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Industrial carbon footprint of several typical Chinese textile fabrics

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ABSTRACT

Carbon Footprint (CFP) can clearly reflect the emission of greenhouse gases (GHGs) in the whole-life cycle of certain human activities. The assessment of CFP is an important tool and a basis for managing and controlling greenhouse gas emissions. At the product level, the CFP and carbon label could contribute to the low-carbon consumption mode by providing more carbon information for consumers, thus playing an important role in impelling society towards a low-carbon mode. China is the largest textile and garment producer and consumer, in the world. Studies on the CFP of textiles are important in the management of domestic greenhouse gas emissions, and in communicating carbon information and carrying out relevant negotiations in international trade. This study selected two types of typical Chinese textiles: wool fabrics and cotton fabrics. Wool fabrics include pure wool fabric and blended wool–polyester fabric; cotton fabrics include 11 kinds of fabrics: yarn-dyed fabric in pure cotton and polyester cotton, bleached fabric made by a plain weave process and a rib process, dyed fabric in pure cotton and polyester–cotton in dark, medium, and light colors, and gray fabric. The production procedures and relevant production data for typical enterprises were meticulously investigated and collected. The system boundaries, relevant methods, and assessment models of each textile industrial CFP were established. Subsequently, based on the calculation of China's CFP coefficients of energy and materials, the study assessed the CFPs of these textile fabric products. A comparative analysis of the results of different types of fabric show the industrial CFP of wool fabrics is almost three times that of cotton fabrics. The industrial CFPs per unit product in descending order are: pure wool fabrics, blended wool-polyester fabrics, and cotton fabrics; the average industrial carbon footprint of each being 14.07 $kgCO_2e/kg$, 13.55 $kgCO_2e/kg$, and 5.34 $kgCO_2e/kg$, respectively. The critical factors influencing the industrial CFP of cotton fabrics are the types of fabric used and the corresponding production processes. The industrial CFP of yarn-dyed fabric is higher than that of dyed fabric, by 70.8%, on average, and the industrial carbon footprint of fabric made by the plain weave process is higher than fabric made by the rib process, by 76.2%. In addition, different raw materials, textile technologies, and dye colors used resulted in CFP differences. Indirect industrial CFP, the major source of which is consumption of electricity, contributes about 87% of the total industrial CFP, while direct industrial carbon footprint only contributes about 13%. The consumption of energy, for instance electricity, steam, and coal, is the main source of industrial CFP. The study results imply that the key approaches for reducing the CFP of textiles are to enhance energy management, especially in the use of electricity, and to improve the output efficiency of production. As regards the consumers, choosing light colored cotton textiles leads to less CFP and climate change impacts.

1. Introduction

In the context of global warming, the assessment of greenhouse gases (GHGs), their management mechanisms and means of emission, is becoming one of the biggest concerns in research into eco-environmental management. Carbon Footprint (CFP) assessment and management, based on the basic conception of life cycle theory, could analyze the GHGs of the study object in the whole life or in some spatial times or spaces. Carbon Footprint (CFP) assessment has become an important direction of research on GHGs. Many researchers in China and abroad, studied and researched CFP in several ways: l the concepts, the calculation methods, and case studies.[1–2] Their researches include many sectors, such as industry, transportation, and architecture [3–5]; and the research scales include individuals, families, organizations and institutions, and cities and nations [6–11].

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PAS 2050: 2008, [12] published by the British Standard Institution (BSI), and co-sponsored by the Carbon Trust and the Department for Environment, Food and Rural Affairs (DEFRA), details some outstanding work on CFP assessment at the product level. About more than 2500 goods have the CFP product label. Research and application of CFP assessment at the product level can provide carbon information for the consumer product at every process of its life cycle. The general concept of product CFP is the total GHGs emitted over the full life cycle of a product or a spatial process. For the producers, the CFP of product help to practice the low-carbon production; for the consumers, the CFP of product provide the data guidance for low-carbon consumption. However, because of the significant difficulty of gaining the support of manufacturers and the high demand for data quality, the research on product CFP is still very few, which results in a lack of a quantitative basis in the control of GHGs at the product level.

Textiles are important consumer products, within China and overseas. Chinese textiles companies produce nearly 30% of textiles in the world's total trade. Current research on textile CFP focuses on life cycle [13], but not many studies address the industrial production CFP of textiles. Many GHG control policies in China require Chinese textile companies to reduce their carbon dioxide emissions by 20% per unit of GDP [14–15]. Above all, the accurate assessment of textile industrial CFP could not only help Chinese textile companies in the global textile trade market, but also offer the reference data necessary to achieve future emission reduction goals.

