THE GREENING OF HEALTHCARE: FABRICS USED IN HEALTH CARE FACILITIES

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INTRODUCTION

"There is no separation between environmental issues and health issues" (Smith and Lourie, 2010 a). Researchers from Environment Canada (Muir and Zegarac, 2001) estimate that North American healthcare costs and lost productivity linked to environmental factors total between $568 billion and $793 billion per year ($46 billion and $52 billion for Canada alone). These are staggering numbers and could be easily overlooked when various government budgets are examined as "silos" and the interconnectivity of the environment and health care costs are not considered. They are costs borne both financially and in terms of quality of life.

The greening of healthcare textiles is a topic of great importance for the overall greening of healthcare spaces due to the large number of chemicals used in the production of fabrics. Both patients and healthcare workers are exposed to these chemicals through dermal contact, inhalation, and ingestion. Hospital "green" teams and purchasing agents need to be aware of how to best select textiles for their facilities.

LEED (Leadership in Energy and Environmental Design) is a comprehensive internationally recognized standard for certification and construction of green buildings (Canada Green Building Council, 2004a). The U.S. Green Building Council (USGBC) started this program in 1993, and there are currently non-profit green building councils in 77 countries around the world (World Green Building Council, 2010). LEED standards are set for energy savings, water efficiency, carbon dioxide emissions reduction, improved indoor environmental quality, stewardship of resources, and sustainable locations. Innovation and education are also rewarded in the certification process. Verifiable third-party standards are set for practical and measurable design, construction, operation, and maintenance of buildings. Programs are available for commercial and residential buildings and neighbourhoods. The USGBC is currently developing a program specifically for healthcare (US Green Building Council, 2010).

The general principles from LEED (Leadership in Energy and Environmental Design) (Canada Green Building Council, 2004a) provide the analytical framework for the five criteria for selecting textiles for healthcare use presented in Table 1.

KEYWORDS

healthcare textile safety, healthcare fabric safety, textile selection criteria, textile chemicals of concern, textile carcinogens, textile certification standards, textile sustainability

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TABLE 1. "Green" Selection—5 Criteria.

• Local Source Availability
• Durability
• Sustainability
• Recyclability
• Surface Finishes & Cleanability

CHEMICALS OF CONCERN IN THE TEXTILE INDUSTRY

There are several certification programs that are pertinent to the textile industry. Labels on healthcare and other commercial fabrics display applicable certifications. It is important to have a brief description of what chemicals are tested for and why these chemicals are of concern before the certifications are summarized.

Formaldehyde

Formaldehyde is used in textile production as a cross-linking agent for a crease-resistant, soil-releasing finish (Hatch, 1993a). Nielsen and Wolkoff (2010) described formaldehyde as an indoor air pollutant in their research on air guideline values. The World Health Organization's International Agency for Research on Cancer (IARC) (2006a) concluded that formaldehyde is classed as Group 1: carcinogenic to humans, which is defined as there being sufficient evidence of human carcinogenicity when all the pertinent epidemiological studies have been evaluated by the international scientific experts at IARC (IARC, 2006b).

Formaldehyde's neurotoxic effects pose an increased relative risk to workers who are chronically exposed and higher temperatures increase the amount of formaldehyde released due to its volatility (Songur et al, 2010: Van Essen et al, 2010). Formaldehyde is on Environment Canada's List of Toxic Substances (Canadian Environmental Protection Agency, 2010a). The IARC working group's report (IARC, 1995) noted extensive reports of cancers of the nasal and nasopharnynx; eye, nasal, and skin irritation; and contact dermatitis. Preuss et. al. (1985), when studying the formaldehyde concentrations in mobile homes, reported that the levels appeared to decrease as products containing formaldehyde aged, with a half-life of four to five years.

Volatile Organic Compounds

Volatile organic compounds (VOCs) contain carbon and are gases at room temperature. Thirty-three of them were measured in the Center for Disease Control's 4th Report on Human Exposure to Environmental Chemicals (Center for Disease Control, 2009a). VOCs comprise much of the off-gassing of materials that creates adverse indoor air quality; are the primary precursors to the formation of ground level ozone; and are on the Canadian Environmental Protection Agency List of Toxic Substances (Canadian Environmental Protection Agency, 2010b). One example of a VOC is dichlorobenzene, which is a chemical intermediate in the synthesis of textile dyes. Although low-level exposure effects are unknown (Center for Disease Control, 2009a), high air levels are linked to eye, nasal, or skin irritation (Elovaara, 1998), asthma, and reduced pulmonary function, (Arif and Shah, 2007: Elliott et al, 2006). The IARC has classified 1,4-dichlorobenzene as a possible human carcinogen (Center for Disease Control, 2009a).

TABLE 2. Textile Chemicals of Concern.

