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Materials for Sustainable Development: A Review on Key Challenges

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ABSTRACT
It has become clear that humankind is facing the greatest challenges in how to reduce the environmental problem without restraining the development needs.Today, the new valuations of sustainable materials in light of their ability to fulfill the requirements of sustainable development are required. This paper focus on the challenges of complicated materials selection in design process for sustainable product, risk of material toxicity, pressure on limited natural resources and waste management. The overall goal of this review is to foster sustainable development of new effective policies, methods and technologies innovation, and accomplishment for new and next-generations of sustainable materials for reducing environmental impact.

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INTRODUCTION

Sustainability is the capacity to endure. It requires reconciliation of environmental, social equity and economic demands. Addressing global mega trends in population growth, emerging economy, limited resources, and energy demand requires new solutions. Engineering material and smart design can be combined to resolve these challenges. Sustainable materials are believed to provide integrated approach toward managing material life cycles to achieve both economic efficiency and environment capability. The properties, performance and content of these materials make significant contribution to reduced environmental impact, from lowering carbon emissions to maximizing use of the earth’s limited resources for sustainable development of the world.

The most generally accepted definition of sustainable development is produced by the World Commission on Economic Development (WCED). Sustainable development is defined as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987). This definition is generally understood to bring together the development needs of humanity, protection and conservation of the natural environment and maintaining the ability of future generations to meet their own needs. However, there are no possibilities to reduce all environmental impacts to zero. There are a number of threats to sustainable development, including environmental degradation, inequitable and inadequate development in many parts of the world and global insecurity (Kirkby *et al* 1995). This paper is intended to stimulate a discussion around this important issue.

Defining sustainable material:

The concept of sustainable development is well understood from a high level perspective but when applied to sustainable materials it is still in its infancy. Lauren Heine (2007) describes sustainable material as material that fits within the constraints of a sustainable material system where in order to be sustainable, the material must be appropriate for the system and the system must be appropriate for the material. Materials support the basis of technology and systems; therefore, it is important to consider how the materials development should contribute to the construction of a sustainable society (Koichi and Kohmei 2001). Public Works and Government Services Canada (PWGSC) address that selecting materials which reduced environmental impacts requires a shift in mind set (PWGSC 2014). The characteristic of sustainable materials can be categorized as durable, resource efficient, non-toxic, recycled, recyclable and renewable.

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The challenges towards sustainable development:

Increasing material flows in volume, diversity and distance transported, had contribute too many of the world's environmental and economic problems. More components and mixed materials in various products, which demand transportation, in combination with higher energy consumption, are examples of over-consumption. Thus, some evaluation indicators should be considered when selecting materials designed for sustainable products which results as little impact on the environment as possible during its life cycle.

i)Complicated Materials Selection in Design Processes for Sustainable Product:

According to Ljungberg (2007), sustainable materials selection methodology should compare a set of candidate materials and, through the aggregation of the three indicators (social, economic and environmental) identifies the best material domains. Material selection is one of the main phases of product design process that has great impact on the manufacturing of sustainable products. Therefore, sustainable material selection can be regarded as a multiobjective problem, being the optimal selection and the best match found between the available materials profiles and the requirements of the design (Dehghan *et al* 2005). Although comprehensive methodology is recommended by the researchers, Ribeiroet, *et al* (2008) point out materials are believed to perform differently regarding different aspect of analysis for example the impact of life cycle costs and environmental profile of material candidates over their life cycle.One of the best approaches of material selection for sustainable products is life cycle engineering (LCE) but LCE is a costly and cumbersome task and it is not economic to perform for a large number of proposed materials in order to choose the most suitable one for a sustainable product (Hosein *et al* 2011). An alternative method such as advanced technologies (expert system) for material selection in designing sustainable product is essential including production processes that gear the design, use, and reuse capabilities to minimize raw material inputs, extend product life spans, and maximize products recycling for further productive use.

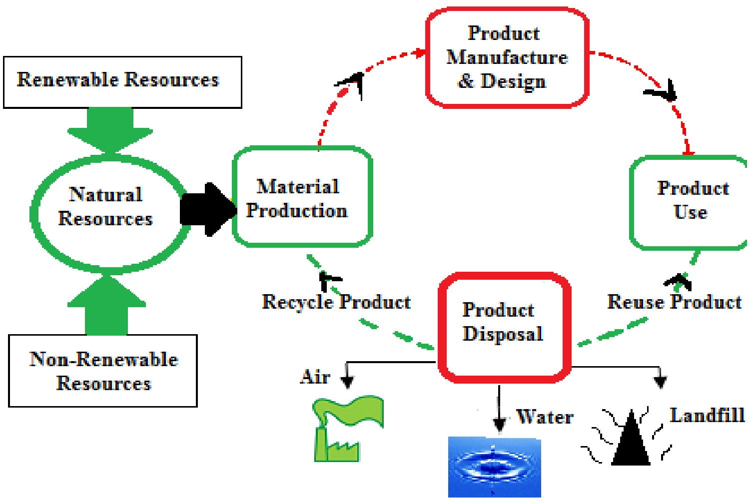

Fig. 1: Life-cycle of Materials.

ii) Pressure on Limited Natural Resources:

