystem and human health are seriously imperilled by the various pollutants discharged from textile factories [6]. This calls for the development and

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promotion of textile manufacturing methods that are harmless to the environment and human health [7].

To answer the call, this paper reviews the green raw materials and techniques in the textile industry, and makes a detailed analysis on the prospects of these new materials and techniques. The research findings shed new light on the application and promotion of green textile methods against water pollution.

2. Green raw materials

The raw materials in the textile industry are either directly extracted from natural substances or artificially produced. Below is a detailed introduction to the typical raw materials of each kind.

2.1. Natural extracts

Banana fibre is a leaf fibre extracted from banana. The latest attempt is to weave fabrics for different consumers using banana fibre as warp yarns and cotton and rayon as wefts. The fabrics can be coloured with direct or reactive dyes. No water pollution arises from the production process of banana fibre (Fig. 1).

Proposed by DuPont in 2000, Sorona is a new polymer compound made from corn. This compound outperforms the existing chemical fibres in comfort, flexibility, wear resistance, wrinkle resistance, etc. In addition, Sorona is featured by good dyeing performance, colourfulness, leather-likeliness and, most importantly, recyclability. Suffice it to say that Sorona is a cutting-edge clothing material free of water pollution. The production and final product of Sorona is shown in Fig. 2.

Polylactic acid (PLA) fibre is produced through the lactic acid fermentation of renewable corn and starch-containing materials (e.g., wheat), polymerization and spinning. The molecular structure of the PLA fibre is shown in Fig. 3. This type of fibre enjoys better strength, elasticity, heat resistance and air permeability than other biodegradable fibres. The fabrics made of the PLA fibre are as soft as skin and as smooth as silk. The PLA fibre products can break down into CO_2 and water, the raw materials of photosynthesis when they are discarded in the soil or river.

Fig. 1. Banana fibre production and final product.

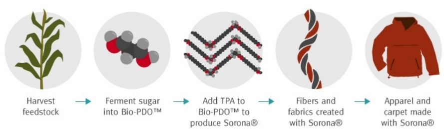

Fig. 2. Sorona fibre production and final product.

Chitin fibre is a product of chitin, an animal cellulose in crustacean shell, mushrooms, fungi, bacteria, etc. The molecular structure of chitin is described in Fig. 4. Since chitin is biodegradable, chitin fibre causes no water pollution in the manufacturing process. Moreover, chitin fibre is an alkaline material known for its high chemical activity and excellent physical properties (e.g., absorbability, adhesiveness and breathability). The textiles made of chitin fibres can prevent skin diseases, kill bacteria and remove foul smell, creating a comfortable wearing experience.

Lyocell fibre is made from the fast-growing trees in renewable forests. It integrates the physical–chemical properties of natural cellulose with the service performance of synthetic fibres. The production of the fibre does not rely on the overexploitation of forest resources, and the wastes of the fibre can degrade naturally without causing any pollution to the water environment. As a result, this fibre is hailed as the green fibre of the 21st century.

Modal fibre is a semi-synthetic cellulose fibre made by spinning reconstituted cellulose from natural wood. With a linear mass density of only 1 decitex, this fibre is extremely silky, smooth, bright and tough. The cloth made from this fibre can absorb 50% more moisture and be dyed into more colours than cotton fabrics. What is more, modal fibre boasts better shape and dimensional stability than cotton. The anti-wrinkle performance of the fibre is also a nice feature.

Soybean protein fibre brings together the attributes of natural silk and the mechanical properties of synthetic fibres. The fibre and its product are presented in Fig. 5. This silk can be made into comfortable wash-and-wear fabrics. As its name suggests, soybean protein fibre is made from natural soybean meal, which is renewable and widely available. In addition, the fibre production process causes no pollution to the water environment. Excipients and auxiliaries are non-toxic during the production process. Besides that, the most of the semi-finished products are recyclable. And the residues after protein purification can be used as fodder. The entire production process complies with environmental regulations.

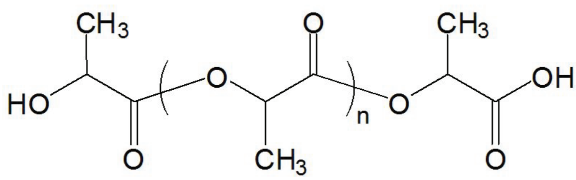

Fig. 3. Molecular structure of the PLA fibre.

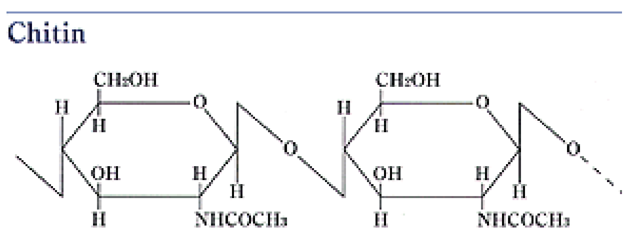

Fig. 4. Molecular structure of chitin.

