Lotus fibre – A possible solution to textile pollution: A review

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Abstract:

The textile industry has been a significant pollution causing sector globally. Concerning environmental protection and sustainable development, the development and application of natural plant fibre and renewable fibre will be the inevitable trend in the future. One such fibre can be obtained from the Nelumbo nuciferastem, root, and peduncle. India has a wetland ecosystem that supports diverse and unique habitats, suitable for Lotus production. Lotus silk production in India is limited to Eastern states like Manipur, while in industrial states like Gujarat and Maharashtra, lotus fibre production is not seen on an impactful stage. Lotus fabric can be mass-produced and popularized in India through proper training of local people. It can prove to be a big employment generating industry and can also help to reduce the carbon footprint of the current textile industry.

Key Words: Nelumbo nucifera, Lotus fibre, natural fibre, Textile, Sustainable development

Introduction:

The textile industry is the second-largest pollutants releasing industry of the world (Sharan and Haldar, 2021), with pollution areas ranging from Water pollution (Kant, 2011), Microfibre pollution (Liu *et al.*, 2021), Metals pollution (Li *et al.*, 2021), Noise pollution (Zare Sakhvidi*et al.*, 2021), Air pollution (Meenaxi and Sudha, 2013), Waste generation (Desore and Narula, 2018).According to an estimate by World Bank, 17 to 20% of total industrial water pollution comes from waste produced after the dyeing and finishing treatment of various textile products (Kant, 2011). Fibre2Fashion's (2012) survey shows that nearly 5% of all landfill space is consumed by textile waste. The raw material to produce textiles, i.e., fibre, can be classified into three major categories: cellulose, protein, and synthetic fibre (Ghaly*et al.*, 2014). Fibres from plants such as cotton, flax, hemp, ramie, etc., are examples of cellulose fibres. Protein fibre is animal-derived fibres like wool, angora, cashmere, and silk. Synthetic fibre is synthesized from petroleum-based products such as polyester, nylon, spandex, acrylic, polypropyleneetc, (Pensupa*et al.*, 2017). Cellulose materials are the most economical and most abundant renewable resources in nature. With the depletion of non-renewable resources such as coal, oil and natural gas, it has been a serious problem for people to look for substitute renewable resources. In environmental protection and sustainable development, the development and application of natural and renewable fibre will be the inevitable trend (Zhao *et al.*, 2015). One such naturally fibre-yielding aquatic plant is lotus (*N. nucifera* G) which is a perennial plant with rhizomes that grow in muds belonging to Nelumbonaceae family of Proteales order. It is a vital plant with its uses varying from ornamental, nutritional, and medicinal (Lin *et al.*, 2019). It is being proposed as a potential source of fibres for the textile industry (Patil, 2018; Tomar and Yadav, 2019).

Figure 1. Lotus growing in natural habitat

The wetland ecosystems in India supports diverse and unique habitats (Bassi *et al.*, 2014). The soil system in wetlands are known as hydric soil, suitable for growing lotus plants (figure1). Lotus is an important cash crop cultivated throughout the country for its wide range of uses. Lotus shows all the aquatic plant features like aerenchyma and the certain unique features that differentiate it from other plant species are also present, like seed longevity and leaf ultra-hydrophobicity and floral thermoregulation. A detailed understanding of the mechanisms responsible for forming these unique properties is important for the basic plant biology and their great potential usage in other areas like bionics, tissue engineering, and regeneration (Nie*et al.*, 2008). The fruit of *N. nucifera* is well-known for its longevity (Lin *et al.*, 2019). Lotus roots are planted in the soil of pond or river bottom, whereas the leaves float on the water and have a hydrophobic layer on the dorsal surface. The plant typically grows upto about 150cm and a horizontal span of about 3 meters. Leaves may be as large as 60cm in diameter, while the flowers can be upto 20cm in diameter when open (Sheikh, 2014).

Lotus is widely distributed in Southeast Asia and is a National flower of India. Other than India, it is also the National flower of Egypt and Vietnam. In India, Nelumbo is distributed from Kashmir to Kanyakumari, showing vast phenotypic variety in shapes, sizes and shades of flowers having petals between 16-160 (Sharma and Goel, 2000).

The fibre–producing lotus is distributed worldwide. In Gujarat state, it is cultivated in Ganeshpura, Savli Taluka**,** Kamlapura Village, Ruvad and Tarsalivillages of Vadodara district (Sharan and Haldar, 2021) (figure 2).