Chemical	Toxicity	Agency
Formaldehyde	Gr1 Carcinogenic to humans	$IARC_6$
	List of toxic substances	$CEPA_3$
Volatile Organic Compounds	List of toxic substances	$CEPA_3$
Phthalates	Inconclusive as to estrogenicity	CDC_2
Di(2-ethylhexyl)phthalate	Reasonably anticipated to be human carcinogen	$ATSDR_1$
Quaternary Ammonium Compounds	contact dermatitis; broncho-constriction if prone to asthma	$PIMS_7$
	Quats release formaldehyde	EHA_4
Vinyl Chloride	Human carcinogen	$ATSDR_1$
	List of toxic substances	$CEPA_3$
Polyurethane	Gr3 not classifiable as carcinogen	$IARC_6$
Toluene diisocyanate	Gr2B possibly carcinogenic to humans	$IARC_6$
	animal carcinogen	$PIMS_7$
Antimony trioxide	Gr2B possibly carcinogenic to humans	$IARC_6$
	Toxic substance	$ATSDR_1$
Perfluorooctanoic acid	Likely to be carcinogenic to humans	EPA_5
Polybrominated diphenyl ethers	List of toxic substances	$CEPA_3$
	Bioaccumulative, biomagnification	$CEPA_3$
	Evidence of thyroid & endocrine disruption	$ATSDR_1$
Decabrominated diphenyl ether	Limited evidence for animal carcinogenicity	$ATSDR_1$
Triclosan	Inconclusive toxicity	CDC_2

$ATSDR_1$ – U.S. CDC's Agency for Toxic Substance & Disease Registry
CDC_2 – U.S. Center for Disease Control
$CEPA_3$ – Environment Canada's Canadian Environmental Protection Agency
EHA_4 – Canada's Nova Scotia's Environmental Health Association
EPA_5 – U.S. Environmental Protection Agency
$IARC_6$ – World Health Organization's International Agency for Research on Cancer
$PIMS_7$ – International Programme on Chemical Safety Poisons Information Monograph

Phthalates

Phthalates are plasticizers that are used in plastics and textile production to create flexibility and are not chemically bound to the plastic, allowing them to be released into the environment during use and at disposal (Center for Disease Control, 2009b). 60% of their use is in the production of polyvinyl chloride (PVC) (Smith and Lourie, 2010b). Humans are exposed by ingesting and inhaling dust and to a lesser extent, dermal contact. Low-level exposure effects are unknown. There are several different types of phthalates and not all types have been studied; however, there are conflicting reports of links to lowered testosterone levels, testicular atrophy, and estrogenic activity (Center for Disease Control, 2009b). CDC's Agency for Toxic Substances & Disease Registry (2002) lists Di(2-ethylhexyl)phthalate (DEHP) as "reasonably anticipated to be human carcinogens." It is used in the manufacture of upholstery fabric, along with other phthalates.

Phthalates are also used in textile wet-printing processing. The Canadian Environmental Protection Agency has classified textile mill effluent wastewater discharges from wet processing as being on the List of Toxic Substances (Canadian Environmental Protection Agency, 2010c).

Quaternary Ammonium Compounds

Quaternary ammonium compounds, such as benzalkonium chloride are cationic surfactants and cationic detergents used in fabric detergents and fabric softeners. They may cause contact dermatitis due to their corrosive nature and they may cause bronchoconstriction in those prone to asthma, according to the Poisons Information Monograph (Arungonda, 1998). "Quats" (as they are commonly known) are used as antibacterials and antifungals, and are used in the last rinse cycle in some hospital laundries (Arugonda, 1998).

THIRD PARTY CERTIFICATIONS APPLICABLE FOR TEXTILES

There are several organisations which provide guidance and certification with respect to the use of textiles which may be used in a health care setting.

LEED®

LEED® is a comprehensive standard for certifying and constructing green buildings (Canada Green Building Council, 2004a). LEED® was not specifically created with textiles in mind. The standards apply only to fabric that is applied to permanent building fixtures such as built-in lounge seating. It would not apply to moveable healthcare patient room upholstered chairs, cubicle curtains, patient or staff gowns, bed sheets, blankets, or window curtains. Even if a hospital being built or renovated to LEED® standards cannot count these fabrics for credit, the merit of selecting "green" textiles for the benefit of patient and staff health and the environment will still be important.

A general contractor of a LEED® Platinum low-income residential building remarked during a recent seminar that the first thing he noticed when entering his completed building was that there was no odour. He added that the situation would change once residents moved in with their toxic furnishings (D'Angelo, 2010). Thus it is important to consider what other textiles are entering the hospital in the form of clothing worn by visitors, staff, and patients, and packaging of food and supplies. Textiles can provide a vehicle for the transport of both chemicals and bacteria. Boyce and colleagues (Boyce et al, 1997) reported that 65% of nurses who had performed patient care activities on patients with Methicillin-resistant *Staphylococcus aureus* (MRSA), contaminated their nursing uniforms with MRSA.

The basis for LEED® certification relies on the use of quantifiable third-party standards (Canada Green Building Council, 2004a). This provides a framework for the analysis of healthcare textiles. "Third party" signifies that the body is independent from the manufacturer, standardized tests are used, and that mulitiple attributes are examined (TerraChoice, 2010). A manufacturer changing only the lamps in the factory and calling the resulting textile product "green" is an example of a single attribute coming from a "first party" lacking independence. Products may also be labelled "green" with misleading statements. Both of these examples would be called "greenwashing" according to the definition of Terrachoice (2010), an environmental marketing organization started by Environment Canada, and now run by Underwriters Laboratory (UL).

McDonough Braungart Design Chemistry

McDonough Braungart Design Chemistry (MBDC) (2010) is an international private third-party certification organisation begun in 1995 by American architect William McDonough and German chemist Michael Braungart. They help companies around the world design products (including textiles) in order to form a continuous "cradle to cradle" closed loop, by eliminating the concept of waste. Products are awarded certification at the basic, silver, gold, or platinum level based on multiple attributes of environmental intelligence, safety and health, using renewable energy, and water efficiency. Products need to be recertified annually by their privately held criteria. McDonough, together with Braungart, co-authored the ground-breaking environmental book, "Cradle to Cradle" (McDonough and Braungart, 2002a).

