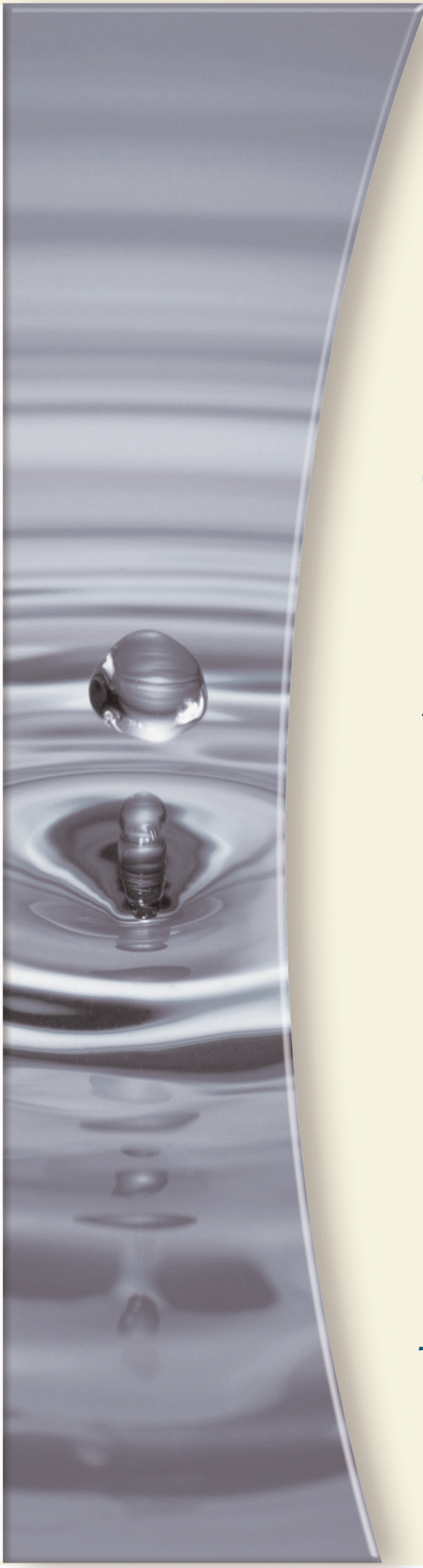

Creating Safe and Healthy Spaces: Selecting Materials that Support Healing

Mark Rossi, PhD, and Tom Lent

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Introduction

> A consistent ethic means that our healthcare organizations must change practices…we see a clear link between environmental responsibility and our basic mission, which is to provide quality healthcare services to all.
>
> There is a direct link between healing the individual and healing this planet. We will not have healthy individuals, healthy families, and healthy communities if we do not have clean air, clean water, and healthy soil.
>
> **— Lloyd Dean, Chief Executive Officer, Catholic Healthcare West, 2000 (Setting Healthcare's Environmental Agenda Conference)**

Every year hospitals consume huge volumes of materials. In 2004 alone, the healthcare sector consumed $23 billion worth of durable medical equipment and $32 billion worth of nondurable medical equipment, while investing another $86 billion in structures and medical equipment.[1] This scale of consumption creates both concerns and opportunities.

The concerns stem from how the plastics, metals, fibers, and minerals used in healthcare construction and medical devices affect our health. Materials matter, as Kenneth Geiser wrote in his book by the same title, because as "we mine, synthesize, process, distribute, use, and, finally dispose of materials, we generate worrisome threats to the sustainability of the ecological systems upon which we depend."[2] As one of the largest economic sectors in the United States, healthcare is a major contributor to the impacts of material consumption.

The opportunities emerge from the position of healthcare—by mission, expertise, and scale of activities—to address material concerns in ways that not only reduce the footprint of their facilities but affect larger change across the medical product industry and even the entire construction industry.

This paper outlines the relationship of the materials and products used in a modern healthcare facility to the chemicals to which our communities are exposed. It emphasizes the opportunities available to healthcare organizations to help society break from its dependence upon toxic materials and define the path to healthier, sustainable materials that benefit patients, communities, nature, and the organizational bottom line. The task is large, but a wide range of healthcare organizations have already outlined manageable steps—see "Recommendations"—that can lead facilities to gain the benefits of the use of healthier, green materials.

Case studies in greening materials

Healing from the inside out

Creating a healing environment requires paying attention to all that patients take into their bodies. In our healthcare facilities, we make sure that the water is pure and that our patients get enough of it. We

Recommendations

First steps

- Adopt purchasing policies that clearly state a preference for green materials that are protective of health and maintain the highest standards of patient care.
- Incorporate green building material preferences into design goals early in capital projects.
- Use the plastics spectrum as a guide when specifying plastic-based products.
  - Prefer polypropylene and polyethylene plastics that do not contain hazardous additives and sustainably-sourced biobased materials.
- Give preference to low VOC products.

Next steps

- Require suppliers to disclose chemical and material content of products.
- Avoid materials that contain highly hazardous chemicals. Start with chemicals listed in Appendix 3.
- Prefer materials and products with high recycled content and end-of-life recycling programs.

Fully engage

- Partner with suppliers who manufacture and develop products using green materials.
- Require suppliers to provide comprehensive hazard data on the chemicals contained in materials and products.

take great care to ensure that each patient receives the exact dose of pharmaceuticals he or she needs. Increasingly hospitals are paying attention to the food patients eat, seeking healthy, balanced meals and avoiding chemicals by increasing the use of organic foods. The air patients breathe is just as important.

