Competing Visions for Building Materials Assessment in US Green Building Certification Programs

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ABSTRACT

The assessment of building materials and products in the US has been rapidly evolving since the onset of the contemporary American green building movement in the early 1990s. Presently three green building organizations, the US Green Building Council (USGBC), the Green Building Initiative (GBI), and the International Living Futures Institute (ILFI), offer competing visions of criteria for sustainable products, among them how to determine the safety of products from a chemical perspective. In assessing the safety of building materials and products in their green building assessment processes, the USGBC Leadership in Energy and Environmental Design (LEED) and the ILFI Living Building Challenge (LBC) rely on hazard-based assessment (HBA) which entails designating specific materials that are not suitable, from a toxicity perspective, for use in a green building. A competing vision, promulgated by the GBI in the forthcoming version of the Green Globes building assessment system, is risk-based assessment (RBA) which contends that simply banning products because they contain certain chemicals is inadequate and unscientific because the dose and the exposure scenario are not considered. Recent changes to the ANSI/GB01 standard underpinning the GBI's Green Globes certification system offer an alternative, risk-based approach for assessing materials toxicity.

Hazard-based tools include Cradle to Cradle, DECLARE, and GreenScreen. Some hazard-based tools provide a list of banned materials while others provide a more detailed analysis with various levels of action required depending on the ingredients of the product. Risk-based product assessment tools follow the procedures outlined in NSF/GCI/ANSI 355: Greener Chemicals and Processes Information Standard which provides the rules for this process.

This paper will present trends in building materials/products toxicity assessment and provide an analysis of these approaches regarding their impacts on the stakeholders in the US design and construction industry.

Keywords: *hazard-based assessment, risk-based assessment, materials toxicity*

1. INTRODUCTION

The sustainability assessment of commercial and institutional buildings in the US dates from 1998 when LEED v1, the pilot version, was completed and issued for testing. Since that time LEED has evolved through several editions: LEED v2 (2000), LEED v2.1 (2002), LEED v2.2 (2005), LEED v3 (2009), and LEED v4 (2013). The early versions of LEED prior to LEED v4 did not address materials toxicity per se but did include consideration of volatile organic compound emissions from interior finishes such as carpeting, paints, ceiling tiles, and other building interior products in the context of indoor air quality. This was also true of the approach used in the first two versions of Green Globes which also addressed VOC emissions from various classes of materials that could affect indoor air quality.

Post-2010 evolutions of LEED and other US green building assessment systems have significantly altered the evaluation of materials and products by including life cycle assessment(LCA), Environmental Product Declarations (EPDs), ingredient reporting, and toxicity evaluations as issues for project teams to consider. This paper will discuss the most recently emerging issue of building materials assessment, materials toxicity assessment, and the two major approaches being used for this purpose risk-based assessment (RBA) and hazard-based assessment (HBA). Building materials toxicity has emerged as an important issue in the green building community and LEED v4, for example, offers three options for addressing so-called chemicals of concern. One of these options is

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transparency with the desired outcome being that the disclosure process will motivate manufacturers to more carefully scrutinize their product ingredients and begin a process of eliminating chemicals with documented significant impacts on humans and ecosystems. More recently, ANSI/GB01-2017 (draft), Standard for Green Building Assessment under development by the Green Building Initiative (GBI) that will eventually become an updated version of Green Globes applies a risk-based approach that takes into account the dose and exposure scenario to assess the statistical probability of harm.

2. RISK ASSESSMENT VERSUS HAZARD ASSESSMENT

At present there are two fundamental approaches competing for inclusion in building product toxicity evaluation process: risk-based assessment (RBA) and hazard-based assessment (HBA). HBA relies on so-called red lists of chemicals generated by promulgating organizations that are considered to be problematical for humans or other organisms. According to the International Program for the Good Management of Chemicals (IOMC), hazard is "… the inherent property of an agent or situation capable of having adverse impacts on something, hence the substance, agent, source of energy, or situation having that property." Hazards are based on the toxicity of a chemical, its ability to produce harm and adversely affect living organisms. Chemicals that have such an adverse effect are also referred to as poisons. In the green building context, the impacts of interest are those that affect humans and other living organisms throughout the life cycle of the product or material. In contrast, risk is the "… probability of adverse effects caused under specified circumstances by an agent in an organism, a population, or ecosystem". The relationship between risk and hazard is straightforward and is credited to Paracelsus in 1538:

