Journal of Sustainable Energy & Environment 2 (2011) 105-115

Eco-Labeling Criteria for Textile Products with the Support of Textile Flows: A Case Study of the Vietnamese Textile Industry

V.N. Thai[1,2,]*, A. Tokai[1], Y. Yamamoto[3], and D.T. Nguyen[4]

[1]Osaka University, Division of Sustainable Energy and Environmental Engineering, Yamadaoka 2-1, Suita, Osaka 565-0871, Japan
[2]HoChiMinh City University of Technology (HUTECH), 144/24 Dien Bien Phu, Binh Thanh District, HCM City, Vietnam
[3]Wakayama University, Faculty of Systems Engineering, Sakaedani 930, Wakayama-city 640-8510, Japan
[4]HoChiMinh City College of Natural Resources and Environment, 236B Le Van Sy, Tan Binh District, HCM City, Vietnam

Abstract: Developing countries are confronted with difficulties in implementing eco-labeling schemes when they adopt eco-labeling criteria from developed countries. Production-related criteria, in particular, must reflect the availability of necessary infrastructures and local conditions. This study identified such criteria in a case study of the Vietnamese textile industry. It aims to (1) understand textile flows by using the mass balance concept and the combination of available data (which is insufficient) in Vietnam and previous reports and (2) identify production-related eco-labeling criteria from resource consumption, 46 pollutants and toxicants discharged by the textile industry. The results show that, in 2008, 1.67×10^6 tons of textiles flowed through Vietnam, approximately 19.4 kg/person. Textile manufacturing represents a majority of the processes of the Vietnamese textile industry with 1.40×10^6 tons of textiles being processed (84% of total flows in 2008). T-shirts and trousers were the major products in the textile manufacturing, i.e., produced (64.8%), exported (17.1% and 13.7%, respectively). Thus, these products are ideal candidates for eco-labeling. By filtering indicators through three conditions (availability of data and testing methods, significant environmental impact, and economic feasibility) and validating the identified criteria through a field survey of T-shirt production, we concluded that water and energy consumption, and SO_2 and COD emissions could serve as eco-labeling criteria. However, other identified key indicators should be considered for further studies. These criteria are useful for the next steps of criteria development. Material flow analysis and the proposed identification of eco-labeling criteria can resolve the constraints imposed by a lack of data in developing countries.

Key words: Eco-labeling criteria; key environmental indicators; manufacturer survey; textile flows; Vietnamese textile industry.

1. Introduction

Among the various eco-labeling schemes in developed countries, life cycle assessment is used as an analytical tool for identifying valid eco-labeling criteria [1-3]. However, the biggest barriers to applying life cycle assessment in developing countries are a lack of data and data confidentiality, especially those regarding background systems [4]; the requirements for time and money consuming inventories through the entire life cycle are another constraint. Furthermore, developing countries face difficulties if they adopt criteria for eco-labeled products from those in developed countries, particularly production-related criteria; these criteria may be virtually impossible for developing countries to implement [5-6]. The criteria should be tailored to the local conditions where appropriate [6-8], taking into account the gaps (e.g., necessary infrastructure, local conditions) between developing and developed nations. As a result, mutual and equivalency recognition between two or more eco-labeling schemes are necessary in order to overcome the problem of differing environmental conditions. This means that if a product receives a label in one scheme, it would be automatically eligible for an eco-label in another labelling scheme. This paper shows a method for identifying eco-labeling criteria related to the production of textile products produced in developing countries by using the Vietnamese textile industry as a case study.

Eco-labeling criteria are specific to particular product groups and can be divided into production-related and product-related criteria [9]. As discussed above, this paper focuses on the former. These Acriteria must be key environmental indicators that consumers can use to choose more environmentally sound products. Several questions arise here: What are the main products of the Vietnamese textile industry? What are the main processes of the textile product chain in terms of environmental issues? How can eco-labeling criteria in the main processes be identified to significantly reduce the environmental impact? The process of establishing eco-labeling criteria setting involves three steps: assessment of the relevant aspects; analysis of products in the market; and final approval by the stakeholders [4]. This paper limits itself to the first step - proposing a set of possible environmental criteria for eco-labeling of textile products.

In this context, this study aims to (1) create a comprehensive picture of textile production in Vietnam through material flow analysis and (2) identify a set of possible production-based eco-labeling criteria for textiles that are appropriate for developing countries. Hence, we proposed a method based on the mass balance concept to convert the available data (monetary and quantity data) into material flows to identify the main processes and products. In terms of eco-labeling criteria, we first identify key environmental indicators that cause significant environmental impacts from resource consumption, water and air emissions, and toxic chemicals released by the main processes of the textile industry. To accomplish this, we use the industrial pollution projection system (IPPS) database and previous studies and then validate the results by conducting a field survey of the main product categories. The reducing of resource use and emissions, in accordance with these criteria, can significantly reduce the environmental impact of the textile industry.

2. Literature overview

2.1 Textile flows

Although the textile industry is one of the most important sectors worldwide, material flow analysis of textiles is rare. Textile flows were used to assess the present and future sustainability of clothing and textiles in the United Kingdom (UK) [10]; however, these flows were built from the available monitored data, both weight and currency - neither of which is available or accurate in Vietnam. To deal with these constraints, we propose a method of estimating textile flows and outline a complete picture of the Vietnamese textile industry on the basis of relevant statistical data and other sources.

2.2 Production-related eco-labeling criteria of textile products worldwide

The environmental label Type I defines the eco-labeling criteria as environmental requirements that products must meet to be awarded an eco-label [8]. Identifying these criteria requires finding key environmental indicators that significantly influence pollution management. The assessment and comparison of such criteria can differentiate environmentally sound products from conventional products in the same category.

Production-related eco-labeling criteria address emission standards through all production stages, including water and energy consumption, air, waste, and water emissions, and the permissible levels of toxicants (e.g., heavy metals, toxic and carcinogenic compounds) in the chemicals used. Various criteria in both developing and developed countries have been adopted from the EU Eco-label scheme; however, they should be developed with regard to local capacities and infrastructure in terms of monitoring and auditing. There are some differences in the eco-labeling criteria of textiles among three major schemes of the EU, Nordic countries, and Japan, because they were identified on the basis of the high-priority environmental policies in those countries. The EU Flower and Nordic Swan schemes focus on controlling effluents of air and water emissions, and hence, some key indicators, such as COD, NaOX (chlorinated compounds), Cu, Zn in wastewater and VOC, acrylonitrile, aromatic disisocyanates, and sulfur in air emissions, were selected as the criteria for awarding eco-labels [2-3]. In Japan, the Eco Mark scheme mainly takes the contents of recycled and recovered fibers into account because of the development of a recycling-oriented society [11]. The Nordic Swan scheme deals with phosphorous concentrations in textile effluents; however, none of previously published papers or documents have addressed the identification of production-based eco-labeling criteria for schemes in developing countries.

2.3 Necessity of eco-labeling for the textile industry

From an international viewpoint, the textile-garment industry faces new challenges following the globalization of the world economy and competition from fast-growing Asian producers. To stay in business, textile producers have to look for differentiating factors by designing high-value textiles and clothing. The recent removal of tariff barriers under the World Trade Organization Agreement (in 2005) may cause exporters to face more stringent environmental standards in the international textile and clothing markets. Therefore, a significant increase has been recorded over the last few years in the use of eco-labels in textile products in both developed and developing nations [12-13].

From a local viewpoint, the textile-garment industry plays a major role in the Vietnamese economy, accounting for 8.5% of GDP, constituting 17.0% (first rank) of employment among manufacturing sectors, and the first rank of income from exports [14]. However, the technologies used in the textile industry are obsolete and inefficient in comparison with those of its competitors. For example, 43% of the machinery was produced in the 1990s and 53% in the 1980s or before [15]. The sector uses a large amount of water and fuels and releases a considerable amount of highly polluted wastewater and emissions. Our previous research pointed out that the textile product category is the highest potential candidate for the Vietnamese eco-labeling scheme [16].