Öeko-tex

Öeko-tex is a third-party global uniform testing and certification system that tests for harmful substances in all stages of textile production. "Standard 100 Confidence in Textiles" labels are awarded to fabrics that pass certification. Formaldehyde is limited to 300 mg/kg for decoration fabric and 75 mg/kg for materials that come into direct contact with the skin. Pesticides, benzene, and toluene are limited to 1.0 mg/kg each. Phthalates cannot exceed 0.1% by weight. No toxic or allergenic dyes may be used. Polybrominated flame retardants are also not allowed (Öeko-tex, 2010a).

Greenguard Environmental Institute

Greenguard Environmental Institute (GEI) provides third-party certification that tests for indoor air quality, certifies a range of products, and lists products on a public directory. Begun in 2001 by the U.S. Environmental Protection Agency, Greenguard® measures and sets limits for volatile organic compounds, formaldehyde, and phthalates (Greenguard Environmental Institute, 2006–2008). Only these 3 sets of compounds are tested for and there may be other properties of the fabric that could cause odour and irritation despite this certification.

Scientific Certification Systems

Scientific Certification Systems (SCS) is a third-party environmental certification developed in California, assessing indoor air quality according to U.S. EPA (Environmental Protection Agency) procedures and certifying products with "Indoor Advantage Gold" labels. For indoor air quality, SCS considers the same three chemicals of concern to be: VOCs, formaldehyde, and phthalates (Scientific Certification Systems, 2007).

Global Organic Textile Standard

The Global Organic Textile Standard (GOTS) is a third-party international certification for processing textiles that are at minimum 95% organic in origin. During textile production, the standard prohibits the use of aromatic solvents, phenols, formaldehyde, fungicides, biocides, halogenated solvents, fluorocarbons, quaternary ammonium compounds, or bio-accumulative substances. Genetically modified organisms are also prohibited. All wastewater must be treated and heavy metals are limited to the standards of the Ecological and Toxicological Association of Dyes and Pigments Manufacturers (ETAD) (International Working Group on Global Organic Textile Standard, 2008).

Ecological and Toxicological Association of Dyes and Pigments Manufacturers

The Ecological and Toxicological Association of Dyes and Pigments Manufacturers have an international code of ethics and a set of voluntary regulations that would be considered second, not third party. "ETAD seeks to base its positions on sound science and to coordinate the efforts of its members to minimize any possible adverse impact of organic colorants on heath and environment." (ETAD Ecological and Toxicological Association of Dyes and Pigments Manufacturers , 2010) Their goal is to guide members with self-regulated labelling, hazardous classification, use of material safety data sheets (MSDS), and trace metal limits.

Association for Contract Textiles

The Association for Contract Textiles (ACT) (2010) has performance guidelines for their member companies. Founded in 1985, ACT is a North American manufacturing association for commercial fabrics which is not third party, however, employs standards based on testing procedures from ASTM (American Society of Testing and Materials) (2002). ACT guidelines include flammability, wet and dry crocking (transfer of dye on fabric to another surface by rubbing), colourfastness to light, abrasion resistance, and the physical properties of pilling (fuzzy balls of fibres attached on fabric surface), breaking strength, and seam slippage. Commercial fabric labels for member companies display symbols of these ratings, providing useful guidelines for the appropriate selection of healthcare textiles even considering that the manufacturer can select their own laboratory for the testing according to ASTM.

"GREEN" SELECTION—5 CRITERIA

Local Source Availability

Local source availability, commonly referred to as "Source Locally," is the concept that products for use in modern development should be obtained from the nearest possible location which supplies that "safe" product.

The first criterion guides purchasing departments to find local sources where possible to both support local communities and reduce reliance on non-renewable fuels for transportation. LEED® provides a quantifiable definition that material is considered local when 80% of the content is transported within 800 km (500 miles) by road, or within 2400 km (1500 miles) by rail or water from the location of manufacturing (Canada Green Building Council, 2004b).

Durability

The goal is to keep products out of landfill. If a fabric wears out prematurely, it would not be considered "green." McDonough and Braungart (2002b) refer to this concept as "eco-effective." This can be quantified by using the performance guidelines from the Association for Contract Textiles (ACT). Heavy-duty commercial upholstery fabric must meet at least 40,000 cycles on the Martindale abrasion test or at least 30,000 double rubs on the Wyzenbeek abrasion test (ACT, 2010). A Minnesota hospital purchasing agent reported a preference for selecting fabrics that exceed 100,000 double rubs due to 24-hour-per-day use (Carlson, 2008). ACT (2010) specifically cautions that claims in excess of 100,000 double rubs should not be judged valid for determining the potential durability of a fabric, and other additional factors need to be considered. If a fabric scores below the standard for pilling, the poor surface appearance would likely cause premature replacement even though the fabric was not technically worn out, gauged by the minimum standard of at least 2 broken yarns or noticeable wear.