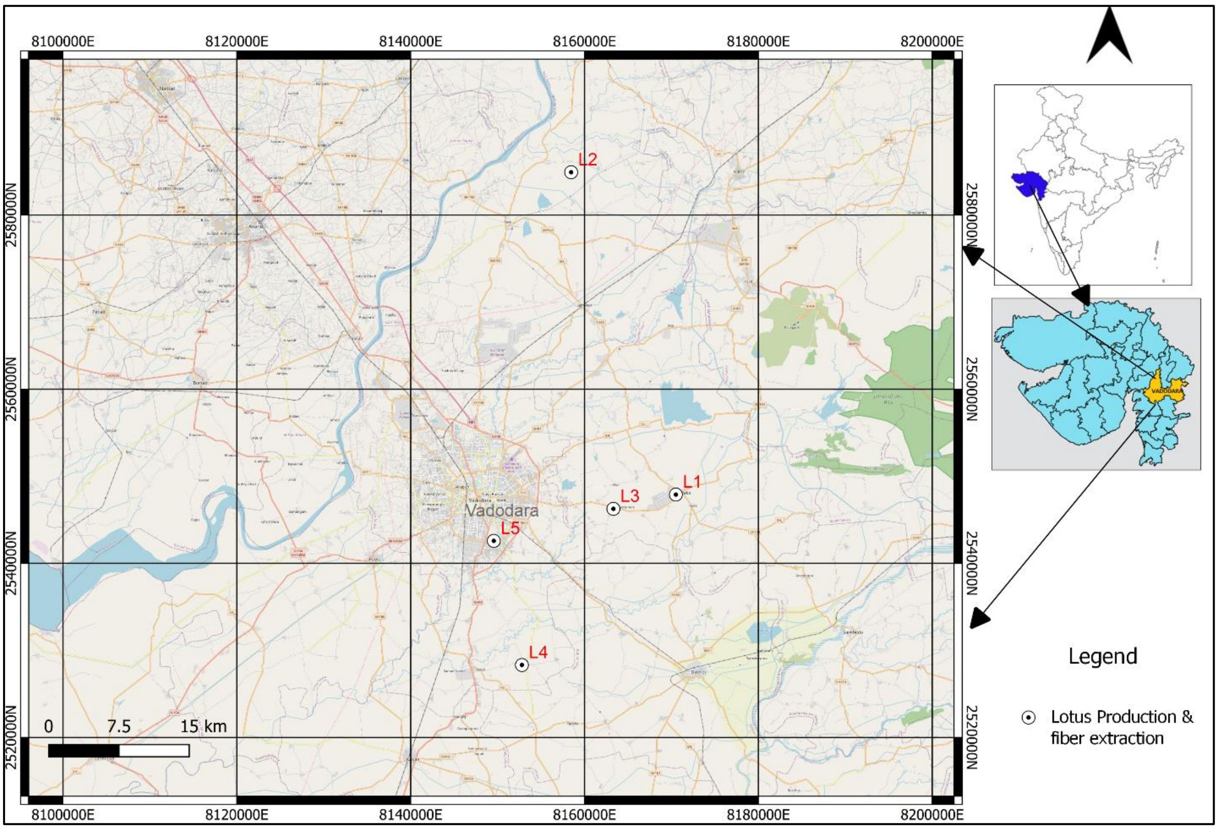

Figure 2. Lotus cultivation and fibre extraction around Vadodara district. L1: Ganeshpura Village, L2: Savli Taluka, L3: Kamlapura Village, L4: Ruvad village, L5: Tarsali village (Sharan and Haldar, 2021)