3. Experimental

3.1 Textile flow analysis

We define the boundaries of the material flow analysis from fiber production to textile disposal, including reuse and recycling of used clothing and textile wastes; the system is shown in Fig. 1. Due to a lack of data on production quantities of the Vietnamese textile industry, we estimated the mass of textile products on other variables including monetary units (US$/product unit), pieces (e.g., shirts, trousers and towels), lengths (e.g., carpet, canvas and fabrics). We divided the textile industry into seven areas to show our estimations and assumptions (Fig. 1). Due to the diversity of textiles and apparel, products in one category, e.g., T-shirt, could differ in weight, thickness, size, and decoration. To create textile flows, we assumed that textile products in each category had the same weight, and fibers and fabrics were homogeneous. The detailed relevant input data are shown in Appendix C.

Domestic extraction: The mass of materials for domestically extracted fibers are available in the Statistical Yearbook of Vietnam [General Statistics Office (GSO), 2008] and the Vietnamese Industry in 20 Years of Renovation and Development (GSO, 2005).

Imported textiles: Cotton and fibers are recorded by mass (tons/year) [17], while fabrics and auxiliaries (e.g., ribbons, labels, thread, lace, zippers, mex, and tulle) are in currency (million US$/year). Hence, we need to convert them to mass by using Equation 1.

$$M_{i(import)} = (V_i / P_i) \times d_i \times 10^{-6} \qquad (1),$$

where $M_{i\,(import)}$ *(ton/year)* is the mass of fabrics and auxiliaries; V_i *(US$/year)* is their total import values; P_i *(US$/m²)* is the price per square meter, cited from the weekly news of the Vietnam National Textile and Garment Group (VINATEX) [18]; d_i *(g/m²)* is the density of products (200 g/m^2 for fabrics on an average, 159 g/m^2 for auxiliaries [19], and 10^{-6} is the unit conversion from grams to tons. Input data and results are shown in Table C1.

Fiber production: The mass of all types of locally produced fibers are also available in documents from the GSO [20].

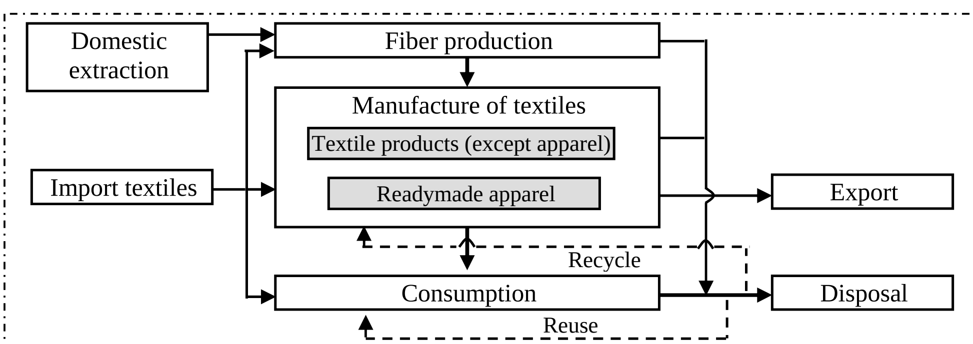

Figure 1. Textile flows in the Vietnamese textile industry, in 2008.

Manufacture of textiles (textiles and apparel): Data related to textile products are recorded in square meters (m^2) or pieces except fiber. Equation 2 shows how their weights were estimated.

$$M_{j(production)} = (N_j / 12) \times k_j \times d_j \times 10^{-6} \quad (2),$$

where $M_{j\ (production)}$ *(ton/year)* is the mass of textiles and apparels; N_j*(pieces/year)* is the amount of textile product (j); k_j *(m^2/12 pieces)* is the length of 12 pieces of the product (j); and d_j *(g/m^2) is* the density of materials making textile products. The value of k_j is cited from the American Textile and Apparel System (ATAS) [21], while d_j is quoted from previous research [19] and is dependent on product type and materials. 10^{-6} is the unit conversion from gram to ton. For textile products, such as canvas, towels, carpet, and tulle, which are recorded by length, the mass is calculated by multiplying length with density. The input data and results are presented in Tables C2–C3.

Exported textiles: All data are recorded in currency (10^6 USD/year). The price of the apparel is its average price at three main export destinations, i.e., the United Sates (US), the EU, and Japan, in 2008. These values are cited from the weekly news of VINATEX, reports from the GSO, and previous reports [22-23]. The density of materials (d_j) is cited from past research and reports [19,24-25]. Because Vietnamese textiles are mainly made of cotton and polyester, we used the densities of textiles made with these materials and then calculated the mass as shown in Equation 2. Relevant inputs and results are shown in Table C4.

Consumption: According to a survey conducted by VINATEX (2009), the domestic expenditure on textile products/apparel was 5 billion USD [26]. To estimate the mass of textiles in the domestic market, we used the population in Vietnam in 2008 (86,210,800) [GSO] and the average fiber consumption demand worldwide, 9.2 kg/capita [27]. For the main textile products, we used the distribution of textiles in the Indian market, and determined that the three key apparel items popular in Vietnamese are T-shirts, trousers, and shirts.

Disposal (to landfill, reuse, recycling, and others): To estimate textile waste from domestic consumption, we identified the contribution of textile waste to solid waste as 4.2% [28]. The total solid waste generated in Vietnam in 2008 was 17×10^6 tons, which gives a calculated weight of textile waste of 714,000 tons. The amount of textile waste (rags) recycled is measured from a case study at Nam Son landfill [29]. Rags are collected by scavengers and sold to recyclers or manufacturers. The recycled textile waste was estimated to be about 4,267 ton/year. With regard to reuse, used clothes are purchased and sold for secondhand use. Based on the price of the clothes purchased (0.117 USD/kg) [30] and the total purchasing value (7 million USD/year) [31], we estimated the amount of clothes reused 60,000 ton/year, i.e., $7*10^6$ (USD/year)/[0.117 (USD/kg)*1,000].

3.2 Methods for identifying production-based eco-labeling criteria

As mentioned in Section 2, the identification of eco-labeling criteria is carried out through addressing key environmental indicators that measure the severity of environmental impacts. The key indicators include resource consumption and emissions, and these can be identified on the basis life cycle assessment. However, this method is difficult to apply in developing countries because of a lack of data and finance, even though it is common in developed countries. Thus, it is necessary to develop a method for determining key indicators of the textile industry in developing countries. According to our worldwide survey of eco-labeling schemes, some schemes use qualitative life cycle assessment (e.g., the US and Germany), and some simplify the full version to an analysis of the most important stages of the product life cycle. Furthermore, the selected key indicators could be controlled and influenced by textile manufacturers. For example, cotton cultivation and clothing use are analyzed as contributors to water usage for the former and electricity consumption for the latter; however, cotton cultivation takes place in various places with high uncertainty of productivity, whereas clothing use is linked to consumer behavior, not production systems. In this context, we identify key environmental indicators during wet processing including de-sizing, bleaching, rinsing, dyeing, printing and finishing, which is the most water, energy, and pollution intensive [16,32-33] of the production phases of textile products.

This section discusses how to identify such key indicators. Key indicators should reflect the high-priority environmental policies in developing countries. Because reducing industrial water, air, and land pollution is an important issue in Vietnam [33], we began the process by looking at water and energy consumption, and examining seven pollutants and 39 toxicants discharged by the textile industry. This set was then reduced to the key indicators by using the following conditions: (1) availability of reliable data and testing methods (e.g., emissions regulated by the Ministry of Natural Resources and Environment [34] and available relevant databases); (2) the importance of each indicator in terms of environmental impact (e.g., high emissions or usage levels, high risk-weighted pollution loads); and (3) indicators that can be economically reduced by local textile producers.