Sustainability

Sustainability is a term that is frequently used without definition on product labels, an example of "vagueness" that is reported in TerraChoice's (2010) *The Sins of Greenwashing.* William

McDonough (1992a) said that "sustainability is a loaded and slippery term." LEED® defines a sustainable product as one that is rapidly renewable in 10 years or less (Canada Green Building Council, 2004b). This would apply to all natural cellulosic and protein fibres used in textiles.

The benefit of using sustainable natural cellulose fibres for healthcare is comfort (high absorption) and ease of machine washing and sanitizing the fabrics (Jackman et al, 2003a). Theoretically, they can be composted at the end of their useful life, provided facilities exist and they are not blended with synthetic fibres. They are not practical for upholstery fabrics where synthetic fabrics may have superior cleanability, soil and water resistance, and abrasion resistance (Jackman et al, 2003b).

The main cellulose fibre in use is cotton. According to an UNESCO report (Chapagain et al, 2005), conventionally grown cotton accounts for 24% of insecticide use and 20% of water pollution on 2.4% of the earth's arable land. Cotton accounts for 40% of the international textile industry and demand for it created the situation where the Aral Sea in central Asia was 80% drained to irrigate the surrounding desert for the growing of cotton crops (Chapagain et al, 2005).

Cotton does have the advantage of being easily cleaned in a healthcare environment when it is not permanently affixed on upholstery. It can be washed at high temperatures and can be bleached due to a high resistance to alkalis (Jackman et al, 2003a). It is therefore the main fibre selected for patient gowns, scrubs (scrubs usually blended with polyester), sheets, and blankets (Neely and Maley, 2000).

Organic cotton is grown without pesticides, herbicides, or chemical fertilizers, avoiding toxic chemicals coming into contact with the user's skin (Raja et al, 2010). The limiting issue is one of limited global availability and high cost.

Another cellulosic sustainable fibre that may be used in healthcare settings is linen. Linen fabric comes from flax fibres that grow in areas of high rainfall (Hatch, 1993b). Little or no irrigation, pesticides, or fertilizers are necessary (Bealer Rodie, 2010). Linen is more resistant to fungi and mildew than cotton (Jackman et al, 2003a). It has stiff hand and poor flexing strength which can result in premature fabric failure due to abrasion at the fabric seams (Joseph, 1972a). Blending linen with cotton alleviates this obstacle. The cost of linen is more than cotton due to lack of mechanization in the manufacturing process (Hatch, 1993b) and this extra cost may be a deterrent to widespread hospital textile use.

Hemp is a cellulosic fibre which has only been grown in Canada since 1998 when the government rescinded the 60-year ban (Agriculture and Agri-Food Canada, 2010). Textile hemp fibres come from the stalks not the leaves, and only plants with low delta-9 tetrahydrocannabinol (THC) are permitted by Canadian law (Armstrong, 2004). Hemp grows in more temperate climates than cotton, requiring limited or no pesticides, herbicides, fertilizer, or irrigation, making it an environmental-friendly textile option. Hemp has been grown since 2,300 B.C. in China and at altitudes as high as 8,000 feet (Joseph, 1972b). It does have a stiffer hand, similar to linen and can be cleaned with organic solvents and bleach. Hemp fibres are not resistant to mildew and will dissolve in the presence of hot concentrated alkalis (Jackman et al, 2003a), making this fibre potentially unsuitable for healthcare laundry. The other challenge is lack of availability due to poor demand, limited marketing (Agriculture and Agri-Food Canada, 2010), and confusion with the illegal cannabis leaves that are grown from more potent THC plants.

Recyclability

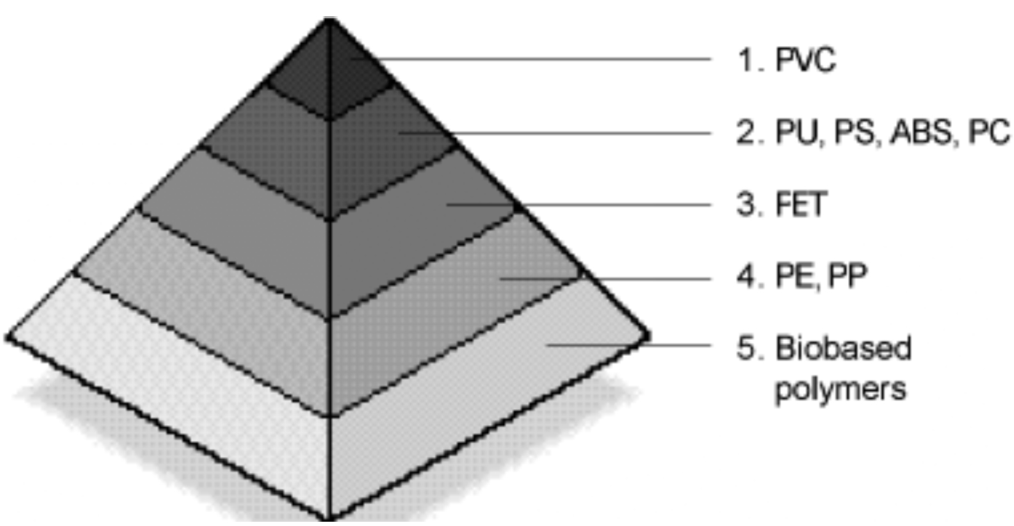
Recycling in healthcare textiles has two component parts—the need for using less "virgin," or new, raw materials in the production of fabric by using recycled content and the recyclability of the fabric at the end of its useful life. Both criteria pertain to synthetic fabrics made from non-renewable petroleum products. Synthetics do not readily compost and are therefore well suited to recycling. When the quality is maintained during recycling, McDonough and Braungart (2002c) call this "closed-loop," and when the quality is lowered over time, it is called "downcycling."

