Materials and Design 43 (2013) 560–571

Contents lists available at SciVerse ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Realizing the environmental impact of soft materials: Criteria for utilization and design specification

Mohamad T. Araji [a,*], Sadeka Abdel Shakour [b]

[a] Environmental Design, Faculty of Architecture, The University of Manitoba, 201 John A. Russell Building, Winnipeg, MB, Canada R3T 2N2
[b] Department of Architecture and Design, Abu Dhabi University, Abu Dhabi, United Arab Emirates

ARTICLE INFO

Article history:
Received 13 June 2012
Accepted 23 July 2012
Available online 1 August 2012

Keywords:
Green materials specification
Environmental design
Sustainable soft materials
Design practice

ABSTRACT

Sustainable soft materials in design applications should aim to have less resources depletion and pollution, plus inevitably less toxicity for the entire ecosystem. The outcome would result in environmental benefits, particularly with the production, specification and usage of proper materials. For this purpose, the paper conducted a survey among manufactures, designers and end-users to explore the concerns related to the inconsequential consideration of environmental factors associated with the extraction, processing, fabrication, and selection process of soft materials. Four criteria, including aesthetical, functional, economical, and environmental, were examined based on a comprehensive set of 33 governing factors. The analysis concludes criteria response rates that capture the intensity of the respondents experience using a three-point Likert scale. Analysis of Variance (ANOVA) was further considered to determine differences and interaction between independent and dependent variables. Results show that the main effect for criteria is not significant, but there are mean differences in consideration of criteria when respondents are evaluating factors based on the rating scale. Overall, the interaction variation and plots highlight the statistically significant differences between criteria. The environmental criterion is of marginal importance to all populations.

1. Introduction

Buildings have a significant impact on the environment for their large portion of carbon emissions and usage of a considerable number of resources and energy. On the whole, the total harmful emissions from the built environment accounts for 30% of greenhouse gases, due to lifecycle operation, and an additional 18% caused indirectly by materials [1–3]. Integrating sustainable thinking into the building design process encourages the use of eco-friendly materials, the implementation of techniques to save resources and reduce waste consumption, and the improvement of indoor environmental quality. The outcome would result in environmental, economical, and social benefits. Yet, sustainability is encumbered by the lack of knowledge and absence of clarity about practice in some cases. As one illustration, this paper realizes the growing argument about product manufacturing and specification process as it relates to soft materials for building interiors. Although an increasing number of initiatives and recourses can help in making product choices, the process is particularly complicated when designers, manufactures and end-users attempt to conscientiously produce, specify and use interior components that are considered sustainable. According to Bonda and Sosnowchick [4], the process has to be informed by understanding upstream and downstream system ramifications resulting from specification. The designer has to create a space that meets aesthetic and functional requirements. So much so, the design decision should ascertain the logical implications of materials and resources used, and how they affect the global environment.

According to the UK Building Research Establishment, nearly 70,000 new synthetic chemicals and materials were introduced in the 20th century, and less than 2% of them have been tested for their effects on human health, while more than 70% have not been tested at all [4]. Responding to the scientific evidence, the health care industry has begun developing criteria to identify chemicals of concern and to prioritize sustainability efforts. The Center for Health Design (CHD) and Health Care Without Harm (HCWH) recently published a priority list of criteria emphasizing avoidance of the international Stockholm Convention's list of persistent organic pollutants (POPs), other persistent bioaccumulative toxic chemicals, carcinogens, mutagens, reproductive or developmental toxicants, neurotoxicants, endocrine disruptors, and volatile organic compounds (VOCs). The list encourages the use of sustainably sourced bio-based materials that are grown without the use of genetically modified organisms and pesticides, and, as well, certified as sustainable for the soil and ecosystems. Other factors include the preference of materials with the recycled/recyclable content [5].

* Corresponding author. Tel.: +1 204 474 9928; fax: +1 204 474 7532.
E-mail address: mohamad.araji@ad.umanitoba.ca (M.T. Araji).

0261-3069/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.matdes.2012.07.053

Central to the confusion is the fact that which products are more ecofriendly, natural fibers (cotton, jute, silk, wool, linen, and hemp) or their man-made petroleum counterparts (nylon and polyester). Research indicates that under certain manufacturing conditions, the latter is more ecofriendly. It was realized that a brief examination of some of the issues related to the manufacturing process for a textile made of natural fibers vs. one made from synthetic fibers underscores the tough trade-offs when deciding between the two. Having said that, the soft materials are composed of more than just fibers. Dyes, additives, and residues of process chemicals are other important components [4].

2. Background

The production and specification of soft materials have been always treated through meeting design and budgetary requirements only. Until recently, decision-makers when manufacturing and selecting appropriate materials never look at environmental goals. The previous generation of bio-based fabrics has been superseded by other synthetic fibers. Performance attributes have been engineered through the increasing use of chemicals and protective coatings that have environmental and health problems on the long-term. The following indicates the concerns associated with soft materials and spur the development and use of better alternatives. It provides a brief review of standards and certification programs governing soft materials. The paper also puts forward a brief statement about how manufactures, designers, and end-users approach the soft materials field.