The textile industry is the largest consumer of water per ton of product in Vietnam. A report of the Vietnam textile cooperation (VITAS) shows that water and electricity consumption are the most intensive during wet processing - this process accounts for 76.6% of the water consumption and 52.6% of the electricity use of the entire product chain [35]. In addition, the percentage of energy expenditure to product cost is higher than that in other countries; this percentage is 10-12% in the Vietnamese textile industry compared to 7-8% in the Thai textile industry [36]. Accordingly, we selected water and energy consumption in wet processing as the key environmental indicators, which must be controlled to reduce the environmental impacts of the Vietnamese textile industry. The consumption of water and energy per kilogram of fabric produced and the pollutant emission loads are estimated as follows:

a. Water consumption: Water consumption can be estimated by multiplying the amount of textile products (GSO, 2008) with the water usage per unit products - 200 $m^3/10^3$ m of canvas [37]. Then, we totaled all water consumption of textile products and estimated the water consumption (m^3) for one kilogram of fabric.

b. Energy consumption: Based on a recent study [38], the electricity, coal, and fuel oil consumptions of the Vietnamese textile industry are 1,293 GWh/year, 603,510 ton/year, and 422,460 ton/year, respectively. Therefore, we can calculate the energy consumption (PJ) of the textile industry and the consumption (MJ) per kilogram of fabric.

c. Pollutants: We used the IPPS database [39] to estimate the pollution loads by multiplying the pollution intensity (pollution per unit of employment) of each emission by the number of employees. The textile manufacturing processes (spinning, weaving/knitting, and wet processing that are the main sources of consumption and emissions, and apparel sewing) causing the highest overall pollution load were selected for the examination [16]. The employment data were cited from the GSO. Equation 3 shows the estimation of pollution loads for environmental indicators. We converted these estimated pollution loads, measured in tons per year, to grams per kilogram of fabric (Equation 4). Since the producers should be the ones reducing the selected criteria, we compare the values of emissions of the Vietnamese textile industry with reference values from other eco-label schemes or countries having better textile technologies. The comparison is shown as a ratio in Equation 5. The selected key indicators are emissions having ratios much higher than one.

$$L_{ni} = I_{ni} \times N_i \qquad (3)$$

$$L'_{ni} = L_{ni} / W_t \qquad (4),$$

$$Ratio = L'_{ni} / R_n \qquad (5)$$

where L is the pollution load (kg/year); L' is the pollution load (g/kg fabric); I is the pollution intensity (kg/1,000 employees); N is the number of employees; n is the pollutants (COD, TSS, SO_2, VOC, CO, TSP, and NO_x); i is the year (2000-2008); W_t is the total weight of fabric produced in year (i) quoted from GSO; R is the reference value of each emission (g/kg fabric). Input values are shown in Appendix A.

d. Toxicants: The toxicities of emissions have recently become a concern in worldwide industrial pollution prevention. But there are no criteria for toxicity in the existing eco-labeling schemes. However, to take this concern into account, it is necessary to identify the toxic chemicals released by the textile industry that have the highest toxicity. Key toxic chemicals are also identified using the IPPS database. We chose 39 toxic substances discharged in the manufacture of textiles (available in the IPPS database) and calculated their pollution loads by using Equation 3. To compare their toxicities, we calculated their risk weighted pollution loads as in Equation 6 [40]. The contribution of each toxicant is measured by $(P_n/ P^t_n)\times 100$ (%). Toxicants with the highest contribution are considered as the key indicators.

$$P_n = w_n \times L_{n2008} \qquad (6)$$

$$P^t_n = \sum_{n=1}^{n=k} P_n \qquad (7),$$

where L_{n2008} is the unweighted pollution load of chemical (n) in 2008; P_n is the risk-weighted pollution load of chemical (n); P^t_n is the total of risk-weighted pollution loads emitted from textile manufacturing; k = 39, (number of chemicals examined); w_n is the sulfuric acid equivalent risk factor associated with chemical (n) (w_n = TLV for sulfuric acid/ TLV for chemical n). W_n and pollution loads are presented in Appendix B.

The threshold limit value (TLV) is a time-weighted average concentration of an occupied space in air, which cannot be exceeded without adverse effects to workers in a normal 8-hour work day or 40-hour work week. In this analysis - we used the 1996 TLVs [41] and updated the values from material safety data sheets (MSDS). Although the TLV values apply to air exposure, we assume that they can be used to approximate the toxicity from the exposed water routes [42].

4. Results and discussion

4.1 Textile flows of the Vietnamese textile industry in 2008 (Figs. C1−C5 and Tables C1−C4 in Appendix C)

Domestic extraction (Fig. C1): The industry produced 125×10^3 tons of fiber materials. Synthetic staple fibers have recently been produced in Vietnam - prior to 2004, they were all imported [15]. Thanks to a government policy that promotes the auxiliary industry, foreign and local investors have established synthetic fiber mills. Accordingly, the share of synthetic staple is dramatically increasing and now comprises 64% of the total domestically produced materials. However, the Vietnamese textile industry still imports 69% of its synthetic staples (172×10^3 tons) although it plans to reduce this to 50% and 30% by 2010 and 2020, respectively [43]. Materials from vegetable origins, such as cotton, silk, jute, and flax, are traditionally produced in Vietnam but with minority shares. Cotton production, for example, represents only 5% (15×10^3 tons of a total of 305×10^3 tons) for cotton fiber production; it is planned to increase the cotton production to 60×10^3 tons by 2020 [43].

Imported textiles (Fig. C2 and Table C1): $1,544\times10^3$ tons of textiles and their materials were imported in 2008 (12.4 times the domestic extraction). The three main textile products imported were fabrics (27.9%) for sewing clothing, fibers (all types) (25%) for fabric processing, and cotton (25%) for fiber fabrication. The remaining imports included clothing and synthetic staples. Clothing imports chiefly come illegally from China (80% of import values), entering the Vietnam market through the border and paying no import duties. Although the auxiliaries comprise small part of overall imports, the Vietnamese textile industry still imported 95% [15].

Fiber production (Fig. C3): Vietnam produced 500×10^3 tons of fibers in 2008. Cotton and synthetic fibers are two key products of the fiber production stage. Polyester (PE) comprises 93% of the synthetic fibers. As a result, clothing is chiefly made of cotton and PE. However, the textile industry still imports 46.3% of its fibers (431×10^3tons) for fabric production.

Manufacture of textiles (Fig. C4 and Tables C2−C3): $1,404\times10^3$ tons of textiles and clothing were manufactured in 2008. Textile products comprise 32% of the total textiles and apparel in which fabrics comprise 40.3%, followed by woollen apparel and towels. However, the industry has to import 53% (386×10^3 tons) of fabrics to complement its demand but plans to reduce this to 50% by 2010 [43]. The weights of the main types of apparel and their distributions are estimated and shown in Table C1. The largest apparel segment is adult casual wear (64.8%, consisting of T-shirts, shirts, skirts, trousers, and shorts) followed by adult jackets (23.6%). Casual wear, especially T-shirts, is mainly made of cotton fabric since this fabric keeps the body cool, is naturally stretchable, and is hypoallergenic. The total mass of apparel produced is around 811×10^3 tons/year.

Export textiles (Fig. C5 and Table C4): In 2008, Vietnam exported 639×10^3 tons of textiles and clothing. Among these export products, readymade apparel plays a vital role in foreign income, and by mass, their share constitutes the largest fraction (52.7%). In terms of specific product categories, T-shirts make up the second highest contribution of mass (the highest in currency, Table C2), followed by trousers (13.7%). Although Vietnamese fiber companies can produce a considerable amount of fibers, due to their low quality for processing exports, a majority is exported to other countries (214×10^3 tons, equivalent to 50% of the total imported fibers of 431×10^3 tons). This is a weak point for the industry because of lack of close contact between fiber producers and fabric and apparel producers. Hence, government policies or regulations should address this issue to improve the industry's ability to use domestic fibers.