LEED® distinguishes between post-consumer and pre-consumer content and gives more credit to the former, due to the need to stimulate the post-consumer recycling market and to keep waste from landfills (Canada Green Building Council, 2004 c). Pre-consumer content is the waste from refining petroleum products and was previously known as post-industrial waste (Canada Green Building Council, 2007). Post-consumer content typically comes from plastic water or soda bottles.

Vinyl Fabric—Polyvinyl Chloride

Polyvinyl chloride (PVC) fabric, known as vinyl fabric, has been used extensively in healthcare upholstery for its water- and stain-resistant properties and its ease of cleaning. There is a growing trend amongst hospitals to move away from vinyl due to toxic components (Carlson, 2008). In order to provide alternatives to PVC, the Greenpeace organisation prepared a "Pyramid of Plastics" with PVC at the top, descending to less toxic alternatives at the base (Figure 1). "Polyvinyl chloride (PVC) is unique in its high chlorine and additives content, which makes it an environmental poison throughout its life cycle" (Greenpeace, 2010). Vinyl chloride is a known human carcinogen and affects the cardiovascular, hepatic, and immulogical systems (Agency for Toxic Substance & Disease Registry, 2010). PVC releases dioxin and other persistent organic pollutants during its manufacture and disposal and cannot be readily recycled due to it chlorine and additive content. Additives are not bound to the plastic and can leach out (Greenpeace, 2010). Vinyl chloride is on the Canadian Environmental Protection Agency List of Toxic Substances and is used to produce PVC (Canadian Environmental Protection Agency, 2010d).

FIGURE 1. Greenpeace Pyramid of Plastics (PVC Alternatives Database).



Polyurethane

Polyurethane (PU) is the second most hazardous on the Greenpeace Pyramid of Plastics. It is typically used for high-resiliency flexible foam cushions under textile upholstery fabric. Isocyanates are reactive compounds used in the synthesis of polyurethane foams and Kennedy and Brown (1992) reported that the correlation between isocyanates and respiratory disease has been established, primarily at the clinical level. The U.S. Department of Labor's Occupational Safety & Health Administration (OSHA, 2010), lists isocyanate exposure health effects to be irritation of the skin and mucous membranes, chest tightness, difficult breathing, and occupational asthma. The production of polyurethane's diisocyanate also uses formaldehyde (IARC, 1979).

The International Agency for Research on Cancer (IARC, 1986), classified polyurethane foams as Group 3: not classifiable as to carcinogenicity to humans due to no adequate data for humans and incomplete data for animals; and toluene diisocyanate as Group 2B: possibly carcinogenic to humans with no adequate data for humans and sufficient evidence for animal carcinogenicity. The International Programme on Chemical Safety Poisons Information Monograph (PIM) rated toluene-2,4-diisocyanate as an animal carcinogen (Kulling, 1986).

The burning of polyurethane releases the most prominent toxicant carbon monoxide and the very low oxygen concentrations can promote the formation of hydrogen cyanide (Landry et al, 2002).

A manufacturer (Ultrafabrics LLC, 2010) has recently introduced polyurethane fabric to replace PVC as an easily cleaned healthcare fabric. They claim the fabric is also phthalate-free, has a low VOC performance, and exceeds 100,000 double rubs of abrasion resistance.

Polyester (Polyethylene Terephthalate)

The best example of recycled post-consumer textiles is polyethylene terephthalate (PET or PETE) obtained from plastic soda and water bottles. The triangular recycling symbol "1" connotes PET or PETE (American Chemistry Council, 2007). Polyester is the third synthetic compound on the Greenpeace pyramid. It is an ideal healthcare fabric with many properties that lend itself to this use. Many polyester fabrics have much higher abrasion counts than natural cellulose fibres such as cotton, giving the fabrics durability. Although not absorbent, polyester has the ability to wick moisture away from the skin, making it feel comfortable compared with other synthetic fibres (Joseph, 1972c). Antimony trioxide, a semi-metallic compound, is the current catalyst in the polymerization process and is not necessary to polyester production according to McDonough and Braungart (2002a).

Also used as a flame retardant in textiles, antimony trioxide is inhaled from fabric dust as particles of the fabric abrade when a person shifts in their seat (McDonough and Braungart, 2002e). Antimony trioxide exposure can come from dermal contact, and has been rated by IARC as Group 2B: possible human carcinogen according to CDC (Center for Disease Control, 2009c). However, the effects on human health at low environmental doses or exposures are unknown (Center for Disease Control, 2009c). Renes (1953) reported that acute industrial inhalation of antimony was associated with respiratory tract irritation and impaired lung function. Antimony trioxide has been linked to toxicity at high doses, targeting the myocardium and altering electrocardiograms, according to the U.S. Agency for Toxic Substances and Disease Registry (1992). Brieger and colleagues (1954) found that 37 of the 75 antimony industrial workers examined from 8 months to 2 years showed changes in mainly flattened T-waves of their EKGs and increased blood pressure.