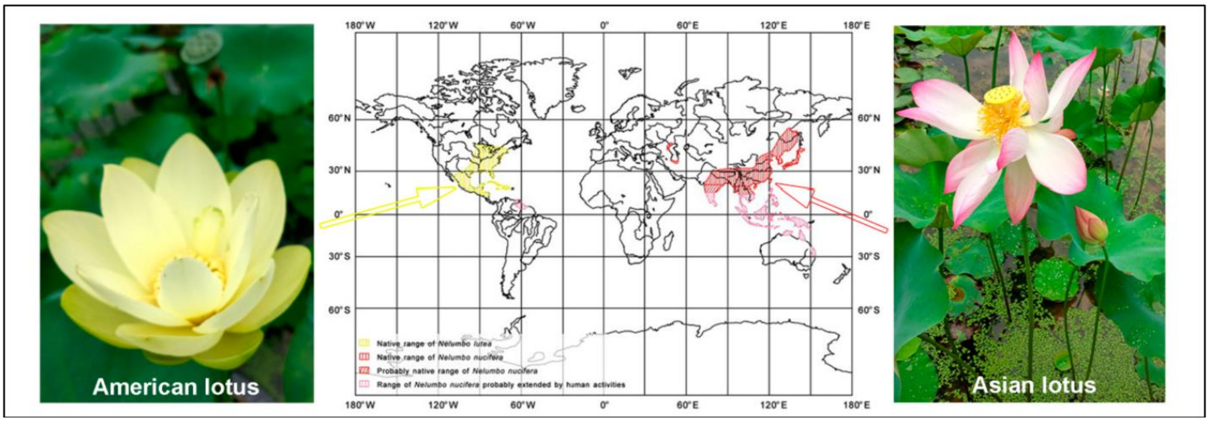

Figure 3. Global distribution of two Lotus species. The left and right panels show the flowers of American (N. lutea) and Asian lotus (N. nucifera), respectively (After Lin et al., 2019).

N. lutea Willd is mainly distributed in the North American sub-continent. Whereas *N. nucifera* Gaertn is distributed in the Southeast Asia as shown in Figure 3 (Lin *et al.*, 2019).

The plant also provides fibres used to make a rare kind of cloth matching with the prime qualities of silk (Gardetti and Muthu, 2015).

After harvesting, many lotus petioles are considered waste and dumped for natural decay. Such debris may cause environmental degradation (Chen *et al.*, 2015). This review focuses on lotus fibre which could be used from the waste of petioles; so the local cultivars could provide the waste when required to produce fibres.

Lotus fibre:

Lotus fibre develops in vascular bundles of leaf, stalk (Liu *et al.*, 2009) and root of *N. nucifera*. (Gan *et al.*, 2009). Botanically, the fibre is the thickened secondary wall in xylem tracheary elements (Pan *et al.*, 2011). Many new plant fibres are introduced to achieve an environment friendly future of the textile industry. One such promising option is extraction of fibre from lotus plant. Lotus fibre is a biodegradable fibre that can be extracted from roots (Nie*et al.,* 2008), stem (Patil, 2018) and peduncle (Pandey*et al.*, 2020) of the plant. Fibre from lotus stem, the most common source, is being extracted since 1910. The lotus fabric is the first natural microfiber i.e., its fineness ranging from 3.963-4.516μm (Zhao *et al.*, 2015) and perhaps the most eco-friendly fabric in the world (Patil, 2018). The fabrics made from lotus fibre are having great application and demand in the textile sector, especially in the luxury sector. The lotus fibre fabrics can be best described as in-between silk and linen; the lotus flower fabric is naturally stain-resistant, waterproof, and soft. This soft, breathable, wrinkle-free fabric was once used to make robes for senior Buddhist monks (Gardetti and Muthu, 2015). Gupta (2020) called lotus fibre as “Spiritual fibre” due to the inspiring way of growing the lotus plant in the mud.

Properties of lotus fibre:

A study was conducted by Wang *et al.*, (2008) to understand the fundamental physical properties of the lotus fibre, in which they stated that the density of lotus fibre varies between 1.184g/cm^3, much less than cotton, ramie and wool fibres, but similar to silk. The linear density of lotus fibre was 1.55 dtex (10,000m of lotus fibre weighs 1.55g), which is finer than ramie and silk fibres, and similar to cotton and cotton-type chemical fibres. Because of the presence of high amount of hemicellulose in the fibre (Rowell, 2005), the moisture regain capacity of the Nelumbo fibre was also recorded to be 12.32% (Wang *et al.*, 2008, Pan *et al.*, 2011), which is same as ramie fibre, higher than cotton and silk, and less than that of wool. This indicates excellent absorbent quality of lotus fibre, comparable to other standard fabrics.

Further, this study also points towards the possibility of producing yarns with good strength, fineness and evenness from lotus fibres. It can be used to spin high count yarns (Wang *et al.,* 2008). In normal state, the strength of lotus fibre is greater than that of cotton and viscose fibre (Yuan *et al.,* 2012).