Consumption Domestic consumers mainly use (69.7%) local products made by manufacturers, tailors, and family companies; while imported products (22.8%) mainly come from China by illegal routes, and 7.5% are secondhand, with T-shirts and trousers considered the most common clothing.

Disposal: $1,011\times10^3$ tons/year of textile waste goes to local landfills. This problem must be addressed because around 90% of the waste from consumption goes to landfills, while in Japan for example, this figure is 79.4% [11]. The reuse and recycling of cloth wastes should be promoted in Vietnam to save natural resources and reduce waste.

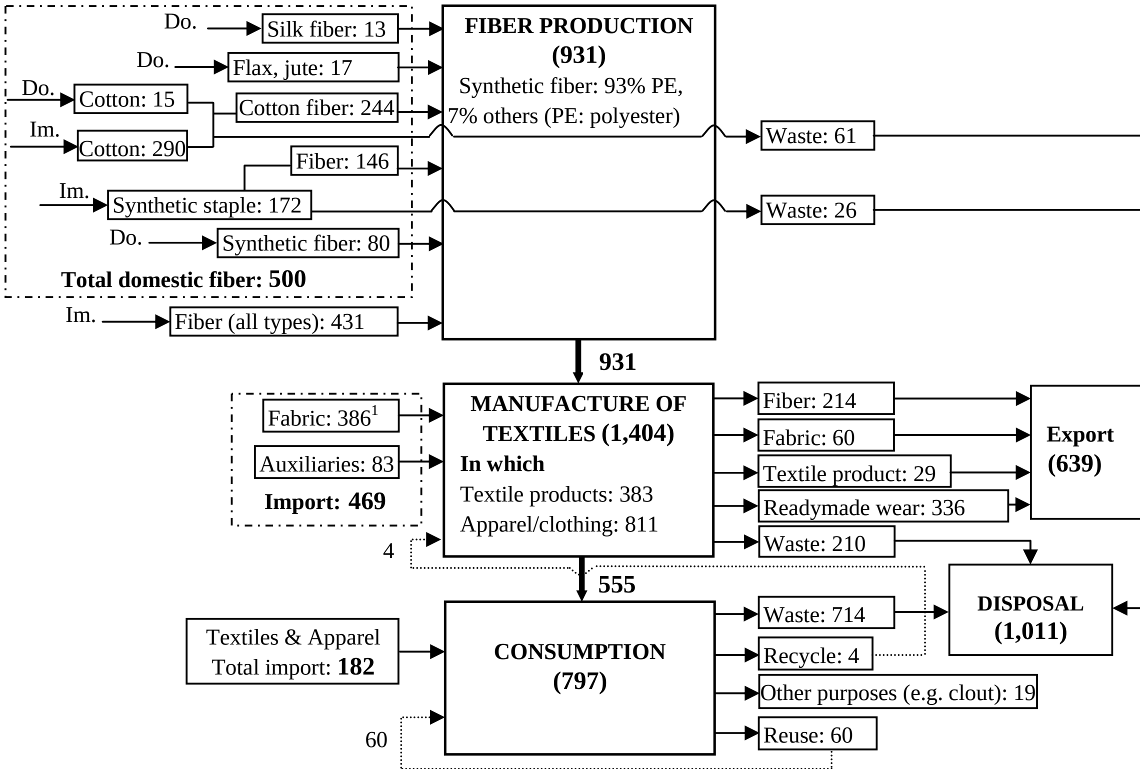

Figure 2. Textile flows of the textile industry in Vietnam in 2008; MF: material flow (thousand tons/year); [1]both raw (unfinished) and finished fabrics; Do. and Im. stand for domestic and imported. (See more detailed results in Tables C1–C4).

Based on the monitored results of cotton, yarn and fibers and estimations for the others, we produced the textile flow illustrated in Fig. 2. As assumed in Section 3.1, due to the diversity of textiles, the textile flows may encounter uncertainties in the estimated data. However, textile products are mainly made of cotton and polyester, so they can be considered homogeneous. Because the Vietnamese textile industry focuses on a few main products (e.g., T-shirts, trousers), there is little diversity. Fig. 2 shows that the textile flow through Vietnam in 2008 was 1.67×10^6 tons, approximately 19.4 kg/person – much lower than that in the UK (3.25×10^6 tons and 55 kg/person).

Textile manufacturing is the main process in the textile industry, with the largest textile flow (84% of total flow) - 1.40×10^6 tons/year. T-shirts and trousers are the main products because they are produced, exported, and used domestically in largest fractions (Tables C2 and C4). Therefore, for eco-labeling, T-shirts and trousers should be selected as specific product categories for Vietnam's eco-labeling scheme. The identification of production-based eco-labeling criteria in the next section will focus on textile manufacturing or wet processing in detail due to its large resource consumption and emissions.

4.2 Identification of production-based eco-labeling criteria for textile products

In Section 3, we discussed how to identify eco-labeling criteria, and observed that this requires finding key environmental indicators that suggest a significant environmental impact, which can be significantly reduced.

Based on previous reports [32-33], we determined that water and energy consumption are key environmental indicators. In this section, by using another method, these indicators were estimated for textile manufacturing. Total water usage in this stage was estimated at 87×10^6 m^3 in 2008. This is approximately equal to 62 kg (total water used per total mass of textiles, i.e., $1,404\times10^3$ tons) of water used to process 1kg of fabric; in the UK, this figure is 60 kg [10]. The total energy consumption was estimated at about 39.3 PJ. This is equivalent to 27.9 MJ/kg, which is higher that in the UK (27 MJ/kg output [10]) and in the range of 10–60 MJ/kg issued by World Bank [45]. Although values in Vietnam and the UK appear similar, a majority of the fabrics used in Vietnam are finished products (the industry imports 53% of its raw and finished fabrics, Section 4.1) that do not use energy and water in this stage. This implies that the water and energy consumption to produce one kilogram of fabric may be two times that of the estimated values. Hence, water and energy are used inefficient, and there is room for improvement. Accordingly, water and energy consumption is considered as eco-labeling criteria for controlling pollution emissions from the textile industry. Water and thermal energy consumption have been accepted as criteria for eco-labeled textiles in the latest version of the EU Flower scheme [3].

As discussed in Section 3.2.c, we first select key indicators from 46 emissions (seven pollutants and 39 toxicants), based on their high emission levels, compared with those of other eco-labeling schemes, or of countries producing textiles with better technologies than Vietnam, and their highest risk-weighted pollution loads. The emission trends of pollutants from 2000 to 2008 are shown in Fig.3, which was obtained by dividing the pollution loads (L'_{ni}, g/kg fabric) of each indicator by reference values (see Appendix A). The reference values are cited from previous reports, i.e., COD = 20 g/kg and VOC = 1.2 g/kg fabric [3] (the EU Flower criteria); NO_x = 30.2 g/kg and CO = 28.2 g/kg [46] (Finnish textiles, better technologies); and SO_2 = 12.3 g/kg and TSS = 70 g/kg [47] (Turkish textile manufacturing, better technologies. The value of SO_2 in Finnish textile discharges is much lower, 6.3 mg/kg). We used these foreign values due to the lack of such values in Vietnam and to understand the possibilities of reduction for each indicator.

Volatile organic compounds (VOC) and SO_2, for instance, can be significantly reduced in comparison with the reference value, while others (TSP, TSS, CO, NO_x) are not problems. Fig. 3 indicates that the ratios of SO_2, VOC, and COD (in descending order) are higher than one, i.e., their emission loads are higher than the reference values - SO_2, VOC, in particular, so they are the key indicators. Controlling these key indicators could reduce the environmental impact of the textile industry.