There are healthcare polyester fabrics on the international market made of polybutylene terephthalate (PBT) that contain no chlorine, no antimony, and have abrasion ratings of 50,000 double rubs or higher. The manufacturers claim they are indefinitely recyclable (where facilities exist) and are Cradle to Cradle Gold certified (Victor Innovatex, 2010).

There are also healthcare polyester fabrics on the market with a moisture barrier that prevents stains, mould, bacteria, and odours. They have reduced or limited formaldehyde, VOCs, halogenated flame retardants, and are Scientific Certification Systems (SCS) certified Indoor Advantage Gold. Some of these polyesters are antimony free and some have recycled content ranging from 50% to 100%, according to the claims by the manufacturer (Crypton Super Fabrics, 2010).

There are cubicle curtain fabrics available in polyester that are Greenguard certified for indoor air quality (Greenguard Environmental Institute, 2010).

Olefin

Olefin fabrics, rated 4th on Greenpeace's pyramid of plastics, have simpler polymer structures than PVC and the highest potential for mechanical recycling at the end of useful life (Greenpeace, 2010). There are two types: polypropylene (PP) and polyethylene (PE). Both are usually solution dyed, and therefore colourfast, and bleach cleanable (Joseph, 1972d).

Polyethylene has properties that make it superior to polypropylene for healthcare use. There is one brand internationally available that is both Cradle to Cradle Silver certified and SCS Certified Indoor Advantage Gold (Carnegie Fabrics, 2010). It is produced with less energy, water consumption, no chlorine, no phthalates, no toxic dyes, and no heavy metals. It is inherently flame retardant, stain resistant, and does not support the growth of bacteria or fungi according to the manufacturer (Carnegie Fabrics, 2010).

Bio-Based Polymers

At the bottom of the pyramid are bio-based polymers that are considered by Greenpeace (2010) to be a promising alternative to non-renewable sources and can also be readily composted. If they are blended with other synthetic fibres, bio-based fibres cannot be recycled but must be landfilled, at odds with the elimination of waste concept (McDonough, 1992b). Other issues to consider are how much and what type of energy is required to produce the bio-based crops and does it divert from the production of needed food crops? The economist Jeff Rubin (2009) contends that bio-based products, particularly corn, are a false alternative to fossil fuels due to the large amount of fertilizer containing ammonia from natural gas, diesel-run farm equipment, the energy required to process the polymers, and the increase in corn cultivation at the expense of other food crops. Corn, in the form of polylactic acid (PLA), is now being blended in healthcare fabrics, although Rubin is most concerned about corn production diverted and increased for ethanol fuel production. The entire life cycle analysis (LSA) needs to be considered when assessing the advantage of bio-based polymers, not simply one aspect of the production.

TABLE 3. Bio-Based Polymers.

Raw Material	Polymer
Corn	polylactic acid (PLA)
Silicone	polysiloxane
Wood pulp	rayon (viscose)
Bamboo	bamboo rayon
Soybean	polyol component in polyurethane

Polysiloxane. Polysiloxanes are a newer textile alternative to polyvinyl chloride or polyurethane. One textile in this category is 51% silicone and 49% PLA (polylactic acid from corn). The member of ACT manufacturer claims it uses less water and energy in the production, has antimicrobial properties, has abrasion counts in excess of 100,000 double rubs, and is cleanable with chlorine, hydrogen peroxide, or solvents. The fabric is Greenguard Indoor Air Quality Certified (The Momentum Group, 2010). Polysiloxanes are macromolecules of a polymer backbone of alternating silicon and oxygen atoms (Dow Corning, 2010). Siloxane D5, a liquid used as a dry-cleaning solvent, is under review from Environment Canada for environmental toxicity and not for toxicity to human health (Environment Canada, 2010a) and there are no current toxicity references to polysiloxane used in this fabric.

Rayon (Viscose). Another fibre in this category that has been in production since the early 20th century is rayon (viscose). It is typically produced from wood pulp into regenerated cellulose. Rayon has variable strength depending on the type, has poor resistance to hot dilute acids, and concentrated alkalis (Jackman et al, 2003 c), thus making rayon not a good choice for hospital use due to the unreliability for sanitizing the fabric.

Bamboo. Bamboo is sustainable because it re-grows and can be harvested in 3–5 years, according to the LEED® standard for sustainability (Canada Green Building Council, 2004 f). However, it is actually regenerated cellulose processed in the same manner as rayon. The Canadian Broadcasting Corporation (CBC) reported in February 2010, that bamboo must now be labelled as rayon according to Canadian law. To process bamboo, the pulp is soaked in sodium hydroxide (caustic soda) and mixed with dilute sulphuric acid (Canadian Broadcasting Corporation, 2010). Whether this is environmentally friendly depends on mixed reviews and difficult-to-obtain information from the Chinese company, Hebei Jigao Chemical Fiber Company, about whether it is grown in conditions respecting biodiversity, how much water is used in the processing, and how the chemicals are disposed of afterward (Nijhuis, 2009). There may be the same cleaning issues as noted with rayon, as this fabric is relatively new to the market in its textile form and has not been available for testing for a long enough period.

Soybean Oil. Soybean oil is a biobased polymer that is being used to reduce the amount of polyurethane in upholstery foam. Verbal reports from several different manufacturers have revealed that a range of 18–39%—and most typically only 20%—can replace the petrochemical without adversely affecting the quality of the foam. There are geopolitical concerns of farmers switching to soy for this use, including the decline in food production (Tenenbaum, 2008) and the use of genetically modified varieties (Benbrook, 2004).