Resources constitute a "limited infinity", although they may be provided for infinite time, their productivity is limited (Gernot and Michael 2008). The world has not recently face significant disruptive crisis in the supply of materials largely because new discoveries and technologies have delayed predictions of shortages. However, World Resources Institute (WRI) found out due to advanced technology for coal (nonrenewable resources) will increased Carbon dioxide (CO_2) emissions contribute to high greenhouse gasses emissions including negative climate characteristic in 2025 (WRI 2008). Beside, the most pressing issue is that many types of environmental problems caused by our current patterns and rates of resource use. These trends make the shift to sustainable materials management become crucial. New approaches and better understanding the concept of material flow analysis (MFA) to address how we extract resources and materials, design, manufacture, use and deal with products at end-of-life such as recycle and reuse, is important as shown in Figure 2. Furthermore, the crises largely raise the accomplishment for designing new and next-generation of sustainable materials, such as high-temperature aerospace materials and bio-degradable polymers.

iii) Risk of Materials Toxicity:

Production of steel, aluminium, glass and paper require high electricity usage, generating CO_2 including increasing global warming (Howarth and Hadfield 2006). In the next 10 to 20 years from now, advances in

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chemistry and other fields will have created abundant of new chemical compounds and hazardous waste as well. WRI (2009) found that total global CO_2 emissions grew 12.7% from 2000 to 2005 for four selected sectors, as shown in Figure 3. Beside, Levin (2008) identify that information on potential hazards of these chemicals prior to specification, purchase or use of these products, is limited, in spite of a notable increase in relevant activity during the past two decades.As the public becomes more aware of hazardous risks, it might demand more comprehensive and pro-active measures from industry and government to mitigate them. An alternative method such as technologies innovation for measuring and managing chemical risk in materials or products is desirable. Thus, ensuring that reused and recycled materials and products are safe, and do not contain unacceptable of potentially harmful substances.

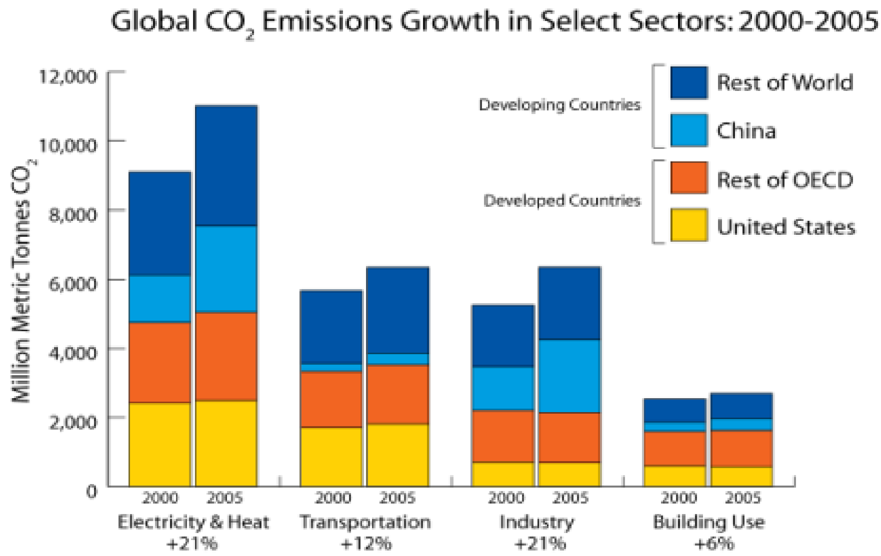

Fig. 2: Global CO_2 Emissions Growth in Select Sectors: 2000-2005 Source: WRI Climate Energy and Transport Database 2009

iv) Materials Waste Management:

United State Environmental Protection Agency **(**USEPA) reported in the year of 2010, total on and off-site disposal or other releases of 3.93 billion pounds of toxic chemicals has been total up from 20,904 facilities that reported to Toxics Release Inventory (TRI), (USEPA 2010). Most were disposed of, or released on-site to land, air or water, or injected underground. WRI (2004) discover a very high percentage of raw sewage is still being discharged without adequate treatment in the developing countries, particularly in rural areas where only a just over a third (36.8%) of the population has access to improved sanitation. The increase of population and the demand of products contribute to logical assumption that some industrial sector will continue to have very low potential of productive reuse or recycling for the materials currently classified as waste but destined for reuse or recycling. Beside, in the next 10 to 20 years from now, the volumes and characteristics of industrial wastes can also be expected to change due to a wide range of sustainable products with efficient materials used. These new trends make the shift to an alternative method such as advanced technologies for waste treatment, including disposal techniques and the performance of landfills also needed. Overall, the more efficient sustainable materials and resource used in products, can minimize solid and hazardous waste generation and protect humans and the environment from risks by hazardous chemicals thus reduce resources used and improve recycling and reuse rates.

Conclusions:

Sustainable material is believed to be solution for an integrated approach towards managing material life cycles to achieve both economic efficiency and environmental capability. Therefore it leads to improvements in product design, technological innovation, better waste-management practices, and more effective policies. Thus, the awareness of materials choices can help us to avoid activities that degrade environment and conserve ecosystems for the future.

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