SHORT COMMUNICATION

Carbon and Ecological Footprint of Textile Industry: Application of R3 Strategy to Mitigate the Environmental Effects of Textile Processing Waste

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Abstract

The carbon footprint reflects the greenhouse gases (GHGs) generated throughout the life cycle of a human activity or product, and is therefore an important tool for assessing and managing GHGs emissions. Ecological footprint display the impact assesments of waste managments process of any industry, as it generates very harmful products in the environment. However, it needs attention to use advanced technology to mentain the equllibrium of carbon and ecological footprint of textile industry. Presented review comprises the carbon and ecological foot prints of textile effluents and 3R strategy for their possible balance. 3R strategy i.e. reduce, recycle and reuse were discussed in terms of carbon reduction through transport management, and waste management generated from textile industries including nutritional value of textile sludge and effluent for agricultural use.

Keywords: 3R strategy, Carbon foot print, Ecological foot print, Greenhouse gas, Textile industry

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Introduction

Global warming poses a threat to the natural environment and human economic development. Many studies have shown that global warming primarily result of increasing emission of greenhouse gases (GHGs) by human activities (Jamali-Zghal *et al*., 2013; Zamani *et al*., 2015; Brito de Figueirêdo *et al*., 2013). The carbon footprint reflects the GHGs generated throughout the life cycle of a human activity or product, and is therefore an important tool for assessing and managing GHGs emissions in a given time frame. Usually a carbon footprint is calculated for the time period of a year (Wang *et al*., 2015). It is estimated that about 70-80% of emission of CO_2 in the environment is due to the fuel combustion in the industries. The carbon footprint assessment is an important approach for the control and management of GHGs emissions (Wang *et al*., 2015). The concept and name of carbon footprint originated from the discussion of ecological footprint and is based upon life cycle assessment (LCA). The ecological footprint (EF) is a measure of human demand on the Earth's ecosystems. It basically used to assess the supply and demand of products and services for an entire planet by expecting that the whole planetary population follows a particular way of life of a known group of individuals. Textile industry is one of the larger environment polluters besides steel, cement and fertilizer industry. To create new green paradigm, the textile and apparel industries needs to adopt 3R concept strategy comprising with reduce, reuse and recycle. 1) Reduce: low carbon foot print processes cut costs by reducing waste of raw materials and energy. Reduction of raw materials and energy used by the textile dyeing and finishing sector consistently reduce global CO_2 emission. By saving energy and water, the textile industry help to slow down climate change. 2) Recycle and 3) reuse: generated waste (sludge) and wastewater (after treatment or dilution) from textile industries can be use as a fertilizer in cotton field or crop production and reduce the chemical applications in agricultural field. Recycle and reuse of industrial waste in agricultural soil could be great source for nutrients fortification to overcome the micronutrient deficiency in the soil, plants and human beings (Jain, 2017; Singh and Rathore, 2018).

To enlighten the above steps this study emphasised the problems created from textiles industries as part of climate change (Carbon foot print and Ecological foot print of textile industry) as well as possible solution to overcome the harmful effects in the environment using R3 strategy i.e. reduce, R1; recycle, R2; reuse, R3.

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Carbon foot print of textile industry

According to the U.S. Energy Information Administration, textile industry is the 5th largest contributor to CO_2 emission in the United States, after primary metals, non-metallic mineral products, petroleum and chemicals (EIA, 2002). India's total emissions are the fourth-largest in the world, after the United States, China and Russia, though its per capita footprint remains lower at 1.2 tons annually, compared to 20 tons in the United States and the world average of 4 tons. Total emission from the textile industry is estimated to be 18.12 million tons in India (Shah, 2016). Although, with 16% of the global population, India's share of CO_2 emission is only 3.11%, yet in one study from the Stockholm environment institute it was found that the embodied energy of organic cotton from India was greater than conventionally produced cotton from the USA because the yields are much less in India, requiring more land to grow (Cooper, 2007). Conventional cotton, which makes up the next largest percentage of worldwide fibre production, is also heavily detrimental to the environment. Cotton growth requires intensive use of pesticides, chemical fertilizers, and water. Cotton manufacturing also requires the heavy use of chemicals and energy. However, dying and bleaching of fabrics involves chemicals, energy, and huge amounts of water.