SURFACE FINISHES AND CLEANABILITY

Stain and water repellent finishes have been an important consideration for the ease of maintaining healthcare textiles. There is a preference for having this property built into the fibre compared to a topical treatment (Carlson, 2008). In 2005, the U.S. Environmental Protection Agency in a Draft Risk Assessment declared perfluoroooctanoic acid (PFOA) to be "likely to be carcinogenic to humans" (U.S. Environmental Protection Agency, 2005). In 2006, a global stewardship programme was set up with eight major manufacturers to phase out PFOA by 95% by end of 2010 and eliminate by 2015 (U.S. Environmental Protection Agency, 2010). Öeko-Tex® certification limits PFOA to 1.0mg/kg (Öeko-Tex, 2010 a). PFOA finishes on textiles are still widely available in Canada despite this phase out.

Flame retardant materials are required to meet commercial building codes, which vary locally. The Association for Contract Textiles (2010) lists four different standards for flammability. Bromine heavy metal flame retardants are frequently used due to low cost. Textiles are either back-coated or immersed in polybrominated diphenyl ethers (PBDEs) to protect the fabric from combustion and to help the furniture withstand multiple industrial-strength cleanings (Ecojustice, 2008). DecaBDE is the most widely used flame retardant for textile and other consumer products and, as of 2001, made up 80% of global PBDE use (Boyd et al, 2006). Since 2006 in Canada, and previously internationally, PentaBDE and OctaDBE have been phased out (Government of Canada, 2010).

PBDEs have been chemically linked to the banned polychlorinated bromines (PCBs) present in house dust, and that dust ingestion contributes significantly to human exposure (Sudaryanto et al, 2009). Flame retardants are used in upholstery foam without transparent labeling. A recent study analysed furniture foam and house dust and found a high prevalence of PBDEs and organophosphate flame retardants present (Stapleton et al, 2009). The presence of polybrominated diphenyl ethers as flame retardant textile finishes and the use in upholstery foam is one of concern since these chemicals do not remain stable in the products, and have been found in tested samples of clothes dryer lint (Stapleton et al, 2005). The state of California has the most stringent fire codes in the United States and a 2008 study by Zota et al (2008) found that PBDE blood serum levels were two-fold higher in Californians tested compared with the U.S. population. Öeko-Tex® (2010b) textile certification disallows all forms of PBDEs.

PBDEs can be released into the environment during manufacturing, use, and disposal. They are deemed by Environment Canada to have immediate or long term harmful effects on the biological diversity of the environment and seven of the forms (tetra, penta, hexa, hepta, octa, nona and deca) have been placed on the list of toxic substances (Environment Canada, 2010b). Environment Canada (2010c) examined studies of bioaccumulation, biomagnifications, and debromination in their analysis of decabromodiphenyl ether and concluded DecaBDE has the potential to accumulate rapidly to high levels as a result of human activity. The U.S. state of Illinois Environmental Protection Agency reported in 2007 that DecaBDE is bioaccumulative and that there is evidence of thyroid, reproductive, developmental, and neurological effects and recommended a ban by 2010. They concluded there is a consensus that UV light breaks down DecaBDE into banned OctaBDE. When they examined alternative chemicals, the best they could do was propose a list of four "potentially unproblematic" ones (Illinois Environmental Protection Agency, 2007). CDC's Agency for Toxic Substances & Disease Registry (2004) cited evidence of thyroid and endocrine disruption and limited evidence for carcinogenicity of decaBDE in animals.

In August 2010, the Canadian Environmental Protection Agency published a Final Revised Risk Management Strategy for PBDEs, including DecaBDE, for both substances and products containing them. They are supportive of taking control measures to prevent exposure and they noted that the U.S. EPA has a voluntary phase-out of manufacturing DecaBDE by December 31, 2013 (Environment Canada, 2010 d).

For viable alternatives, health care purchasers should consider fabrics that have inherently high melting temperatures. Fibres in the classification of aramid, a type of aromatic polyamide (which is also used for bullet-proof vests), are resistant to heat and fire during prolonged exposure to temperatures of 370°C (700°F) (Jackman et al, 2003 b). Needlepunched felt fabrics made from aramids are used as a flame-blocking lining between the furniture foam and the outer upholstery fabric (Dupont, 2010a; Dupont, 2010b). Modacrylic fibres are modified acrylic fibres made from acrylonitriles. Some modacrylic fabrics are inherently flame retardant since the fibre will not support combustion and is heat sensitive above 150°C (300°F) (Jackman et al, 2003b). Some polyethylenes are also inherently flame retardant (Carnegie Fabrics, 2010). Most important is that purchasing agents look at individual fabric labels since each fabric needs flame retardant testing and not all fibres in a classification will fail to support combustion, particularly if the weave is loose.

The U.S. Center for Disease Control (2003) requires that hospital laundry specify hot washing at greater than 71°C (160°F) for greater than 25 minutes as an effective means of destroying microorganisms. CDC specifies that suitable chemicals of the proper concentration may be used if washing temperature is less than 70°C. Blaser et al (1984) found that bacterial counts of low (22°C) and high (71°C) temperature washed hospital fabrics were comparable when bleach was added and concluded that lowering temperature is an effective method to save vast amounts of energy while eliminating pathogenic bacteria from hospital laundry.