$$\text{Risk} = f\,(\text{Hazard} \times \text{Exposure})$$

Equation 1

Risk is a function of both the hazard and the exposure or dose of the chemical based on exposure scenarios. The risk to workers manufacturing a product, to construction workers installing the product in a building, to occupants of the building during the building's use phase, and to demolition workers during the end of life removal phase are likely all different. The science of toxicology, which controls all regulatory decisions regarding chemicals and toxic organisms in food and other products to which humans are exposed, is based on risk. Although common foods often contain small quantities of hazardous substances such as arsenic, nickel, and formaldehyde, government agencies tasked with protecting the general public have determined that if the concentrations of these chemical are below a specified thresholds, then for the likely exposure scenarios the risks are acceptably low. Gasoline and diesel fuels, well-known hazardous chemicals that are toxic and flammable, are used in automobiles and other vehicles because they are engineered to make the risks from chemical exposure, fire, and explosions within an acceptable range.

2.1 HBA for building materials

HBA is predicated on identifying chemicals that can threaten the human and ecosystem health. Chemicals that could be used in green building products and materials and are considered hazards are published as "red lists" generated by green building organizations such as the ILFI use in conjunction with the LBC building assessment system. Perkins + Will, a well-known design firm has developed and publishes a Precautionary List, a variety of a red list for use in its projects (See Table 1). As described by Perkins + Will, "… the Precautionary List includes substances commonly found in the built environment that have been classified by regulatory entities as being harmful to the health of humans and/or the environment." HBA tools such as Green Screen have been developed to provide comprehensive assessment. Referenced in LEED v4, Green Screen reviews 650 internationally recognized lists and sub-lists of high hazard chemicals for its clients for the purpose of highlighting potential problems with their products.

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Alkyphenols+	Hexavalent Chromium (VI)
Arsenic*	Hydroflurocarbons (HCFCs)
Asbestos+	Lead
Bisphenol (BPA)	Mercury
Bromochlorodifluoromethane*	Organostannic Compounds
Cadmium	Pentachlorophenol*
Chlorinated Polyethylene (CPE)	Perfluorocarbons (PFCs)
Chlorinated Polyvinyl Chloride (CPVC)	Phthalates
Chlorobenzene+	Polystyrene*
Chlorofluorocarbons (CFCs)	Polyurethane foam*
Chloroprene (2-chloro-1, 3-butadiene)	Polyvinyl Chloride (PVC)
Chlorosulfinated Polystyrene (CSPE)	Short Chain Chlorinated Paraffin+
Copper (for exterior material)*	Urea-Formaldehyde
Creosote	Volatile Organic Compounds (VOCs)
Halogenated Flame Retardants	

Table 1: Chemicals listed in the LBC Red List and the Perkins + Will Precautionary List.

Note: Chemicals that are only on the LBC Red List are designated with a (+) and those that are solely on the Perkins+ Will Precautionary List are followed by a (*). All other chemicals are on both lists.

There is currently no such thing as a standardized red list and there are significant differences in the chemicals listed in the versions published by the ILFI, Perkins+Will, and others. Clearly it is open for question as to why arsenic and asbestos are not on both lists.

Hazard-based assessment does not take into account exposure scenarios and thus there is no associated probability of impacts. Various hazard tools or certifying organizations have different reporting thresholds for determining if a hazardous chemical must be reported. Most require de minimis reporting of chemicals present in a product at a concentration of 1000 ppm (0.1%) or greater, the standard used by the US Environmental Protection Agency. However, some organizations have a requirement to report the presence of all chemicals down to a concentration of 100 ppm (0.01%).