The percent crystallinity and preferred orientation of crystallites in the lotus fibres are 48% and 84% respectively (O'Malley, 2011). Gardetti and Muthu (2015) reported that lotus fibres have breaking tenacity and young's modulus very similar to cotton and the elongation of the lotus fibres is only about 2.6%. A later study conducted by Chen *et al.,* (2012) further reported the other properties of the lotus fibre, like its crystallinity, orientation, density, fineness, strength and breaking elongation. The lotus fibre is typically cellulose with around 48% crystallinity and 60% orientation (Chen *et al.,* 2012). The fibre also contains lignin (outer layer) and hemicellulose (between microfibrils) in high amount (Pan *et al.,* 2011). The density of fibres is 1.1848g/cm^3 and fineness is 1.55 dtex (Chen *et al.,* 2012). It has high strength and low stretchability (Only 2.75% breaking elongation) with an initial modulus of 146.81cN/dtex its breaking strength is 3.44cN/dtex (Chen *et al.,* 2012). The length-to-fineness ratio of this fibre is 10^4, which makes it an acceptable fibre for modern textile processing, for which the optimum length-to-fineness ratio should be in the range of 10^2 - 10^5 (Mu, 2013). The fibres of lotus stem can be further processed using sodium hydroxide (NaOH) that removes impurities and sodium chlorite ($NaClO_2$) which improves cellulose content in the fibres, these chemicals are reported to remove up to 91.56% impurities from

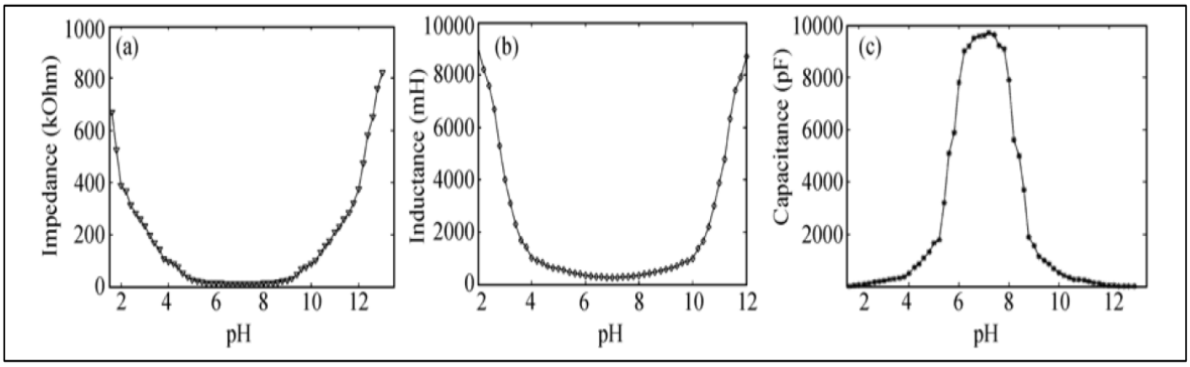

Figure 4. The impedance curve (U-shaped) (a), the inductance curve (U-shaped) (b), and the capacitance curve (Ω -shaped) (c) of lotus root silk varies with the pH value of Alcohol (Nieet al., 2008)

the fibres, this is very valuable for lotus fibres preparation on industrial scale (Cheng *et al.,* 2018). All the data mentioned above indicates that lotus fibre is acceptable for preparing clothing and garments. Studies on electrical parameters on lotus fibre dipped in liquor found that at the pH of liquor, the inductance and impedance vary in 'U' shape curves on graph, and the capacitance varies in 'Ω' shape curve on the graph. The minimum value of the U curves and the maximum value of the Ω curve appear at the point where the pH is 7. These phenomena (figure 4) are referred as the "U or Ω effect". This actively demonstrates that the lotus fibre is perfectly bio-compatible with the human tissues. The study results may imply that the *Nelumbo* fibres have broader potential applications away from fashion industry, in biomedicine, tissue engineering, and bioelectronics (Nie*et al.,* 2008).

Extraction and processing of the lotus fibres:

N. nucifera grows very well in warm tropical climate and sometimes its seed can endure even below-freezing temperatures. 5 to 6hr of direct sunlight every day for at least 3 to 4 weeks with an air temperature of about 27 °C and warm water whose temperature ranges from 4 to 15.5 °C and in some cases up to 26.6 °C is ideal for the lotus flower to thrive. To obtain lotus stems of optimum length and quality, the harvesting must take place in the rainy season from June to November (Fraser-Lu and Ma, 2007).