The risk-weighted pollution loads (ton H_2SO_4 eq/year, Section 3.2.c) of 39 toxicants are shown in Appendix B, and the chemicals discharged into air and water that have the highest toxicities are presented in Table 3. These chemicals should also be considered as key indicators, especially formaldehyde and sodium hydroxide (NaOH), due to their high contributions. Sodium hydroxide has not been mentioned as a criterion in existing schemes, but an alternative criterion, pH, could be. In fact, the levels of formaldehyde, VOC, and chlorine emitted are criteria for eco-labeled textiles in Nordic Swan [2] and the EU Flower [3]. In addition, from January, 2010, all Vietnamese textiles exported into the US market must be tested for the lead remaining in clothing [48].

Table 1. Contribution of risk-weighted pollution loads of main toxic substances to air and water at the wet processing.

1. Air emission	**RWPL[2]**	**% Cont.**	**Cumulative %**
Formaldehyde	865.5	51.6	51.6
Lead	239.6	14.3	65.9
VOC (Toluene)	217.6	13.0	78.9
2. Wastewater[1]	**RWPL[2]**	**% Cont.**	**Cumulative %**
Sodium hydroxide	4,971.6	94.1	94.1
Chlorine	242.4	4.6	98.7

[1]*Heavy metals (lead, chrome and copper) make up 0.2%*
[2]*RWPL: risk-weighted pollution load (ton H_2SO_4 eq/year)*

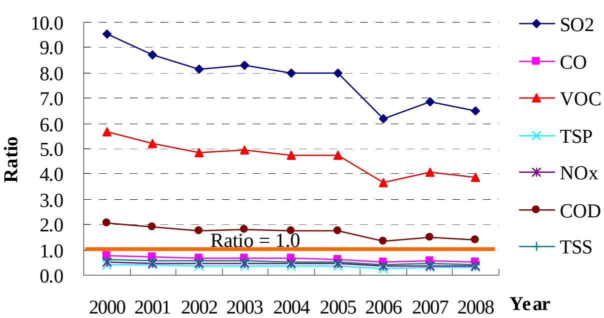

Figure 3. Trends of some emissions in textile wet processing
Ratio = estimated values/reference values (see Eq. 5)

Above, we pointed out the key indicators of significant environmental impacts. We must understand the economical means of reducing them in Vietnamese textile mills. A program carried out in 12 Vietnamese textile dying mills in the period 1999-2003 demonstrated a high potential for reducing water and energy consumption in textile mills - 13-36% for electricity, 10-15% for fossil fuels, and 13-20% for water consumption - and significantly reducing levels of emission loads - 15% for NaOH, 16-32% for COD, and 16% for SO_2 [49]. No data were recorded for reductions in lead, formaldehyde, VOC and chlorine emissions; however, as these are eco-labeling criteria for eco-labeled textiles in Nordic Swan and the EU Flower, they are promising to investigating their reduction potentials further.

In summary, based on the inefficient use of water and energy, the high emission loads of 46 indicators, and the possibility for significant reductions shown by the cleaner production demonstration project in Vietnamese textile mills, we concluded that water and energy consumption, two emissions (SO_2, COD), and a toxicant (NaOH) would serve as eco-labeling criteria. As discussed above, such criteria are feasible and effective for local textile producers who apply environmentally sound methods or technologies. Two criteria, SO_2 and NaOH, have not been mentioned in other existing eco-labeling schemes. The high concentration of SO_2 comes from using coal and high-level sulfur oil (3%) in Vietnamese textile mills. This suggests that the usage of biomass residues, which are plentiful in Vietnam, could be a way of reducing SO_2 emissions from textile mills. SO_2 is also considered to be one of the most pressing air pollution issues in Asia [50]. The EU Flower criteria mention NaOH in the form of NaOX, when it combines with chlorine, but discharges into the environment in its single form (NaOH) must be considered. Other key indicators (formaldehyde, VOC, lead, and chlorine) should also be further considered and tested for their economic feasibility. The proposed method differs from previous studies on two points: (1) it uses a simple method that developing countries can utilize to identify eco-labeling criteria instead of life cycle assessment, which focuses on air emissions and consumes much time and money; (2) the economics and feasibility of the proposed criteria should be tested at local textile mills.

Accordingly, we validate this proposal with a case study of T-shirt production for 19 textile manufacturers, considering their product chain (from fiber production to T-shirt making).

4.3 Validation of proposed criteria through analysis of T-shirts made of 100% cotton fabric

To validate the plausibility of the proposed criteria and determine if they have a significant potential of being reduced and whether the estimated and monitored results at textile mills agree, we conducted a survey of textile/garment factories in LEMINHXUAN and TANBINH industrial parks in HoChiMinh City (2008), where a majority of the textile industries (56% of the total industry) are located. We focused on T-shirt production because it comprises the largest fraction of the Vietnamese textile industry (Section 4.1). Based on a study of life cycle assessment of T-shirts at ThanhCong company [51] (one of the largest textile enterprises in Vietnam), fabrics constitute 95.5% of the composition of a T-shirt. Hence, the production of auxiliaries, e.g., ribbon, label, and thread, were excluded.

The validation mainly focused on the proposed criteria; water consumption (WC), energy consumption (EC), and SO_2 and COD emission but not NaOH as there are no records on its use and/or alternatives (Na_2CO_3) used in textile mills. Other data, such as annual productivity, number of laborers, and numbers of days worked per month, were collected to convert into grams of emissions per kilogram of fabric. Nineteen factories employing typical technologies cover the product chain of T-shirt were collect data to validate - one for cotton fiber production (spinning); two for raw fabric production (knitting); six for finished fabric production (wet processing); and ten for T-shirt making.

The results show that spinning and knitting consume no or little water, while wet processing uses about 84% of total water consumption. Wet processing is also responsible for 82% of the total energy consumption. This energy consumption in the wet processing mainly comes from fuel usage for boilers. The high consumption of fuels (fuel oil and coal) leads to high emissions of SO_2. In short, water and energy consumption have the highest usage in wet processing. This again indicates that focusing on wet processing, as in Section 4.2, is important.

There are no validated emissions from the spinning and knitting processes, while emissions from T-shirt sewing are much less than those from wet processing - 58.9 versus 5.4 (g/kg fabric) SO_2 and 64.9 versus 4.4 (g/kg fabric) COD emissions from wet processing (Table 2, average values) and sewing, respectively.

Hence, we only considered wet processing. First, we compared the emission concentrations with Vietnam's emission standards at six textile mills (Table). The results indicate that the average values of COD and SO_2 are significantly higher than the standard limits; five textile mills emit SO_2 at rates 1.1-2.1 times higher than the standard and the COD of five mills exceeds.

Secondly, we compared the loads of the proposed criteria with reference values (see Appendix A), since such data do not exist for Vietnam. The monitored parameters, expressed in loads (unit/kg fabric), are shown in Table 2, including reference values for other countries. This table shows that the surveyed results are comparable with the proposed criteria. The rule of selection for reference values is that the values of the World Bank are the first priority because of their common usage, and the next priority is the maximum values of references. The average levels of almost all criteria are higher than the references: 1.5-2.7 times that of WC, 1.2-3.9 times that of EC, 1.8-7.2 times that for SO_2, and 1.5-4.9 times that for COD; thus they afford potential for reduction. In addition, if we compare these real ratios of COD and SO_2 with those in Section 4.2, they are also comparable. Accordingly, we assert that water and energy consumption and SO_2 and COD emissions are suitable production-based criteria for assessing whether a textile product deserves eco-labeling. In the case of NaOH, a monitoring system for usage and emission should be set in textile mills to check its plausibility.