2.2 RBA

The framework and requirements for RBA are described in NSF/GCI/ANSI Standard 355: Greener Chemicals and Processes Information (2011). This standard identifies chemical ecologic, health, and safety characteristics of concern, plus process manufacturing factors for assessing sustainability impacts (i.e., mass efficiency, water usage, energy consumption, bio-based content, and process safety). Risk based assessment requires that the exposure scenario be considered to determine if for a given hazard, a hazardous effect is produced. The route of exposure (oral, dermal, or inhalation) and the amount, duration, and frequency of exposure are all major determinants of toxic manifestation. Product formulation is also important because the other produce constituents such as solvents, binders, surfactants, and viscosity agents greatly affect the exposure and absorption of a hazardous constituent. Additionally, the toxic effects are also a function of the concentration of a hazardous constituent in the product, the total volume used, and the rate of exposure. To be able to fully characterize the hazard of a specific chemical ingredient, the type of effect, the exposure conditions, and circumstances of exposure must be known. The combination of exposure and the spectrum of hazards are expressed as a dose-response relationship. Care must be taken when extrapolating data from, for example, animal tests, where high concentration of chemicals may be used to determine the likely impact on humans for much smaller doses. A number of chemicals on red lists are likely the result of the difficulty in connecting high dose animal test results to human impacts. When the situation has been thoroughly described and the dose-response relationship can be applied, a risk characterization can be performed. This can be carried out using the process described in the national consensus standard, NSF/GCI/ANSI Standard 355. This standard identifies the chemical, ecologic, health, and safety characteristics of concern. It also identifies process manufacturing factors for assessing sustainability impacts such as mass efficiency water usage, energy consumption, bio-based content, and process safety. In the implementation of this process, web-based tools, such as GreenSuite, incorporate algorithms that utilize the ecological, health, and safety hazard characteristics defined in NSF/GCI/ANSI Standard 355 and normalized data to screen and prioritize chemical inventories, determine product risks, or assess comparative product risks for procurement, utilizing objective criteria and standardized hazard characteristic data.

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3. MATERIALS HAZARD AND RISK-BASED ASSESSMENT SYSTEMS AND PROGRAMS IN THE U.S.

The following paragraphs describe the most commonly used HBA and RBA systems in the U.S. The HBA systems referred to in LEED v4 include Cradle to Cradle, the Safer Choice Label, the Health Product Declaration (HPD), DECLARE, and GreenScreen. The LBC relies on the DECLARE system, a HBA developed by the LBC promulgating organization, the ILFI. The new version of Green Globes relies on RBA as defined in NSF/GCI/ANSI Standard 355 and implemented in tools such as GreenSuite. REACH is a European system designed as a RBA but the REACH Restricted List is sometimes used to support HBA.

3.1. Registration, Evaluation, Authorization and Restriction of Chemicals (REACH)

REACH is a regulation developed in 2007 by the European Chemicals Agency (ECHA) to improve the human and environmental protection against risks posed by chemicals ranging from industrial processes to day-to-day use. According to the ECHA, "In principle, REACH applies to all chemical substances; not only those used in industrial processes but also in our day-to-day lives, for example in cleaning products, paints as well as in articles such as clothes, furniture and electrical appliances. Therefore, the regulation has an impact on most companies across the EU. REACH places the burden of proof on companies. To comply with the regulation, companies must identify and manage the risks linked to the substances they manufacture and market in the EU. They have to demonstrate to ECHA how the substance can be safely used, and they must communicate the risk management measures to the users." REACH has four processes to regulate a substance, which include registration, evaluation, authorization, and restriction. Registration is required for all substances manufactured or imported in quantities of over one ton per year, unless no risk is associated with the chemical. The information required for registration varies according to the available information on that chemical, the tonnage to be manufactured/imported, the use, and exposure. In the evaluation phase, manufacturers must electronically submit a Technical Dossier and a Chemical Safety Report (CSR) through the International Uniform Chemical Information Database (IUCLID), a software application used to store and exchange data on chemical's information. The chemical assessment or CSR ensures that the risks from the chemical life-cycle are under control. If risks are not under control and no more iterations are possible to control the negative effects, the chemical use will be restricted and will be included on the REACH restricted list. The REACH regulation is referred to in the LEED v4 rating system under the Material Ingredient Optimization criteria. Although designed for RBA purposes, in the context of LEED v4, the REACH Restricted List functions as a very large red list.

