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論文内容の要旨

Ecolabeling[1] means providing information about the environmental friendliness of a product or service. By this, the government can encourage the demand (consumers) for and supply (producers) of those products and services that cause less stress on the environment. One study by UNOPS (2009) shows the rapid development and dissemination of the concepts of ecolabels, green production, consumption, procurement worldwide. These implications have been mainly used in developed countries while some research indicates that developing countries should have their own ecolabeling schemes[2] to prevent developed countries to force them to adopt their programs. The Guideline Document by Global Ecolabeling Network (GEN, 1999) also guides that an ecolabeling scheme has to meet the unique requirements of a particular country and its economic, social and environmental setting. Although increasing levels of international cooperation for adopting the work done by existing programs, the need to tailor product categories and ecolabeling criteria to domestic conditions is inevitable. In addition, such a Vietnamese scheme regarding product category selection and the establishment of products' ecolabeling criteria have not developed yet even though some relevant documents were issued, e.g., the National Strategy for Environmental Protection orients "…towards 2020, 100% of export products and 50% of domestic goods will be ecolabeled according to the ISO 14024 standard". This lateness is due to the short of relevant data availability and lack of expertise. In this context, this thesis aims to (1) understand the interest levels of Vietnamese consumers and a range of producers' views on ecolabeling that support vital information for a scheme establishment; (2) propose a selection method of product categories for a national ecolabeling scheme in developing countries; (3) determine production-related ecolabeling criteria for textile products (the highest potential candidate for the Vietnamese ecolabeling scheme); (4) develop a model to assess the plausibility of adopted product-based ecolabeling criteria with a case study of formaldehyde in clothing; and (5) provide some policy recommendations and research outlooks regarding the establishment of an ecolabeling scheme for relevant policy makers and researchers based on the results of four preceding objectives. The following paragraphs show how to approach these aims and main findings.

The first aim is to assess the interest levels of Vietnamese consumers and producers on ecolabeling. Consumer questionnaires were carried out at ten supermarkets in the inner of Ho Chi Minh City (HCMC) for public opinion, while manufacturer survey was conducted in three most highly developed, industrialized areas of Vietnam. Interviewed consumers said that how they believed in ecolabeled products and are willing to pay a price premium 10% but a few of them often experienced in purchases. Surveyed producers present that a majority of them perceived ecolabeling as important but not confronted with much in their trading activities. The export share and ISO usage influence significantly producers' interest levels in ecolabeling while producers' readiness to apply the ecolabel is affected only by the export share. Based on the findings of questionnaire survey results, potential product categories and manufacturers for the scheme should be whose with high export share and ISO 14001 usage. This section provides a first baseline for the two most important stakeholders not only in Vietnam but in other developing countries.

The second aim attempts to identify appropriate factors for product category selection and formulate a prioritization method applicable to developing countries. We first examined the selection factors currently utilized in schemes worldwide by conducting a questionnaire survey of representatives of foreign schemes. Selection factors were illustrated on a plot graph, which indicated the percentage of factors implemented in the schemes of developing and developed countries, and their plausibility assessed when utilized in the schemes of developing countries. In this way, we divided and collected three groups of factors: an exclusion factor, five core factors and seven operational factors. Then, under the conditions of developing countries, such as socioeconomic issues and availability of data, we used and modified some judging guidelines of the EU Flower, e.g., determining the environmental impacts and potential of environmental improvements, in the scoring method to prioritize product categories by weighting factors. In light of our findings, we utilized the proposed factors and modified the scoring method to prioritize the screened primary list of product categories of Vietnamese manufacturing sub-sectors. By scoring factor-based questions and prioritizing in three ways, i.e., following the scoring method of the EU Flower program, totalling all values with equal weighting, and totalling all values but by doubling the weighting of core factors compared with operational factors, we observed that the weighted prioritization differentiates priority product categories more clearly than the other methods. We proposed the two highest potential candidates for ecolabeling in Vietnam, namely textile/garment and fishery products. As a result, the textile industry will be deeply studied on establishing ecolabeling criteria.

The third deals with production-related criteria. These criteria, in particular, must reflect the availability of necessary infrastructures and local conditions. This section 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 criteria from resource consumption, 46 pollutants and toxicants discharged by the textile industry. The results show that textile manufacturing represents a majority of the processes of the Vietnamese textile industry since $1{,}404\times10^6$ tons of textiles were processed (84% of total flows). T-shirts and trousers were the major product categories produced (64.8%), exported (17.1% and 13.7%, respectively), and domestically used. Thus, these products are ideal candidates for ecolabeling. 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 production-related criteria. However, other identified key indicators should be considered for further studies. Cost-benefit analysis of selected criteria was then assessed by applying cleaner options to understand the economic feasibility based on these criteria. Material flow analysis and proposed identification method of ecolabeling criteria can resolve the constraints imposed by a lack of data in developing countries.