5. Conclusions and Implications

Our main conclusions are summarized as follows:

Comprehensive picture of the textile industry and its implications: Domestic materials contribute little to fiber production and are mainly cotton and PE: 48.8% and 42%, respectively. The main industrial process is textile manufacturing: $1,404\times10^3$ tons of textiles and clothing were processed in 2008. The industry imports 53% of its fabric, mainly for sewing export products that must meet requirements of import partners. In 2008, 1.67×10^6 tons of textiles flowed through Vietnam, approximately 19.4 kg/person. In this textile flow, T-shirts and trousers were the major product categories produced, forming the largest segment of exports and domestic consumption; therefore, they should be selected as specific product groups for the Vietnam eco-labeling scheme. The proposed method can monitor the mass of textiles and their changes annually; the results in this paper could be considered as baseline values. The methods can overcome the problem of an absence of monitored quantitative data for the textile industries of developing countries. However, the estimates have two weak points: the diversity of textile items because they are decorated with different auxiliary items even though they fall in the same product category, and fiber usage is counted twice because fibers can be used to produce intermediate products (yarns and fabrics), and then they belong with the intermediate products, can be used to produce various textile and clothing products. However, this problem also occurs in the case of monitored data as the UK textile flows.

Production-based eco-labeling criteria and their implications: Through validation by a field survey of T-shirt production, we proposed water and energy consumption and SO_2 and COD emissions as indicators of production-based eco-labeling criteria. Other key indicators, such as NaOH, VOC, formaldehyde, lead, and chlorine, are considered to be promising indicators and should be studied further to investigate their economic feasibility and plausibility. This paper proposed a set of possible eco-labeling criteria; the results can be used for next steps such as addressing quantitative values by using cost-benefit analysis, analyzing products in the market, and final approval by the stakeholder board. These criteria could be used to assess pollution reduction and perform cost-benefit analysis by implementing cleaner methods or technologies in textile mills. To deal with toxicants, the government should issue regulations regarding VOC, NaOH, formaldehyde, lead, and chlorine discharge and monitoring, and evaluate their economic feasibility. Identifying such criteria by using the IPPS database is easier than life cycle assessment and can be transferred to other industries. However, the limitation of IPPS database is twofold: (1) the data is old and (2) the pollutants examined are limited. Hence, renewal of IPPS database should be the first step for the development of our method. Furthermore, the data collected and method proposed can be used to build a LCA database and maybe used in the future to start a Carbon Footprint or Water Footprint Label for Vietnamese textile products.

The analysis of textile flows indicates that the link between fiber producers and textile producers is weak, creating a situation where the industry imports far too much fiber and fabric. This can be solved by policies that encourage the use of domestic materials. Another issue to be addressed in the textile industry is low ratio of reuse and recycle of textile wastes.

Acknowledgments

We thank the Division of Sustainable Energy and Environmental Engineering, Osaka University for financial support of the project. We express our gratitude to the members of the Department of Environmental Management in HoChiMinh City, who helped with data collection. Special thanks are due to the Rotary Foundation for its scholarship for the PhD course in Osaka University, Japan.

Table 2. Environmental loads per one kilogram of finished cotton fabric during wet processing.

No	Code of Company		WC (g/kg)	EC (MJ/kg)	SO_2* (g/kg)	COD (g/kg)	SO_2*(mg/m^3)	COD (mg/L)
1	LMX016		276	66.0	42.6	141.8	2,456	642
2	LMX071		176	63.9	22.1	31.6	1,680	225
3	LMX073		186	140.1	29.2	49.5	800	722
4	TB026		250	41.4	NA	105.7	-	529
5	TB085		325	72.6	53.3	26.0	2,280	100
6	TB102		186	103	88.1	34.9	3,125	234
	Average		**233**	**81.2**	**47.1**	**64.9**	**2,068**	**409**
	References	[1]	30.5	36	NA	34–61	-	-
		[3]	NA	NA	NA	20	-	-
		[45]	70–120	NA	NA	9.6–21.6	-	-
		[47]	NA	NA	12.3	NA	-	-
		[52]	-	-	-	-	1,500	-
		[53]	-	-	-	-	-	150

*WC and EC are water and energy consumption, respectively; *Emissions from energy production not included; NA: Not available; LMX and TB stand for LEMINHXUAN and TANBINH industrial parks. References 52 and 53 are Vietnamese emission standards for air emissions and water emissions, respectively.*

References

[1] Kalliala E, Talvenmaa P, Environmental profile of textile wet processing in Finland, *Journal of Cleaner Production* 8 (2000) 143-154.

[2] Nordic Eco-labelling (2011) *Nordic eco-labelling of textiles, skins and leather*, Version 3.4. 18 March 2004-30 June 2011.

[3] Bigguet R, Dascot M, Frischer K, Fourcade F, *Revision of the textile eco-label* (2007).

[4] Mungkung R, Udo de Haes HA, Clift R, Potentials and limitations of life cycle assessment in setting eco-labelling criteria: A case study of Thai shrimp aquaculture product, *International Journal of Life Cycle Assessment* 11 (2006) 55-59.

[5] Nimon V, Behgin JC, Eco-labels and international trade in textiles, *Center for agricultural and rural development (CARD) publications* 99-wp 221 (1999) Iowa state university.

[6] European *Chemical Industry Council, Trade implications of eco-labelling schemes*, Report, Brussels (2002).

[7] Goodland R, *Eco-labelling: opportunities for progress toward sustainability* (2002) Environmental department of the World Bank.

[8] ISO 14024: 1999, *Environmental labels and declarations - Type I environmental labelling - principles and procedures* (1999).

[9] Neitzel H, *Applying non product-related criteria in eco-labelling: Some controversies and experiences* (1998).

[10] Linstead C, Ekins P, *Mass balance UK (mapping UK resources and material flows)* (2001).

[11] *Japan Environmental Association - Eco Mark Office, Product certification criteria for clothes version 2.3* (2006).

[12] Atilgan T, Eco-labelling applications in the textiles & apparel sector in Turkey, *Journal of Fibres & Textiles in Eastern Europe* 15 (2007) 14-19.

[13] Boura AD, *Overview of existing textile/clothing eco-labelling schemes* (2002) Report, Barcelona, Spain.

[14] OECD, *Using the pressure-state-response model to develop indicators of sustainability* (1998). http://oecd.org/env/indicators/index.html

[15] Vietnam Central Institute for Economic Management, *Report on the survey of technology innovation at manufacturing enterprises in Vietnam, Hanoi* (2004). (in Vietnamese).

[16] Thai VN, Morioka T, Tokai A, Yamamoto Y, Matsui T, Selection of product category for national eco-labelling scheme: A case study of Vietnamese manufacturing sub-sectors, *Journal of Cleaner Production* 18 (2010) 1446-1457.

[17] Vietnam Textile and Apparel Association (VITAS), Available at http://www.vietnamtextile.org/ChiTietTinTuc.aspx?MaTinTuc=67&Matheloai=58

[18] Vietnam Textile Cooperation, Available at http://www.vinatex.com/WebPage/News/NewsCategory.aspx?CategoryID=286 [assessed on 23, April 2009]

[19] Hirschler MM, Piansay T, Survey of small-scale flame spread test results of modern fabrics, *Fire and materials* 31 (2007) 373–86.

[20] Vietnam General Statistics Office, *Statistic Yearbook of Vietnam* (2008) http://www.gso.gov.vn/default.aspx?tabid=512&idmid=5&ItemID=9232

[21] *Agreement about textile products between Vietnam and the United State, Annex A* (in Vietnamese).

[22] Nieuwoudt T, *Vietnam's Textile Industry – Opportunities and Challenges* [assessed in 2009]. http://thesupplychainlab.wordpress.com/2009/10/04/ vietnam%E2%80%99s-textile-industry-opportunity-and-challenge/

[23] Reports from Vietnam Customs, Available at http://www.customs.gov.vn

[24] Sportswear collection, Available at http://www.involution.co.uk/Game-Gear-Cooltex-Top-s-10-ss-96-p-380.html

[25] Informaion from Hongteng Printing and Dyeing Mill Jinzhou Company, Available at http://www.materialtrade.net/prices/hongfeng.doc

[26] Vietnam Textile Cooperation, *Survey results of Vietnam Textile Cooperation* (2009).