2.1. Review of concerns and alternatives

Soft materials are often conceived, since ancient times, as intertwined with nature through primitive peoples use of flax fibers, separated into strands and plaited into simple fabrics colored with natural dyes from plants. With industrialization, this materials field transformed from one grounded in nature to one that relies heavily on synthetic materials and chemicals [6]. Synthetic fabrics were introduced to overcome some of the inherent limitations of natural fibers such as wrinkling of cotton and linens; delicate handling of silk; and shrinking of wool. In 1910, Rayon became the first man-made fiber that is produced to emulate silk. Nylon came to market in 1939 as one of the first synthetic fibers created from petrochemicals. By 1945, cotton production had decreased to 75% and its use in the market continued to decline. Synthetic fibers made up 15%, with wool and other fibers contributing the additional 10% [5]. Subsequent fossil fuel fibers and films such as acrylic, polyester, and polyvinyl chloride (PVC) continued to replace natural fibers. In the mid-1990s, the effective evolution of PVC used as protective coatings to vinyl "fabrics" for improved stain repellency and to resist bleach washing solutions, as well as antimicrobials and germicides for cleaning. Other flame retardant additives were also added to some high performance vinyls in order to meet challenging fire safety standards [7]. According to Silas et al. [5], synthetics delivered greater comfort, soil release, broader aesthetic range (for example, special dullness or luster could be achieved), dyeing capabilities, improved fiber cross section and longitudinal shape, tensile strength, abrasion resistance, colorfastness and better blending qualities, as well as lower costs.

There are significant challenges coupled with the great performance improvements that the synthetic materials development has brought. Growing concerns are recently realized about the environmental and health impacts of those materials and the finishes plus treatments added to them. Emerging science links many of the applied chemicals to environmental contamination and negative human health effects [5]. In order to cope with the sustainable design viable venture, many industries, including that of soft materials, have begun developing criteria to identify chemicals of concern and to prioritize sustainability efforts. Designers today want cost competitive, high performance material choices; yet evoke a calming and environment friendly space. By addressing these dimensions jointly, they can advance beyond offering only technological fixes and identify innovative methods for improvement suited to the creation of a coherent built environment. The manufacturers of soft materials has additional challenges today in that they must operate under increasingly stringent and exclusive environmental regulations for emissions to air, noise, and water pollution. Simultaneously, In the United States and Europe, the industry faces high competition from companies overseas that are able to produce fabrics less expensively and according to environmental regulations that are either lax or disregarded [5].

In order to move to more sustainable choices, manufacturers, designers and end-users must address the environmental and health issues in each of the major aspects of production and specification for design applications, including: (1) fibers; (2) finishes or treatments; and (3) coloring and/or dyes. According to Rossi and Lent [8], transition to green materials is not without challenges, including: collecting the data needed to evaluate materials and the products they are part of, identifying products made with green materials, and adjusting work habits to the properties of new materials [7].

For fibers, all of the petrochemical-based products emit toxic chemicals in the process of refining the oil or gas from which these plastics are made. In particular, vinyl presents the extreme toxicity of additional chemicals involved in its production [7]. Concerns are uniquely associated with its dioxins [9–12] and phthalates [13–15]. Emphasizing the core of resources consumption, carbon dioxide emissions, waste reduction, economic challenges, and unstable access to petrochemicals that are associated with synthetic fibers have led to an increased usage of recycled fibers to replace virgin ones (including both pre-consumer and post-consumer materials for fiber). As just beginning to enter the marketplace, bioplastic fabrics utilize plastic resins made from plants instead of oil. They offer the potential to develop bionutrients, with the possibility of composting at the end of their useful life, as an alternative to either recycling or landfill.

According to [5], finishing is broadly categorized into three major areas, each with particular chemical components and related health issues, including: stain repellents, flame retardants, and antimicrobials. Relying on finishes and treatments to achieve certain performance characteristics, scientists and researchers have begun to find some of the chemicals used to create these finishes accumulating in both the environment and in human bodies. Perfluorooctane sulfate (PFOS) is part of a family of perfluorinated compounds (PFCs) that are primary toxic compounds used in stain repellent finishes. PFCs are fluorocarbons, related to the chlorofluorocarbons (CFCs) that have been banned because of their ozone-depleting effects. While science has only focused its attention on the public health concerns of PFCs for the past 5–10 years, their findings are alarming: researchers are finding PFCs in humans throughout the world [16–18]. Such results are causing great focus on reducing the sources and transmission of PFC chemicals linked to both cancer and developmental damage [19,20]. Flame retardants are required to meet fire safety standards for soft materials, either through application of the finished product or as a component of the fiber production process. The most common approach has been to add halogenated flame retardants (HFRs) such as Polybrominated diphenyl ethers (PBDEs). Although flame retardants additionally increase stain resistance and cleanability, recent research has raised concerns about the persistence and toxicity of its chemicals [21–26]. Other antimicrobials and volatile organic compounds (VOCs) that involve formaldehyde, acetaldehyde, toluene, and benzene are readily released from building materials,