The fourth takes product-related criteria into account. Such criteria should comply with requirements of those in international ecolabeling schemes for export purposes by adopting their criteria. However, such adopted criteria should be assessed for Vietnamese consumers by an exposure model for health risk assessment. Thus, we preliminarily developed a health risk assessment model for formaldehyde in clothing (as a case study), then by using the model, to assess the potential health risk of formaldehyde on adults and infants in imported textiles in Vietnam, and finally examine the plausibility of adopted permissible values of formaldehyde. In the model, two exposure factors for dermal exposure and overall exposure routes, i.e., sweat type and perspiration area, were considered. The margins of exposure (MOE) were calculated to estimate the health risks from worst case

and average exposures. The assessment shows that acute exposure via inhalation can pose health risks to Vietnamese consumers in both cases. Accordingly, to reduce the health risk posed by formaldehyde in clothing, a focus should be put on eliminating acute formaldehyde exposure. In regards to chronic exposure, dermal exposure is about four (for infants) and seven (for adults) times higher than exposure via inhalation, but no risks were found for average exposure. If a MOE of 100 is defined as 'safe' used, dermal and total chronic exposure to worst case cause potential risks, whereas no health risks were found for exposure to average case. With the model, the adopted Vietnamese permissible values for formaldehyde in clothing were assessed as not posing a health risk to Vietnamese consumers, hence they are accepted.

By case studies, we can reach the fifth. The findings can be generalized for other cases, namely, the exposure model for formaldehyde can be used for other product-related criteria (heavy metal or dyestuffs); the determination of production-related criteria of textile products can exert to other product categories (e.g., fishery products, footwear, plastic, i.e., three next priority product categories for the Vietnam ecolabeling scheme); the proposal of selection of product categories of Vietnamese manufacturing sectors can be utilized for other developing countries (broad concept) or prioritization of a list of given particular products (specific concept). From this study, we proposed some vital characteristics of the Vietnamese scheme, clarified the methods for two steps (out of three steps, i.e., product category selection, criteria development, and certification) of one ecolabeling scheme in developing countries, and brought about some recommendations for relevant policy-makers, and future studies for relevant interested readers.

[1]The most popular and prestigious type, i.e., ecolabeling Type I defined in ISO 14024 standard that has much broader application and possible understanding in the public domain, is studied.
[2]Around the world, some organizations refer to their ecolabeling initiatives as "schemes" while others use the term "programs". In this thesis, the term "scheme" is predominantly used.

論文審査の結果の要旨

本論文は，開発途上国における工業製品由来の環境負荷を削減・管理するためのエコラベル制度（製品の環境面に関わる品質表示制度）の開発を行ったものである．先進国ではすでに導入されているこの制度が開発途上国に未だ導入されてはいない理由として，３つ挙げられる．第１に，開発途上国の経済的，産業的側面を反映したエコラベル制度の基本的な枠組みができていないこと，第２に，具体的にエコラベル制度を適用する製品の選択手法ができていないこと，第３に，エコラベルの効果を判定する指標が未確立であることである．本研究では，以上の観点に基づき，ベトナムを対象として，生産企業，消費者に対する現地調査に基づき，ベトナムの全産業を対象として，優先的にエコラベルを付与するべき産業の選択方法を構築するとともに，繊維産業を対象にして，環境負荷の解析，健康リスク評価をエコラベル制度との関連において議論したものであり，６章から構成されている．本論文で得られた主要な結果をまとめると以下のとおりである．

（１）ベトナムを対象とした現地調査を行い，ホーチミン市の２００人の市民を対象として消費者の立場からエコラベル制度に対する理解レベル，問題点，導入に際しての負担等を調査するとともに，１１９の企業を対象に，生産者の立場から見たエコラベル制度に対する理解レベル，品質保証に対する期待，環境保全面への効果等を調査している．その結果，高い関心のレベルと導入にむけた準備が進んでいることが判明するとともに，企業の属性情報を説明変数としてエコラベル制度導入にむけた準備レベルを統計的に説明している．

（２）ベトナムの全産業を対象として，優先的にエコラベル制度を適用する必要のある製品カテゴリを選び出す方法を構築している．欧州，日本で構築されたエコラベル制度を基本にし，開発途上国で利用可能なデータを活用した製品カテゴリの選択問題を多属性効用関数理論を基礎に構築し適用した結果，繊維産業の製品がもっとも高い優先順位に位置することを明らかにしている．さらに，繊維産業をとりあげて，生産，消費，廃棄を通じての資源，環境負荷の流れを解析するとともに，寄与が相対的に高い環境負荷としては，製品重量あたりの水消費量，製品重量あたりのエネルギー消費量，二酸化硫黄，揮発性有機化合物，COD であることを明らかにし，これらをエコラベルに付与すべき指標であることを結論付けている．加えて，繊維産業の製造工程にクリーナープロダクションの技術を導入することで，環境負荷を改善できることを示している．

（３）繊維製品のなかで衣料品をとりあげ，製品に残留するホルムアルデヒドによる健康リスクの予備的評価を行っている．従来の評価モデルに３つの暴露シナリオを適用し経皮・吸入，急性・慢性に関して大人，子供を対象とした評価を行い，製品由来のリスクを定量化している．

以上のように，本論文では開発途上国での工業製品カテゴリに対するエコラベル制度の構築と環境計画上の含意を得ており，環境システム工学の発展に大きく寄与している．よって本論文は博士論文として価値あるものと認める．