A compound of peracetic acid (peroxyacetic acid) and hydrogen peroxide is used by the laundry facility of the London Health Sciences Centre in London, Ontario, Canada. They replaced chlorine bleach due to better quality wash, less harm to fabrics, and more environmentally-friendly wastewater. They discontinued using phosphates and fluorides many years ago for the benefit of lake and river quality (London Hospital Linen Service Inc., 2009). Both peracetic acid and hydrogen peroxide are classified as oxidizing agents and used as disinfectants according to the Environmental Protection Agency (2007).

Solution dyed textiles (synthetic fabrics that have pigment dyes added before polymer extrusion), provide an extra measure of durability since they are more colourfast than disperse dyed fabrics (Jackman et al, 2003d).

According to the manufacturer, The Momentum Group, they have developed a recycled polyester fabric for healthcare use that will withstand hot washing temperatures of 71°C (160°F). They had not previously had a recycled-content product with this capability (The Momentum Group, 2010). Since virgin (new, not recycled) polyester is a thermoplastic fibre, it is resistant to prolonged heat up to 120°C (250°F) (Jackman et al, 2003b).

The antibacterial and antifungal additive triclosan (2,4,4"-trichloro-2"-hydroxydiphenyl ether) was first registered as a pesticide in 1969 by the U.S. Environmental Protection Agency (2010). For the last 30 years, this pesticide additive has started to appear in products ranging from antibacterial soaps, toothpaste, clothing items such as stockings and underwear, countertops, and healthcare textiles. It acts as a very potent site-directed inhibitor of enzymes (Levy et al, 1999). In a pub-med review of the 1980–2006 literature, Aiello et al (2007) concluded that soaps containing triclosan used in the community at concentrations of 0.1% to 0.45% wt/vol were no more effective than plain soap at preventing infectious illness symptoms. Several laboratory studies indicated triclosan-adapted cross-resistance to antibiotics among different species of bacteria (Aiello et al, 2007a). Aiello and colleagues further explain the risk in terms of emergence of microbes that are less susceptible to triclosan and/or become resistant to antibiotics used clinically. They describe resistance mechanisms that are similar to antibiotic resistance formation, such as "mutations at the drug target site, chromosome-mediated drug efflux and overexpression of the target protein" (Aiello et al, 2007). The Center for Disease Control (CDC) and the Healthcare Infection Control Practices Advisory Committee concluded that there is no evidence that products containing antimicrobials make consumers or patients healthier or prevent disease and that their use is not supported in sound infection control strategy (Centers for Guidelines for Environmental Infection Control in Health-care

Facilities, 2003). Hospital purchasing agents need to be aware of when antimicrobial properties are necessary for healthcare textiles and when simple cleaning techniques would be more appropriate.

Healthcare fabrics should not require fabric softeners, which contain quaternary ammonium compounds that release formaldehyde. Phthalates are also added to make fragrances last. Softeners work by leaving a residue on the fabric which does not wash off. Hot washing water, hot dryers (if dryer sheets impregnated with fabric softener are used) and ironing enhance the release of the formaldehyde (Environmental Health Association for Nova Scotia, 2010). If fabric static is a problem, an alternative is to add 1/4 cup of vinegar to the final rinse cycle of washing. Fabric softeners should be especially avoided for laundry application to polyester fabrics due to interference with the wicking abilities of the fibre (Joseph, 1972c). Wicking moisture away from the body contributes to the comfort of polyester.

There is a new technology introduced in the last decade which uses nanotechnology for high-performance textiles, including healthcare use, according to the manufacturer, DesignTex (Gurian, 2009). A nanometer is one billionth of a metre or the width of 3–5 atoms. One example is the use of "nanowhiskers" which are bonded to the fibres to produce a durable resistance to stains (Gurian, 2009). Lee et al (2003) researched the antibacterial efficacy of nanosized silver applied to fabrics and found that the silver withstood many launderings and had excellent efficacy against both gram-positive and gram-negative bacteria.

Although enormous potential exists for this new class of materials, A.D. Romig Jr. (2003) expressed caution, and expressed that scientific research with peer review be undertaken with respect to this great potential. Kaiser Permanente (2008), one of the largest hospital groups in the United States, has raised concerns about the lack of regulatory oversight, absence of safety testing, and lack of data about environmental and human health effects. Environment Canada (2007) does acknowledge the potential for interference with normal cell function due to the greater number of reactive sites and yet recognizes the enormous market potential for this technology.

CONCLUSION

In summary, healthcare textiles may pose a risk to the health and safety of patients and healthcare workers when they are unknowingly exposed to chemicals of concern. Many studies have been done on acute or chronic exposure of large doses and it is difficult to assess the risk of exposure at low doses over a long period of time or the risk to patients who are already immuno-compromised. Governments appear to side with scientifically "proven" hazards rather than risk the liability of banning a product that is only potentially harmful. Their approach is to work with manufacturers for voluntary discontinuation over a period of time. Environmental groups appear to be at the other extreme of demanding immediate bans. The middle ground suggests the advisability of selecting textiles that have third-party certifications applicable to textiles. Decisions based on the criteria of sourcing locally, selecting durability, using credible standards of performance, selecting sustainable natural fibres, recycled or recyclable synthetic fibres, selecting minimal topical finishes, and selecting fabrics with ease of cleanability are advised for the greening of healthcare fabrics.

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