Fig. 5. Soybean protein fibre production and final product.

Fig. 6. Spider silk fibre.

2.2. Artificial products

Naturally coloured cotton is cotton that has been bred to have colours other than the yellowish off-white typical of modern commercial cotton fibres. The new type of cotton retains the colour of natural cotton, which will not fade in the long term. It is also noted for its elegance, softness, flexibility and brightness. The cloths weaved from coloured cotton are natural, elastic and comfortable to wear. From fibre growth to weaving, the entire production achieves zero water pollution.

Spider silk fibre (Fig. 6) is made from spider silk, a special protein fibre stronger than steel wire. The raw material can be stretched by 30% and withstand extreme temperatures. There are three ways to produce spider silk fibre: first, inserting the spider's silk protein gene into specially trained cows, and extracting the fibre from the milk of the cows; second, injecting the gene into silkworm eggs via electroporation and extracting the fibre from the silk spun by the silkworms; third, inserting the gene into plants such as potato and tobacco and harvest silk protein from the transgenic plant. The spider silk fibre inherits the strength of spider silk, and enjoys high flexibility and solubility. The production process uses no organic solvents and causes no environmental pollution.

3. Green production techniques

The water pollution arising in textile production is mainly attributable to the chemicals used in dyeing and washing processes. The leading cause of pollution is the dyeing additives. To eliminate the pollution, green additives have been developed to minimize the harmful residues on the dyed and finished textiles. This chapter reviews some representative green additives designed to curb the water pollution in the textile industry.

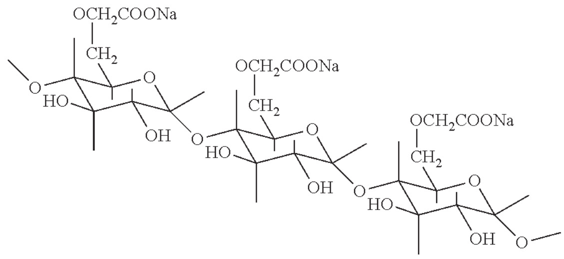

Fig. 7. Molecular structure of microwave-modified starch.

3.1. Green slurry

Microwave-modified starch is a non-polluting slurry. As shown in Fig. 7, the macromolecular chains of starch have degraded due to the high-frequency directional oscillations in the alternating electromagnetic field of the microwave. The microwave-modified starch exhibits excellent sizing performance, as evidenced by the reduced slurry viscosity and serosa strength. This type of starch also enjoys good bactericidal effect and mildew resistance. Throughout the production process, there is no addition of chemical additives or discharge of toxic sewage.

3.2. Green surfactants

The green surfactants are mostly non-ionic or anionic. The alkyl polyglucoside (APG) is a typical non-ionic green surfactant produced through the reaction between glucose and fatty acid/alcohol. As a non-toxic and biodegradable surfactant, the APG can work in synergy with other surfactants. Another popular non-ionic green surfactant is ethylene oxide/propylene oxide copolymers (polyethers), which is a class of biodegradable non-ionic compounds.

The popular anionic surfactant sodium dodecylbenzenesulfonate has been replaced by alkyl ether sulfate (AES), secondary alkyl sulfonate (SAS) and sodium alpha olefin sulfonate (AOS). The AES can be synthetized with alcohols (2EO AES) or natural cinnamyl alcohols (3EO AES). Among the products, the 3EO AES has the least irritation and toxicity and the best biodegradability. SAS and AOS are both biodegradable with good emulsifying and degreasing properties. The two surfactants also have excellent solubility, wetting ability and compatibility, and can withstand electrolytes, alkalis and high temperature.

3.3. Green dyes

Dyeing is a key process in textile production. However, the average dye loss rate is as high as 20%. Statistics show that a total of 10 million tons of dyes are dissolved in water around the world during the dyeing process. The polluted water flows into the environment, causing great ecological damages. Against this backdrop, it is necessary to control the loss of dyes in textile production.

Natural dyes are colourants derived from plants, invertebrates, or minerals. These dyes contain one or more metal salts that ensure ideal colour fastness under the sun and washing conditions. The vivid fibre colour and high fixation rate hinge directly on the mordant function of metal salts. Different mordants can lead to different colours. For example, shikonin colorant produces a red colour, tin chloride a skin brown colour, alum leads a purple colour, stannous chloride a dark skin colour, ferrous sulfate a moss green colour.

The most frequently used natural dye is green tea. The cotton yarn and cloth dyed by green tea can eliminate foul smell, kill bacteria and prevent allergy. To ensure colour fastness, the original yarn is often blended with tea dyed cotton at the ratio of 1:1.