After harvesting the plant, within 24 hours, Nelumbo stems/roots are lightly cut with knife such that it doesn't damage the vascular bundles and then twisted and separated to extract the fibres (figure 6). Likewise, heated silk was also obtained from lotus roots by heating them before extracting silk, in a dry oven at 100 °C for 2 hours (Zhang and Guo, 2014). Since the old times, the extracted lotus fibres are rolled into a single thread (figure 7) by a worker using his/her hand and dried by keeping them with dry maize seeds. The subsequent step is yarn preparation, where a bamboo spinning frame is used to make yarns having 40m of threads spun together. Besides the physical method of fibre extraction, which is very time-consuming (figure 5) and requires a lot of skill, an alternate and lesser skill-intensive method was proposed by Cheng *et al.,* (2017) that relies on micro waves for extraction and isolation of lotus fibres. In microwave irradiation, 5cm long pieces of dried Nelumbo stems about 2g are placed in 100ml of 0.5M NaOH solution and showered with microwaves of 2450MHz frequency 750W power for 20 mins. The Nelumbo stems were then treated with DI water (de-ionized/demineralized) to neutralize the altered pH due to the microwaves. Subsequently, the fibres were isolated from vascular bundles of the Lotus stems by hand, squeezing and rinsing them removing the stem fibres. Lastly, the fibres were dried at 50°C and the threads obtained are the raw lotus fibres/lotus silk (Cheng *et al.,* 2017). These threads are spun into yarns and later used to make various fabrics, ranging from handkerchiefs to robes (Tomar & Yadav, 2019).

As far as the processing of lotus fibre is concerned, it is a particular skill & labour-intensive and tiresome process. It takes approximately 32,000 lotus stems to make 1.09 yards of fabric, and around 1,20,000 lotus stems must be processed for making an average garment. As mentioned earlier, lotus fabric production is very slow; it takes almost 1.5 months to make a complete lotus fabric garment. Although there is no waste as all parts of the lotus are utilized which ensures the production of a product that is entirely sustainable/ eco-friendly (Gardetti and Muthu, 2015).

Due to its highly time-consuming production, the lotus flower fabric appears as a rare and exclusive fabric. The lotus fabric shows properties like soft and comfortable to wear, especially breathable and wrinkle-free fabric, making it a suitable fabric for high-quality fashion clothing (Mahapatra, 2012).

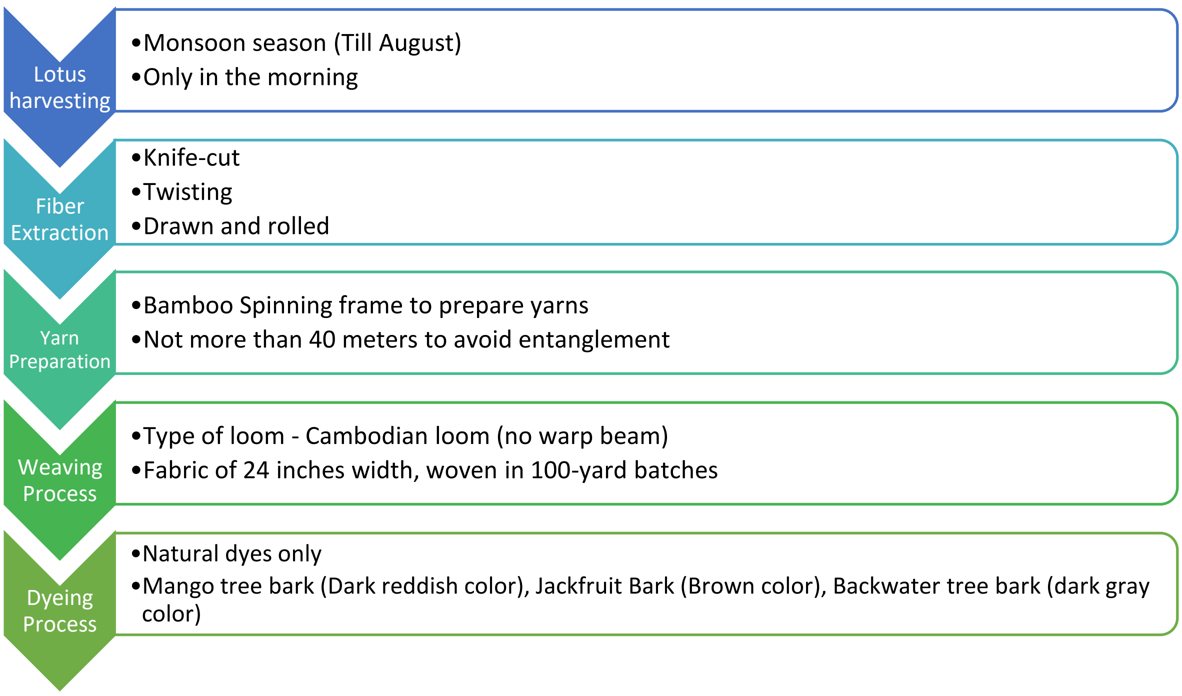

Figure 5. Lotus fabric manufacturing process (Tomar and Yadav, 2019;