Based on the methodology and study of life cycle assessment, the 4th report of the IPCC, and PAS 2050:2008, this study constructs an assessment method and model of industrial CFP for textile fabrics. We choose pure wool fabric, wool–polyester blend fabric and four kinds of cotton fabrics as assessment objects. The cotton fabrics included yarn-dyed fabric, bleached fabric, dyed fabric, and gray fabric. The research tracked the production flow of each textile fabric, created an inventory of their industrial CFP and calculated the product industrial CFP of these typical textile fabrics.

2. Methods and model

2.1. Implication of industrial CFP and assessment method

The CFP of textiles referenced to the textile industry throughout the life cycle of textiles. It contains two parts: direct emissions and indirect emissions. Direct industrial CFP is the GHG emissions of fossil-fuel combustion at the industrial production stage, and indirect industrial CFP is the GHG emissions of secondary energy consumption, the use of raw materials and dye additives in the textile production process. The purpose of the industrial CFP of textiles is to assess emissions caused by energy and material use, and to identify factors in the production process that impact the environment [15–16].

Life-cycle assessment is the environmental impact assessment for some materials, processes, or products from cradle to grave in the whole-life cycle. The assessment method based on life cycle theory is the most feasible means in industrial product CFP assessment. This study analyzes the integrated impact of GHGs from textile production activities, along the technology and supply chains of textiles [14].

2.2. General system boundary of product industrial CFP

The industrial CFP of textiles system boundaries are divided into two parts: direct CFP and indirect CFP. Direct CFP is the source of GHG emission directly from the industrial processes of textiles, such as emissions of fossil-fuel combustion or process emissions caused by chemical reactions. Indirect CFP is GHG emissions from the consumption of industrial raw materials, auxiliary materials, and secondary energy [16].

In this context, based on the process analysis, we classify the inputs and outputs of textile industrial CFP assessment, which is acquired by the life cycle inventory analysis. The determinate system boundaries are shown in Fig. 1.

Direct emissions of the industrial CFP of textiles include four parts: fossil-fuel combustion; the process of physical and chemical reactions; industrial processes and transport links in the production process; and fugitive emissions of equipment at the interface. Emissions of fossil-fuel combustion include coal, oil, and gas combustion emissions. During the production, the physical and chemical reaction processes include textile dyes and GHG emissions of auxiliaries used in the reaction chemistry. GHG emissions of transport links include all sectors of industrial production, from the last link between the intermediate products during transport, to the place of the next link in the combustion of fossil fuels, leading to direct discharge to the environment of GHGs.

Indirect emissions include GHG emissions from the consumption of industrial raw materials, auxiliary materials, and secondary energy. The CFP of industrial raw materials and auxiliary materials and chemical additives is the GHG emissions of these materials during the entire process life cycle. Raw materials referred to as the CFP of cotton textiles, wool, hemp, and other crops used in the manufacturing process. Auxiliary materials referred to as the CFP of packaging bags as accessories in manufacturing. CHG emissions also arise from dyes and the chemical additives used in dyeing, or to accelerate chemical reaction processes,

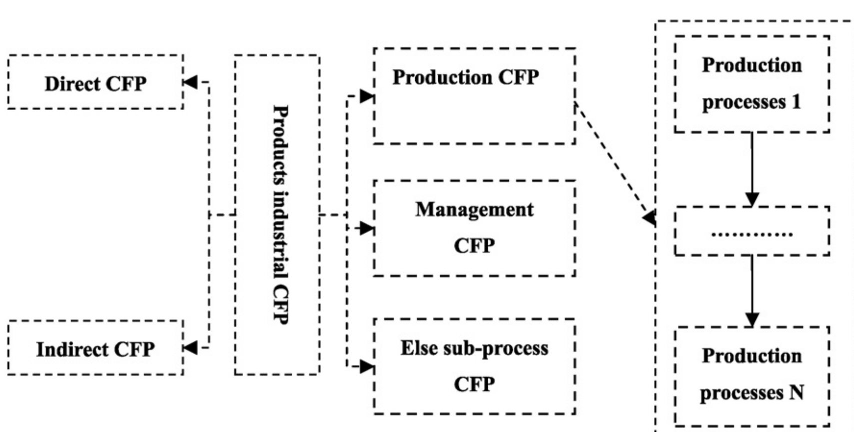

Fig. 1. The evaluation boundaries of industrial carbon footprint of products.