3.2. Cradle to Cradle

The Cradle to Cradle (C2C) product certification system suggests that products should be designed based on the nature's model and eco-efficiency, encouraging the upcycling vision of converting products and materials into biological or technical nutrients at the end of their useful life without compromising the human and environmental health. Therefore, the C2C is a health-based assessment focused mainly on the waste generation of products and the hazard assessment of ingredients. C2C is one of the HBA tools reference in the LEED v4 Materials and Resources category/ The C2C certification is a multi-attribute evaluation on five categories: material health, material reutilization, renewable energy and carbon management, water stewardship, and social fairness. Requirements are completed in chronological order for each category, so the level of accomplishment on each category determines the category achievement rating, which could be Basic, Bronze, Silver, Gold, and Platinum. The product final certification is based on the lowest achievement level from all five categories. The Material Health category has 11 requirements that range from a simple verification on banned chemicals until a hazard-risk assessment of the product. The very first step for the material assessment is a comparison of the product's chemicals with the two C2C banned lists, a group of chemicals forbidden to be intentionally used over 1000ppm because of their adverse effects on the environmental (Biological Nutrients list) or human health (Technical Nutrients list). The allowable threshold may vary for some chemicals in the Technical Nutrient list if management plans are able to minimize the exposure effects. Manufacturers are required to characterize all homogeneous and generic materials in their products, creating a "Bill of Materials".

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3.3. US EPA: Safer Choice Label

The Safer Choice Label is the most recent update of the program known as "Design for the Environment"(DfE) developed by the U.S. Environmental Protection Agency (EPA) in 1992 to recognize products with reduced impacts for human health and the environment. The program was first developed to help consumers make decisions during purchases. Nowadays, the Safer Choice label is mandated by many jurisdictions and is referred to in the LEED v4 requirements for existing buildings and is preferred for Federal Agencies by virtue of Executive Order 13693 (2015).

Manufacturers are required to disclosure all chemicals intentionally added to the product, including those from third-party suppliers, regardless of the percentage on the product. A third-party profiler, normally NSF International or ToxServices, is responsible for developing the hazard profile, and identifies and evaluates the available toxicological and environmental fate data. The report is reviewed by the EPA and evaluated against the EPA's Safer Choice General Standard and the specific requirements according to the ingredient functional-class.

The Safer Choice program uses a Safer Chemical Ingredients List (SCIL) designed to help manufacturers find alternative chemical that satisfies the Safer Choice criteria. The list contains around 750 chemical ingredients divided according to the chemical functional class and labeled with colors according to the level of concern of each chemical. The complete assessment will provide thresholds levels and information about the chemical safer use that can be included on the SCIL.

3.4. Health Product Declaration (HPD)

The Health Product Declaration (HPD) is a customer-led collaboration that aims at improving building industry performance by increasing transparency, openness, and innovation in the product supply chain of the building industry. HPD is an open standard that lists the product contents and health hazards associated with the products. Hazard identification in HPD is based on HPD priority hazard lists, the GreenScreen list translator and, if available, full GreenScreen assessment (HPD Standard Version 2). HPD does not provide any information regarding the risk associated with handling and/or using materials and products. Also the HPD does not provide any information regarding the environmental impact of a products life cycle or the health impacts of substances used/created during the manufacturing of products. The HPD standard focuses on materials and substances. For materials, HPD is concerned with the percentage of the materials in the final products (variation range of material, ranges in similar products, alternate and undisclosed percentage) and the inventory threshold (100 ppm, 1000 ppm) required level for Safety Data Sheets (SDS) as described by the Globally Harmonized Systems of Classification and Labeling of Chemicals (GHS), OSHA MSDS thresholds and/or other types of protocols. HPD can be used as material certification in both LEED v4 and LBC.

3.5. DECLARE

DECLARE is a building material ingredients disclosure system that aims to increase transparency and open communications in the building industry. Manufacturers can enter DECLARE and reveal all ingredients of their products to the public. Designers can also use the DECLARE database to choose non-hazardous substitute materials. DECLARE requires reporting of all intentionally added ingredients by manufacturers plus residuals up to 100 ppm, the name of the chemicals, CAS number, and the percentage range and weight of all ingredients. It is worth noting that there is no need to report natural occurring, unintentionally added ingredients and process chemicals. Manufacturers should evaluate their products to see whether there are any materials on the DECLARE red list (determined Red List Compliance). However, there are some exceptions for some specific red-list materials.