Lotus fabric and the luxury clothing:

Figure 6. Extraction of Nelumbo stem fibres

Luxury fashion played a prominent role in the social and economic order of previous centuries (Royal people and noblemen wore distinct and better clothes than the common people) and this continues to have a major impact on our modern societies and economies to this day. Within the luxury sector, luxury fashion (clothing and accessories) accounts for around $150 billion USD (Cherny-Scanlon, 2016). The luxury fashion market size was valued at $ 110.64 billion USD in 2020 and is expected to reach USD 153.97 billion by 2026 growing at a Compound Annual Growth Rate (CAGR) of 5.66%, as per "Luxury Fashion Market - Global Outlook & Forecast 2021-2026" report published in "GLOBE NEWSWIRE" (2021). Despite being very different concepts, Luxury and sustainability both have a few common features like - respect for old tradition and workmanship, the preference given to quality over quantity and the pursuit for harmony between humans and nature. According to Kleanthous, with passing time, Luxury is becoming less about exclusiveness, less wasteful, and more about enabling people to express themselves and their deepest values (Gardetti and Muthu, 2015). However, sustainability has a "status" problem in the fashion industry. On one hand, there is the mainstream, single-use "fast fashion" clothing that almost everyone is familiar with and on

Figure 7. Rolling of Nelumbo stem fibers into a single

the other hand, there is the emerging “sustainable” fashion, which still has a marginal market share and is typically considered uncool (Cherny-Scanlon, 2016).

According to Hockerts and Wüstenhagen (2010), there are two main types of brands in the sustainable textile market. First group of brands is the “Davids” and the second is the “Goliaths”. The Davids, also referred to as the ‘Emerging Davids’, are the new emerging sustainable fashion brands in the industry. The Goliaths, also called ‘Greening goliaths’, are the already established major international fashion companies adopting sustainable eco-friendly clothing. (Hockerts and Wüstenhagen, 2010). Both of those mentioned above ‘Emerging Davids’ and ‘Greening Goliaths’ brand shave an extensive role in transforming the modern fashion industry to move it forward towards sustainable clothing (Hockerts and Wüstenhagen, 2010). In fact, the interaction between Davids and goliaths resembles a naturally occurring phenomenon called as “co-evolution”, where each side moves the transformation forward. “Co-evolution” is a term from evolutionary biology describing the simultaneous evolution of two or more different species (in this case ‘Emerging Davids’ and ‘Greening Goliaths’) that are mutually depended on each other (Ehrlich and Raven, 1964). The David’s brands have an active attitude based on a novel approach to standards to generate social and environmental changes leading to sustainability. Unlike the Goliaths, the Davids are not afraid to break the norms and promote innovative answers to environmental and social issues. Davids have less interest in the status quo and have less to lose and more credit to gain from eco-friendly innovations (Gardetti and Muthu, 2015).

In turn, the major international brands are still anchored to the usual mind-set of generating the most profit by selling the thing that sells the most. Numerous recent reports show that established fashion giants' transition towards sustainability is slow. Even though a few brands have a positive approach towards the challenge of sustainability, it is observed that, in general, the industry reacts to the market and consumers’ demands (Gardetti and Muthu, 2015). Examples of these types of companies include “Loro Piana” a company based in Italy, which can be termed as a ‘Greening goliath’. Another brand called Samatoa based in Cambodia, can be termed as a ‘Emerging David’ in terms of Hockerts and Wüstenhagen (2010).