Recent years saw the emergence of new dyeing methods such as microwave and sonic dyeing. Both microwave and sonic wave can intensify the reaction between the fabric and the dye. Comparatively, microwave dyeing is fast, while sonic dyeing is relatively efficient. Cotton is suitable for sonic dyeing.

Another new method is called supercritical CO_2 dyeing. This is an anhydrous dyeing method that does not produce sewage during the process and does not waste water resource. Less energy is consumed because it does not require cleaning and drying. In addition, harmful gases are not produced during the dyeing process, and residual dyes can be completely recovered. The method also has the characteristics of fast coloring and leveling.

Chitosan, as a reactive dye, it has the characteristics of high dyeing rate and color yield when it is used on cotton fabric. Although the color fastness is not particularly good, but it can be improved by post processing. The dyeing effect of chitosan is affected by the baking temperature. The best baking time is 3 min.

Coupled with ultrasound, disperse dyes can achieve a colourful effect in a short time, at a low temperature, using less chemical additives.

4. Environmental prospects of textile industry

Environmental protection is essential to the sustainable development of the world. Almost all countries are competing to develop new green fabrics. As the largest developing country, China is paying enormous efforts to narrow the gap with developed countries in green fabrics development. The term "green " has multiple meaningful, including pollution-free energy, resource development, water saving techniques, high utilization rate, waste recycling, pollution reduction, and so on. The potential of green textile materials and techniques should never be ignored.

4.1. Natural materials

Many types of fibres have been developed besides the traditional cotton, hemp, silk and wool. These fibres are often extracted from plants and animals, and in line with natural and degradable requirements. As mentioned before, green cellulose fibres have been created based on bananas, wheat, soybeans, corn and wood. One of the most promising green fibres is chitin fibre, an embodiment of naturalness and health care. It is safe to say that natural fibres will be a mainstay in the raw material market.

4.2. Advanced techniques

Numerous advanced techniques are available to curb the water pollution of textile production, such as genetic technology, biotechnology and physical technology. The popularity of genetic technology is well demonstrated in the emergence of natural coloured cotton, spider silk fibre, etc. The biotechnology such as enzymolysis has already entered the textile industry. Its presence is seen in multiple processes, ranging from bleaching to dyeing, from pre-processing to post-treatment. There is still an ample room for integration of biotechnology in textile production. As for physical technology, ultrasound and microwave have been embedded into textile manufacturing, while plasma and supercritical dyeing are being introduced to the industry. In future, even more advanced physical techniques will be integrated in the sector.

4.3. Green additives

Currently, green additives, hydrophilic/lipophilic auxiliaries and non-ionic/anionic reactive dyes are increasingly popular in the textile industry. This trend will continue in the future.

5. Conclusion

In pursuit of textile manufacturing methods that are harmless to the water environment, the green raw materials in the textile industry were categorized, enumerated and analyzed. Typical examples include banana fibre, Sorona, polylactic acid (PLA), etc. Then, the green production techniques were reviewed one by one, including but not limited to green slurry, green surfactants and green dyes. Based on the current status, the prospects of these new materials and techniques were discussed in detail. The research findings shed new light on the application and promotion of green textile methods against water pollution.

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References

[1] A. Hasanbeigi, L. Price, A technical review of emerging technologies for energy and water efficiency and pollution reduction in the textile industry, J. Cleaner Prod., 95 (2015) 30–44.
[2] T. Ito, Y. Adachi, Y. Yamanashi, Y. Shimada, Long-term natural remediation process in textile dye-polluted river sediment driven by bacterial community changes, Water Res., 100 (2016) 458–465.
[3] D. Subroto, S. Shubhra, Assessment of ground water and surface water quality around industrial area affected by textile dyeing and printing effluents, Pali, Rajasthan, India, J. Environ. Res. Dev., 8 (2014) 574.
[4] G. Samchetshabam, H. Ajmal, T.G. Choudhury, Impact of textile dyes waste on aquatic environments and its treatment, Environ. Ecol., 35 (2017) 2349–2353.
[5] E. Ozturk, M. Karaboyac, U. Yetis, N.O. Yigit, M. Kitis, Evaluation of integrated pollution prevention control in a textile fiber production and dyeing mill, J. Cleaner Prod., 88 (2015) 116–124.
[6] M.A. Ahmed, Reduction of textile industrial waste water pollution, Gezira J. Eng. Appl. Sci., 10 (2015) 01.
[7] A. Munnaf, M.S. Islam, T.R. Tusher, M.H. Kabir, M.A.H. Molla, Investigation of water quality parameters discharged from textile dyeing industries, J. Environ. Sci. Nat. Resour., 7 (2015) 257–263.