DECLARE has a large red-list database. Although the DECLARE red list database was launched in 2006, it is constantly updated to be in compliance with LBC version 3, the EPA Action Plan Published List, the REACH Substances of Very High Concern (SVHC) List and the Cradle to Cradle Banned List. DECLARE is mainly used in LBC, however, it is recently officially recognized by USGBC as a way of earning points in LEED v4.

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3.6. GreenScreen

GreenScreen for Safer Chemicals is a hazard-based assessment method developed by Clean Production Action. GreenScreen is an open source assessment with publicly available criteria for categorizing chemicals based on their hazards. There are two type of analysis in GreenScreen assessment including the GreenScreen List Translator and the GreenScreen full life cycle assessment. A GreenScreen full life cycle assessment evaluates chemical hazards, identifies concerns, and considers safer alternatives. GreenScreen provides a third party verification HPD for green facade products. The List Translator does not include the hazards associated with manufacturing and degradation of the product. The List Translator is an online tool to check 650 internationally recognized lists and sub-lists of high hazard chemicals. The List Translator categorizes chemicals based on their hazard level. There are two types of lists for categorizing chemicals: authoritative lists and screening lists. The full GreenScreen assessment is categories into five benchmarks, and provides all the data based on 18 hazard endpoints. The evaluation includes the chemical hazard after its breakdown in the environment. The GreenScreen benchmark is built based on 12 Principles of Green Chemistry and the US EPA's Design for the Environment (DfE) alternatives assessment method. DfE aims to produce information about safer commercial products and has proposed hundreds of alternative chemicals and technologies to ensure safer products. GreenScreen is a hazard-based assessment and as such there is no consideration of dose and exposure scenarios.

3.7. GreenSuite

GreenSuite is a risk assessment tool supported by hazard data from Relational Chemical and Product Database (R-CPD) for 30,000 chemicals and categorized in modules with 44 ecological, health and safety (EH&S) endpoint criteria as defined in NSF/GCI/ANSI 355: Greener Chemical and Processes Information standard. It is one of the tools that meet the requirements of the Green Globes section that addresses risk assessment The R-CPD database is claimed to be the largest available database that continuously collects data and has been in existence since 1985. GreenSuite has an integrated Environmental Health and Safety (EH&S) system that utilizes a web-based technology to customize via the data for specific industries. The GreenSuite system benefits from an advanced internet technology known as the Sustainability Oriented Architecture (SOA4), which allows users to design, modify, organize, and integrate database applications over the Internet. GreenSuite includes the issues from pre-manufacturing and Material Safety Data Sheet (MSDS), to emissions monitoring and waste disposal.

The GreenSuite analysis includes several modules. The first four modules provide analytical data for any product in any industry. The fifth module develops factors for the sustainability assessment of the manufacturing process including water usage, energy consumption, waste generation, and others. The sixth module requires detailed and confidential process information from suppliers to assist supply chain risk assessments. The final two modules comprise the exposure scenario risk assessment for chemicals and products.

4. SUMMARY AND CONCLUSION

In the U.S., building assessment systems such as LEED, Green Globes, and the LBC began to incorporate consideration of product and materials safety from a toxicity standpoint into the materials category for each system. In the assessment systems developed prior to 2010, hazard or risk assessment of materials was not considered and thus consideration of materials toxicity in building assessment is a relatively new addition to the portfolio of issues addressed by these systems. The initial strategy was the HBA approach, simply generating red lists of chemicals to be used as a basis for banning products and materials. In the case of the LBC, as an example, the appearance of any chemical on their red list was cause for either eliminating the product or being denied certification. More recently RBA, which takes the dose and exposure scenario into account and applies the science of toxicology to the analysis, is gaining traction and is in the process of being incorporated into the next version of Green Globes. Tools such as GreenSuite provide a user friendly, web-based approach for determining the risks of the chemicals in a product as a function of the actual use of the product. These tools afford a high degree of flexibility and allow analysis of not only the use phase scenario but also the manufacturing, installation, and demolition phases as well.

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