Conclusion and some forward thinking:

The textile industry is the second-largest pollutants releasing industry globally; 20% of all freshwater pollution occurs due to textile treatment and dyeing processes. Surveys show that textile waste is consumed nearly 5% of all landfill space. Since lotus fibre is obtained from the discarded stems of Lotus, it can help reduce waste production and aid in its management. Also, lotus fabric production will create employment opportunities for local people since it takes around 24-25 individuals to harvest the stems, fibres, and process it. Softness, exceptionally breathable, and crease-resistant properties make the lotus fabric an attractive alternative to present synthetic clothing materials. Through proper encouragement, training, and cooperation with the local population, lotus fabric can be mass-produced and popularized in India. Other than fabric production, lotus fibres also show the "U/Ω effect" because it also has possible implications beyond textile in the field of tissue engineering, regeneration, and bioelectronics.

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References:

2012. Various Pollutants Released into Environment by Textile Industry. Fibre2fashion dated May 2012. https://www.fibre2fashion.com/industry-article/6262/various-pollutants-released-into-environment-by-textile-industry#:~:text=Surveys%20show%20that%20nearly%20five,unimaginable%20harm%20to%20the%20environment [Accessed on 15 January 2022.]

2021. The Worldwide Luxury Fashion Industry is Expected to Reach $153+ Billion by 2026. GLOBE NEWSWIRE dated 11 November 2021. https://www.globenewswire.com/news-release/2021/11/11/2332342/28124/en/The-Worldwide-Luxury-Fashion-Industry-is-Expected-to-Reach-153-Billion-by-2026.html [Accessed on 17 January 2022.]

Bassi, N., Kumar, M. D., Sharma, A., & Pardha-Saradhi, P., 2014. Status of wetlands in India: A review of extent, ecosystem benefits, threats and management strategies. J. Hydrol. Reg. Stud. (2): 1–19.

Chen, D. S., Gan, Y. J., & Yuan, X. H., 2012. Research on Structure and Properties of Lotus Fibres. Adv. Mat. Res. 476: 1948-1954.

Chen, D. S., He, J., Wang, J. G., & Gan, Y. J., 2009. Research on the shape of lotus fibre. J. cellul. Sci. and Tech., 17(1): 57-60.

Chen, Y., Wu, Q., Huang, B., Huang, M., & Ai, X., 2015. Isolation and Characteristics of Cellulose and Nano-cellulose from Lotus Leaf Stalk Agro-wastes. Bio – Resources 10.1: 684-696.

Cheng, C., Guo, R., Lan, J., & Jiang, S., 2017. Extraction of lotus fibres from lotus stems under microwave irradiation. Royal Soc. Open Sci. 4(9): 170747.

Cheng, C., Guo, R., Lan, J., Jiang, S., Du, Z., Zhao, L., & Peng, L, 2018. Preparation and characterization of lotus fibres from lotus stems. J. Text. Inst. 109(10): 1322-1328.

Cherny-Scanlon, X., 2016. Putting Glam into Green: A Case for Sustainable Luxury Fashion. Spiritual and Sustain. 40: 183–197.

Desore, A., & Narula, S. A., 2018. An overview on corporate response towards sustainability issues in textile industry. Environ. Dev. and Sustain. 20(4): 1439-1459.

Ehrlich, P. R., & Raven, P. H., 1964. Butterflies and Plants: A Study in Coevolution. Evolution 18(4): 586-608.

Fraser-Lu, S., & Ma, T., 2007. Stemming from the Lotus: sacred robes for Buddhist monks. Material choices: refashioning bast and leaf fibres in Asia and the Pacific. Fowler Museum at UCLA, Los Angeles: 93-103.

Gan, Y. J., Yuan, X. H., Wang, J. G., He, J., & Chen, D. S., 2009. Analysis on microstructure of lotus fibres. Text. Res. J. 30(11): 14-17.

Gardetti, M. A., & Muthu, S. S., 2015. The lotus flower fibre and sustainable luxury. In Handbook of sustainable luxury textiles and fashion, Springer 1: 3-18.

Ghaly, A. E., Ananthashankar, R., Alhattab, M. V. V. R., & Ramakrishnan, V. V., 2014. Production, characterization and treatment of textile effluents: a critical review. J. Chem. Eng. Process Technol. 5(1): 1-19.

Gupta N., 2020. The spiritual power of lotus fabric. IOSR Int. J. Humanit. Soc. Sci. 25(7): 2279-08345.

Hockerts, K., & Wüstenhagen, R., 2010. Greening Goliaths versus emerging Davids — Theorizing about the role of incumbents and new entrants in sustainable entrepreneurship. J. Bus. Ventur. Insights 25(5): 481–492.

Kant, R., 2011. Textile dyeing industry an environmental hazard. Nat. Sci. 4(1): 22-26.