[27] Jaipuria S, *Trends in fibre consumption in India*, Available at http://garco10.vn/index.php?idnew=295

[28] HoChiMinh Waste Disposal Company, *Waste disposal report* (2002) Cited by Phan VA. Municipal waste. An essential part of our life (2006).

[29] Hoang VC, Solid waste management, *Solid waste management: issues and challenges in Asia* (2007) 298-327.

[30] Purchasing secondhand clothing. Available at http://www.xaluan.com/modules.php?name=News&file=article&sid=134459

[31] Vietnam Textile Cooperation (VITAS), *Strategy for textile and clothing exportation period 2006 – 2010*, (2006) Hanoi (in Vietnamese).

[32] Ren X, Development of environmental performance indicators for textile process and product, *Journal of Cleaner Production* 8 (2000) 473-481.

[33] NRDC (The Earth's Best Defense), NRDC's ten best practices for textile mills to save money and reduce pollution, *A practical guide for responsible sourcing* (2010). http://china.nrdc.org/files/china_nrdc_org/RSI%20full%20guide.pdf

[34] MONRE, Circular number 0707/2007/TT-BTNMT (2007).

[35] VITAS, *Conditions to reach the targets of Vietnam's textile and garment industry 2006–2010* (2004) (in Vietnamese).

[36] Le TT, *Evaluation of cleaner production implementation in textile companies of Vietnam and plans for coming years* (2009) (in Vietnamese).

[37] Ngo KC, Water related industrial development and industrial wastewater, *Final report of water sector review* (2008) Hanoi, Available at http://www.vnwatersectorreview.com/files/Water_related_industrial_development_EN.pdf

[38] Vietnam Energy Efficiency Program (VEEP), *National program for saving and efficient utilization of energy* (2007).

[39] Hettige H, Martin P, Singh M and Wheeler D, *The industrial pollution projection system*, The World Bank, policy research department (1995) http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/1995/03/01/000009265_3970311121557/Rendered/PDF/multi_page.pdf

[40] Susmita D, Benoit L, Craig M, *Accounting for toxicity risk in pollution control: does it matter?* (1998) The World Bank.

[41] American Conference of Governmental Industrial Hygienist (ACCGIH), *Report in 1996*.

[42] Benoit L, Karlis S, *Estimating industrial pollution in Latvia* (1998) The World Bank.

[43] Vietnamese Prime Minister, *Development strategy of textile/garment industry of Vietnam until 2015 vision toward 2020* (2008) (in Vietnamese).

[44] Unknown author, Growth in China's market for man-made fibers may be about to grind to a halt, ICIS Asian chemical connections. http://www.icis.com/Articles/Article.aspx?liArticleID=9151246&PrinterFriendly=true

[45] World Bank Group, *Environmental, health and safety guidelines for textile manufacturing* (2007). http://www.ifc.org/ifcext/enviro.nsf/AttachmentsByTitle/gui_EHSGuidelines2007_TextilesMfg/$FILE/Final+-+Textiles+Manufacturing.pdf

[46] Kalliala EM, Nousiainen P, Life cycle assessment -

environmental profile of cotton and polyester-cotton fabrics, *AUTEX Research Journal* 1 (1999) 8-20.

[47] Aysen M, Air pollutant emission potentials of cotton textile manufacturing industry, *Journal of Cleaner Production* 6 (1998) 339-347.

[49] Vietnam Cleaner Production Centre, *Situation analysis paper on cleaner production in Vietnam, Report* (2005) (in Vietnamese).

[50] Cofala J, Amann M, Gyarfas F, Schoepp W, Boudri JC, Hordijk L, Kroeze C, Junfeng Li, Dai Lin, Panwar TS, Gupta S, Cost-effective control of SO_2 emission in Asia, *Journal of Environmental Management* 72 (2004) 149-161.

[51] Nguyen ND, Koppen KV, Nguyen TMH, *Life cycle assessment of T-shirt of Thanh Cong extile*, *Company*, International conference on industry and environment in Vietnam (2001).

[52] MONRE, *National technical regulation on the effluent of textile industry* (2008) QCVN 13:2008/BTNMT, Hanoi.

[53] MONRE, *National technical regulation on industrial emission of inorganic substances and dusts* (2009) QCVN 19:2009/BTNMT, Hanoi.

Appendix

Appendix A Input values for estimation of pollution loads of pollutants and the values of pollution loads (L_{ni}) from 2000 to 2008; Pollution load (L'_{ni}) = I_{ni}×N_t/W_t (Eqs. 3 & 4)

Pollutants	I_{ni} (kg/year)	Year									Reference Value (R_n)
		2000	2001	2002	2003	2004	2005	2006	2007	2008	
Employees (N_t)		81,180	85,400	91,344	98,317	95,765	106,836	84,005	114,528	119,281	(mg/kg fabric)
SO_2	102,928.7	8,355,752	8,790,111	9,401,919	10,119,641	9,856,967	10,996,491	8,646,525	11,788,259	12,277,459	
CO	19,060.0	1,547,291	1,627,724	1,741,017	1,873,922	1,825,281	2,036,294	1,601,135	2,182,911	2,273,500	28.2
VOC	5,992.9	486,504	511,794	547,415	589,204	573,910	640,257	503,434	686,357	714,840	1.2
TSP	18,418.6	1,495,222	1,572,948	1,682,429	1,810,861	1,763,857	1,967,770	1,547,254	2,109,453	2,196,993	32.6
NO_x	14,202.0	1,152,918	1,212,851	1,297,267	1,396,298	1,360,055	1,517,285	1,193,039	1,626,532	1,694,032	30.2
COD	21,755.4	2,943,506	3,096,519	3,312,042	3,564,876	3,472,343	3,873,767	3,045,937	4,152,685	4,325,017	20
TSS	39,420.2	3,200,132	3,366,485	3,600,799	3,875,676	3,775,075	4,211,496	3,311,494	4,514,732	4,702,089	70
Mass of fabrics (ton/year) (W_t)		71,280	82,020	93,920	99,280	100,340	112,160	114,060	140,080	154,100	

Appendix B Values of w_n and risk-weighted pollution loads to air and water of the manufacturing of textile stage (*The 1996 TLVs [41] were used)*

No	Chemicals	TLV (= w_n)^1	Load to air^2	Load to water^2	No	Chemicals	TLV (= w_n)^1	Load to air^2	Load to water^2
1	Formaldehyde	0.37	86,5464.3	96.7	21	Di (2-ethylhexyl) phthalate	5	768.2	0.0
2	Acetone	1780	126.38	0.12	22	Tetrachloroethylene	170	1,614.1	64.9
3	N-butyl alcohol	20^3	0.0	0.0	23	Captan	5	11.0	0.0
4	1,1,1-trichloethane	1910	180,214.1	0.0	24	Hydrazine	0.013	5,597.0	0.0
5	Methyl ethyl ketone	590	472.8	0.0	25	Decabromodiphenyl oxide	3.5^3	0.0	102.2
6	Trichloroethylene	269	2,102.8	1.8	26	Sodium hydroxide	2^3	4,019.8	4,971,345.8
7	Dibutyl phtalate	5	269.6	0.0	27	Aluminum oxide	10	5,260.3	171.8
8	Butyl benzyl phthalate	5^3	0.0	0.0	28	Lead	0.05	239,516.2	5,964.1
9	Naphthalene	52	25.9	0.0	29	Manganese	0.2	1049.7	0.0
10	Biphenyl	1.3	34,123.5	468.6	30	Antimony	0.5	150.3	33.4
11	Ethylbenzen	434	51.3	0.0	31	Arsenic	0.01	5,486.9	0.0
12	Bis(2-ethylhexyl) adipate	0.5^3	811.1	0.0	32	Chromium	0.5	0.0	205.2
13	1,3-Butadiene	4.4	0.0	81.3	33	Copper	0.2	0.0	3,578.4
14	1,2-Dichloroethane	40	2,430.9	0.0	34	Zinc (fume or dust)	5	0.0	0.0
15	Ethylene glycol	100^3	546.3	63.7	35	Ammonia	17	34,493.3	13,182.7
16	Vinyl acetate	35	5.45	0.00	37	Nitric acid	5.2	91.8	0.0
17	Methyl isobutyl ketone	205	178.9	0.0	38	Chlorine	1.5	9,542.5	242,442.6
18	Maleic anhydride	1.0	823.0	0.0	39	Chlorine dioxide	0.28	10,351.9	0.0
19	Toluene	188	217,606.0	0.0		Total		1,675,751.6	5,284,221.3
20	Phenol	19	52,546.4	0.0					