Table 1: CO_2 emission of spun fibre (Kg/ton) from organic and conventional production of cotton harvesting

	Crop cultivation	*Fibre production*	*Total*
Polyester	0.00	9.52	9.52
Cotton, conventional	4.20	1.70	5.90
Hemp, conventional	1.90	2.15	4.05
Cotton, organic, India	2.00	1.80	3.80

Source: O Ecotextile (2013)

Evaluation of carbon foot print of textile industry

Textile processing industry is characterised not only by the large volume of water required for various unit operations but also by the variety of chemicals used for various processes (Chavan, 2001). There is a long sequence of wet processing stages requiring inputs of water, chemical, energy and generating wastes at each stage. It is estimated that about 132 million metric tons of coal (or 1,074 billion KWh of electricity) is burned in a year and about 9 trillion of water is used in the processes (Rupp, 2008). To estimate the embodied energy in any fabric/ textile process it's necessary to add the energy required in two separate fabric production steps:

1. Find out what the fabric is made from, because the type of fibre tells you a lot about the energy needed to make the fibres used in the yarn. The carbon footprint of various fibres varies a lot, so start with the energy required to produce the fibre.
2. Energy used to weave those yarns into fabric. Once any material becomes a "yarn" or "filament", the amount of energy and conversion process to weave that yarn into a textile is pretty consistent, whether the yarn is wool, cotton, nylon or polyester (U.S. Energy Information Administration, 2008).

The precise carbon footprint of different textiles varies considerably according to a wide range of factors. However, studies of textile production in Europe suggest the following CO_2equivalent emissions footprints per kilo of textile at the point of purchase by a consumer (Berners-Lee, 2010) i.e., 1) Cotton: 8, 2) Nylon: 5.43, 3) polyethylene terephthalate (e.g. synthetic fleece): 5.55, 4) Wool: 5.48.

The global textile industry produces about 60 billion kg of fabric annually and is responsible for the production of large amount of carbon emission by various processes such as dying, bleaching, and finishing.

A study done by the Stockholm Environment Institute on behalf of the BioRegional Development Group concludes that the energy used (and therefore the CO_2 emitted) to create 1 ton of spun fibre is much higher for synthetics than for hemp or cotton (Table 1).

Ecological footprint of textile effluent

The ecological footprint indicator was mainly founded on the carrying capacity concept, which refers to the number of individuals who can be supported in a given area within natural resource limits and without degrading the natural, social, cultural, and economic environment for present and future generations (Kratena, 2008; Roca and Herva, 2015). The textile and clothing supply chain demands a lot of resources at each of the six stages of textile industry typically required material and chemicals to make a garment, the negative impacts on the environment are as numerous as they are varied. Spinning, weaving and industrial manufacture undermine air quality (Roca and Herva, 2015). Dyeing and printing consume vast amounts of water and chemicals, and release numerous volatile harmful agents into the atmosphere. Therefore, each stage of the life cycle chain for textile products contributes to the ecological footprints (from fibre production to waste disposal) (Muthu, 2014). The application of ecological footprint to textiles showed that the type of material used is a key issue in the sustainability of this activity (Fig. 1A). A number of works done considering different types of fibres (conventional and organic cotton, wool, hemp, synthetic stich and polyster among others) (Cherrett *et al.*, 2005; Herva *et al.*, 2012; Muthu, 2014; Roca and Herva, 2015).

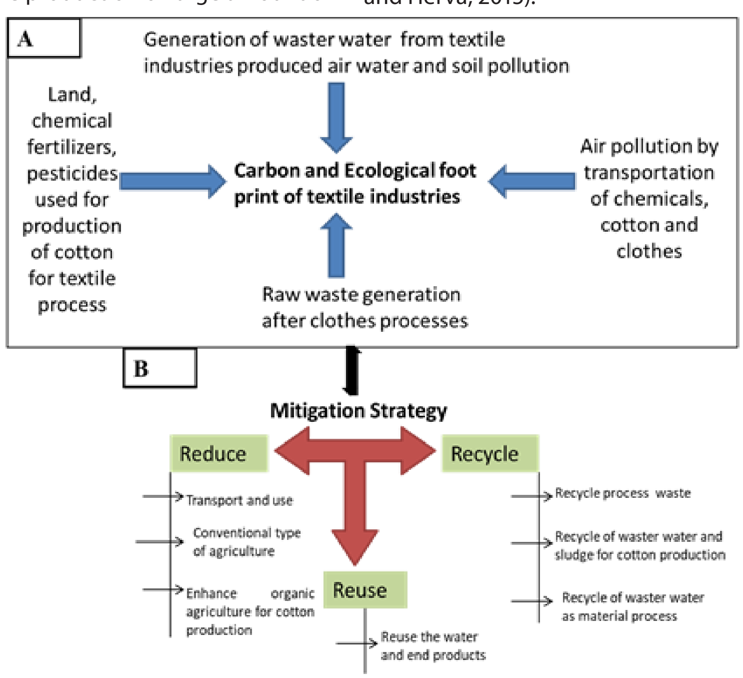

Fig. 1: A) Sources of carbon and ecological footprint of textile industry; and B) mitigation using R3 strategy.