Li, F., Zhong, Z., Gu, C., Shen, C., Ma, C., Liu, Y., Yin, S. & Xu, C., 2021. Metals pollution from textile production wastewater in Chinese South eastern coastal area: occurrence, source identification, and associated risk assessment. Environ. Sci. Pollut. Res. 28(29): 38689-38697.

Lin, Z., Zhang, C., Cao, D., Damaris, R. N., & Yang, P., 2019. The Latest Studies on Lotus (*Nelumbo nucifera*)-an Emerging Horticultural Model Plant. Int. J. Mol. Sci. 20(15): 3680.

Liu, D., Han, G., Huang, J., & Zhang, Y., 2009. Composition and structure study of natural *Nelumbo nucifera* fibre. Carbohydr. Polym. 75(1): 39–43.

Liu, J., Liang, J., Ding, J., Zhang, G., Zeng, X., Yang, Q., Zhu, B. and Gao, W., 2021. Microfibre pollution: an ongoing major environmental issue related to the sustainable development of textile and clothing industry. Environ. Dev. Sustain. 23(8): 11240-11256.

Meenaxi, T., & Sudha, B., 2013. Air pollution in textile industry. Asian J. Environ. Sci. 8(1): 64-66.

Mu Y., 2013. Textile Materials, Beijing: China Textile Press: Pp. 25-39.

Nie, M., Zhang, T., Pei, C., Quan, D., & Chen, N., 2008. The U/Θ effect of electricity parameters of the lotus root silk in the liquor with different pH values. Sci. Bull. 53(12): 1924–1928.

O'Malley, C., 2011. Lessons from the entrepreneurial path. Leadership for Sustainability: An Action Research Approach: 138-141.

Pan, Y., Han, G., Mao, Z., Zhang, Y., Duan, H., Huang, J., & Qu, L., 2011. Structural characteristics and physical properties of lotus fibres obtained from *Nelumbo nucifera* petioles. Carbohydr. Polym. 85(1): 188–195.

Pandey, R., Sinha, M. K., & Dubey, A., 2020. Cellulosic fibres from Lotus (*Nelumbo nucifera*) peduncle. J. Nat. Fibres 17(2): 298-309.

Patil K., 2018. Lotus Fibre: A new facet in textile and fashion. Int. J. Humanit. Soc. Sci. Invent. 7(12): 71-75.

Pensupa, N., Leu, S.Y., Hu, Y., Du, C., Liu, H., Jing, H., Wang, H. & Lin, C.S.K., 2017. Recent Trends in Sustainable Textile Waste Recycling Methods: Current Situation and Future Prospects. Top. Curr. Chem. 375(5): 189-228.

Rowell, R. M. (ed.) 2005. Moisture properties. Handbook of wood chemistry and wood composites, Boca Raton, Florida: CRC Press Inc. Pp. 77–98.

Sharan M. and Haldar S., 2021. Lotus (*Nelumbo nucifera*) - An Exploration of Hygro waste for Textile Applications. Acta sci. agric. 5.5: 119-126.

Sharma S.C. & Goel A.K. 2000. Philosophy and Science of the Indian Lotus (*Nelumbo nucifera*).International Society of Environmental Botanists. Millennium Issue 6(1). https://www.isebindia.com/2000/00-01-08.html

Sheikh, S. A., 2014. Ethno-medicinal uses and pharmacological activities of Lotus (*Nelumbo nucifera*). Journal of Medicinal Plants Studies 2(6):42-46.

Tomar S. & Yadav N., 2019. Lotus fibre: An Eco Friendly Textile Fibre. Int. Arch. App. Sci. Technol. 10(2): 209-215.

Wang J., Yuan X., He J., Gan Y., Chen D., 2008. Physical property of lotus fibres. J. Text. Res. 29(12): 9–11

Yuan, X. H., Gan, Y. J., Chen, D. S., & Ye, Y. J., 2012. Analysis on Mechanical Properties of Lotus Fibres. Advanced Materials Research, 476: 1905–1909.

Zare Sakhvidi, M. J., Bidel, H., & Kheirandish, A. A., 2021. Investigation of Noise Pollution Distribution in Different Parts of Yazd Textile Factories. Archives of Occupational Health 5(2): 993-999.

Zhang, Y., & Guo, Z., 2014. Micromechanics of Lotus Fibres. Chemistry Letters 43(7): 1137–1139.

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