^1w_n = TLV since TLV of sulfuric acid = 1; ^{2}Unit: ton H_2SO_4/year; ^{3}updated values by Material Safety Data Sheets

Appendix C Contributions of textile products produced, imported, and exported by the Vietnamese textile industry in 2008

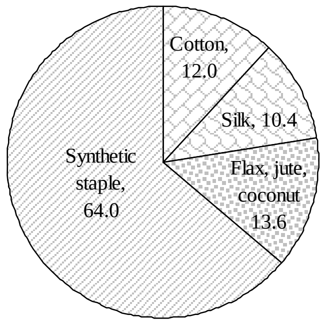

Fig. C1 Contribution (%) of domestically extracted raw materials

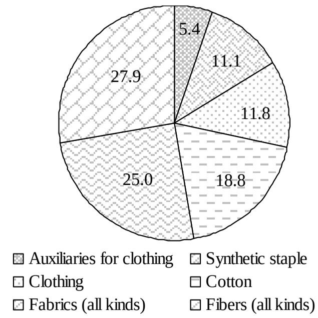

Fig. C2 Contribution (%) of imported textile materials and clothing

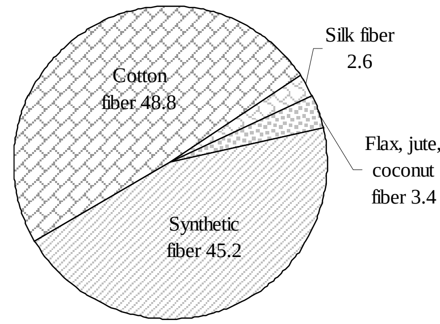

Fig. C3 Contribution (%) of domestically produced fibers

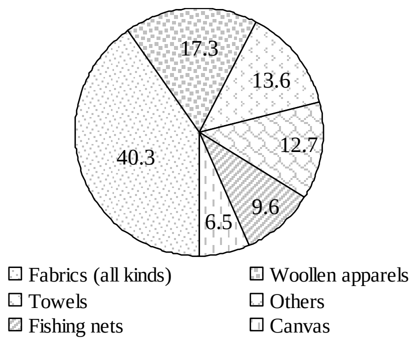

Fig. C4 Contribution (%) of domestically produced textile products

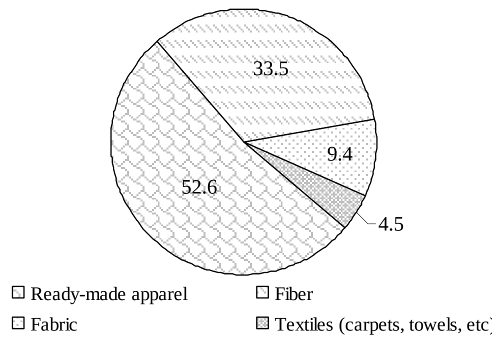

Fig. C5 Contribution (%) of exported textile products and readymade clothing

Table C1. Estimation of masses of imported textiles and auxiliaries.

No	Items	Value (million USD)	Price (USD/m^2)	Quantity (million m^2)	Quantity (ton)
1	Cotton	299.6			290,000
2	Staple and yarn	260.5			172,000
3	Fibers	578.5			431,000
4	Fabrics ($130g/m^2$)	4,453.8	1.5	2,969.2	385,996
5	Auxiliary materials*	1,393	2.65	526	83,438
6	Textiles and apparel**	-	-	-	182
	Total	**6,985.4**			**1,544,434**

** Zipper, mex, thread, lace, ribbon, tulle ($6.3m^2$ /kg)*

** Textiles and apparel were calculated by using mass balance at the consumption stage

Table C2. Estimation of masses of ready-made apparel domestically produced by the Vietnamese textile industry (2008).

No	Items	10^3 pieces[1]	m^2/12pieces[2]	Length (m^2)	d (g/m^2)	Mass (ton)	(%)
1	Adult jacket	172,868	45.1	649,695,567	295	191,660	23.6
2	Adult coat	65,984	45.1	247,989,867	244.8	60,708	7.5
3	Adult casual wear[3]	1,566,719	20.1	2,624,254,325	200	524,851	64.8
4	Sportswear for adult	56,575	12.5	58,932,292	150	8,840	1.1
5	Safety working articles	19,365	19.2	30,984,000	280.4	8,688	1.1
6	Underwear all types (excluding knitted articles)	97,475	9.2	74,730,833	83	6,203	0.8
7	Others	70,688	12.5	73,633,333	130	9,572	1.2
Total mass of apparel (ton/year)						**810,522**	**100**

[1]Data are annually recorded by GSO and VINATEX; [2]Values issued by ATAS; [3]T-shirt, shirt, skirt, trousers and shorts

Table C3. Estimation of mass of other domestically produced textile products.

No	Items	Unit	Quantity	Density (g/m^2)	Mass (ton)
1	Fabrics of all kinds	10^6 m^2	770.5	200	154,100
2	Cotton fabric for mosquito	10^3 m	26,113	64.7	1,690
3	Canvas	10^3 m^2	102,284	244.5	25,008
4	Towels(1)	10^6 pieces	775.3	168.2	52,162
5	Woollen carpet	10^3 m^2	94	475	45
6	Jute carpet	10^3 m^2	30	475	14
7	Sewing thread	ton	19,345		19,345
8	Fishing nets	ton	36,804		36,804
9	Stockings(2)	10^3 pairs	55,135	60.3	1,053
11	Tulles	10^3 m^2	203,487	61.3	12,474
10	Woolen apparel(3)	10^3 pieces	82,044	315	66,333
12	Hosiery(4)	10^3 pieces	121,461	121.9	13,819
	Total mass				**382,846**

(1) - 0.4m^2/piece; (2) - 3.8m^2/12 pieces; (3) - 30.8m^2/12 pieces; (4) - 11.7m^2/12 pieces

Table C4. Estimation of masses of export textile products produced by the Vietnamese textile industry.

No	Items	Value (10^6USD)	Price* ($/piece)	Quantity (10^6pieces)	(m^2/12pieces)	Length (10^6m^2)	d (g/m^2)	Mass (ton)	(%)
1	T-shirt	2,102	3.6	584	18.4	895	121.9	109,137	17.1
2	Shirt	500	6.54	76	20.1	128	125	16,007	2.5
3	Trouser & Short	1,891	5.37	352	14.9	437	200	87,448	13.7
4	Jacket & Coat	1,673	13.68	122	34.5	352	244.8	86,071	13.5
5	Dress (skirt)	364	4.7	77	14.9	96	130	12,501	2.0
6	Underwear	251	2.26	111	9.2	85	83	7,067	1.1
7	Sportswear	125.5	6.0	21	12.5	22	150	3,268	0.5
8	Children clothes	309.2	2.5	124	9.3	96	159	15,240	2.4
9	Fabrics (10^6m^2)	360.0	1.21^2			298	200	59,600	9.3
10	Fibers (1.45USD/kg)	405.8						214,000	33.5
10	Others	1,100.7	5.2	212	12.5	220	130	28,664	4.5
	Total export	**9,082**		**1,679**		**3,978**		**639,005**	**100**

** Average price of apparel at three main destinations; Items 1–8 are readymade apparels with total contribution 52.7%.*