Application of R3 strategy to mitigate carbon and ecological footprint of textile industry

Reduce (R1)

Cotton is the most pesticide intensive crop in the world, these pesticides injure and kill many people every year. Growing cotton uses 22.5% of all the insecticides used globally (Aktar *et al.,* 2009). The most effective way to reduce a carbon footprint is to either decrease the amount of energy needed for production or to decrease the dependence on carbon emitting fuels (Fig. 1). In addition using natural fibres can also take part in reduction of carbon foot print compare to synthetic fibre in different way which is described as follows:

Biodegradble and less production of pollution in the environment

Being able to be degraded by micro-organisms and composted (improving soil structure); in this way the fixed CO_2 in the fibre will be released and the cycle closed. Synthetics do not decompose in landfills they release heavy metals and other additives into soil and groundwater. Recycling requires costly separation, while incineration produces pollutants in the case of high density polyethylene, e.g., 3 tons of CO_2 emissions are produced for 1 ton of material burnt (Fletcher, 2008).

Carbon sequestration

Carbon sequestration is the process through which CO_2 from the atmosphere is absorbed by plants through photosynthesis and stored as carbon in biomass (leaves, stems, branches, roots, etc.) and soils,for example, Jute absorbs 2.4 tons of carbon per ton of dry fibre (FAO, 2009).

Recycle and reuse (R2 and R3)

Although air, water, and noise pollution are created at every step of fabric process in textile industry, the most problem filled in terms of the huge amount of water and well known number of chemicals used in wet processing to complete the whole process, leftover dyes and chemicals together with water are discharged as effluents. The textile industry consumes a substantial amount of water in its manufacturing processes used mainly in the dyeing and finishing operations of the plants (Chequer *et al*., 2013). It had also been estimated approximately one million tons of chemical dyes are used every year in textile industry (Zhao *et al.,* 2012). Up to 200,000 tons of these dyes are lost to effluents every year during the dyeing and finishing operations, due to the inefficiency of the dyeing process, unfortunately these dyes persist in the environment , however, removal of effluent dissolved dyes might be use in textile processing (Chu, 2001). Therefore recyle of dyes and water is a great topic of concern (Bilińska *et al*., 2019).

As the amount of sludge created by wastewater treatment increases, so the effective reuse and safe disposal of wastewater and sludge becomes most important (Vajnhandl and Valh, 2014).

Despite the evident reuse potential within the textile, state of the art indicates that implementation of water and sludge reuse is still an uncommon practice industry (Visvanathan and Asano, 2009). The reusability study showed high potential with respect to water reclamation, as well as, reduction of the associated chemicals consumption. With the need to safeguard the quality of freshwater supplies and reduce freshwater usage as required by the increasing demands of food and clothes due to increasing population, the possible applications of wastewater reuse has been growing. Textile processing generates many waste streams, including liquid, gaseous and solid wastes. Although they contain known number of hazardous compounds, but generally textile effluents and generated sludge contains high quantity of different plant essential nutrients including nitrogen, phosphorus, sulphur, calcium and some essential micronutrients. Therefore, industrial wastewater reuse has the advantage that undesirable pollutants are not discharged into the water environment as they are removed at source. In addition, the recovery of process chemicals, by-products and heat energy is achievable in some instances (Marcucci *et al.,* 2001). Different study were published regarding the application of industrial effluents in terms of soil nutrient availability and for irrigation purpose after proper treatment and dilution. Moreover, application of industrial wastewater and sludge reduce the use of chemical fertilizers and also take part in conservation of energy needed to synthesize chemical fertilizers such as nitrogen, phosphorus etc. (Aubert *et al.,* 2009). In brief, when we discuss about the nutrient composition of textile waste, a great concentration of sulphate and phosphate ion has been reported in effluent generating from textile industries (Imtiazuddin *et al.,* 2014). In addition, these wastes also contain some essential micronutrients such as Zn, Ni, Co, Cu etc. required by all plants for their growth and developments (Saratale *et al.,* 2009). Hence, the application of this waste (sludge and waste water) as fertilizer, irrigation in agriculture, as well as recycle of chemicals and dyes for industrial purpose can be directly or indirectly helps in carbon and ecological foot print reduction of textile effluents by reducing the use of extra water, energy, and chemical fertilizer for cotton production.

Conclusion

Increasing values of carbon and ecological foot print created by textile effluent by different ways such as, cropping, harvesting, transportation, processing of cottons and dying the clothes as end product, suggest the needs of proper management of waste disposal, energy and reduction of carbon emission. Based on the above discussion, it might be concluded that 3R strategy can be best approach for the reduction of carbon and ecological foot prints. In addition, agriculture part will also be in benefited for macro and micronutrient availability for better crop production replacing the chemical fertilizer.

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