We close windows and set up filter systems on outdoor air intakes to protect against outdoor pollutants entering the hospital. Unseen, however, is an influx of toxic chemicals into hospitals from building materials. The materials that cover the floors, walls, and ceilings release hundreds of different chemicals into hospital air. Furniture, curtains, casework, and office and medical equipment contribute their share. Finally, the chemicals used to clean and maintain hospitals add even more to the toxic chemical soup.

Volatile organic compounds (VOCs) such as formaldehyde, acetaldehyde, naphthalene, and toluene are released into the air from particle board, carpets, and other finish materials to be inhaled by patients and staff alike. Semivolatile compounds such as phthalates and halogenated flame retardants latch on to the dust and float into breathing spaces. The potential implications can be subtle but significant, including effects ranging from longer patient recovery times to more sick days for staff.

The health effects from building materials reach farther than the occupants of the building, stretching into the broader community. Roof coatings and paints spread VOCs into the surrounding air contributing to smog. Particulates kicked up by construction and spewed with other carcinogens from exhaust pipes and smokestacks threaten the lungs of residents in the area.

The effects don't end with the local community. Design decisions play out across the whole life cycle of the materials brought into hospitals, starting with the extraction of the raw materials and their manufacture into building materials and medical products. Plastics, for example, have been a boon for the production of high-performance finishes and medical equipment, but at a cost to human health and the environment. Drilling for the oil and gas from which plastics are made releases cadmium, mercury, and a host of other toxic chemicals such as xylene, arsenic, chlorophenols, and polycyclic aromatic hydrocarbons into the environment. The hazardous releases continue at petroleum refineries, which emit lead, naphthalene, benzo(a)pyrene, and other toxic chemicals. The trail of toxic chemical emissions continues at each subsequent step along the path to manufacturing a final plastic product. Polyvinyl chloride (PVC) production alone contributes releases of dioxins, furans, ethylene dichloride, and vinyl chloride monomer. End-of-life disposal continues the saga with the release of yet more toxic chemicals.

The life cycle of materials paints a sobering picture. The very building materials we use to shelter and nurture our patients and the medical devices with which we attempt to heal them contribute chemicals to the air they breathe that can cause the diseases we seek to cure. With the boom under way in healthcare construction today—estimated at $65 billion in 2006[3] and growing rapidly with increases projected to be 10 percent to 15 percent in 2006 and 2007,[4] the industry is poised to bring many more toxic materials into the environment. Or not. Significant players in the healthcare industry have been looking at this construction boom not as problem but rather as an opportunity—a unique opportunity for the industry to leverage changes in the entire building materials industry far beyond healthcare.

Hackensack cleans up

Tackling the whole range of health and environmental issues raised by the array of materials and products used in a modern healthcare facility can be very daunting. Yet an increasing number of facilities are showing that it can be done—often starting with small steps that lead with time and experience to bigger steps. For Deirdre Imus, founder and director of the Deirdre Imus Environmental Center for Pediatric Oncology at Hackensack University Medical Center (HUMC), it started with cleaning chemicals.[5]

"Research regarding the kinds of things that can cause cancer…led me to finding out about hazards associated with some ordinary, everyday cleaning agents—and then to wondering what sorts of things were being used to sanitize places where kids were being treated and cared for," said Imus. "Hospitals," she continued, "are supposed to be places of healing. So it doesn't make sense to expose sick patients to potentially harmful chemicals and gases."

A discussion with HUMC President and Chief Executive Officer John Ferguson in the winter of 2000 led to an investigation of healthier alternatives to the traditional commercial cleaning products. Their research showed that traditional cleaning products were loaded with known or suspected human carcinogens, hormone and endocrine disruptors, and neurotoxins. In response to these findings, they developed a Greening the Cleaning program for the hospital, which included a list of hazardous ingredients to avoid in cleaning agents (see Appendix 1). Small-scale tests provided a proving ground for alternative products. Now the program has developed into a full-scale cleaning protocol across the facility based upon environmentally friendly, nontoxic cleaning products that utilize natural or naturally derived ingredients.

Beyond cleaning: VOCs from building materials

Their concern with the chemicals introduced into the healthcare environment from cleaning products grew to include chemicals released from the materials used in HUMC facilities, including building materials. Suzen Heeley, director of design and construction for HUMC, frames this as a logical part of the effort to create healthy spaces: "You can't just create a healing environment," said Heeley, "with visual amenities alone."

HUMC staff learned that standard particle-board millwork, doors, fiberglass insulation, paints, stains, finishes, adhesives, and sealants all are commonly made with urea formaldehyde and other VOCs that are known or suspected carcinogens and asthma triggers among other health concerns. As design progressed for the new Women's & Children's Pavilion, "we looked holistically at pollutants in the environment from materials, seeking to avoid those that would have potential negative impacts on the occupants of our building, on our community, and beyond," explained Heeley. They found that they could use wheat/strawboard material for millwork and recycled cotton insulation instead of fiberglass. Both of these products had no added formaldehyde plus the benefit of using more rapidly renewable resources. Low VOC paints, stains, finishes, adhesives, and sealants all contributed to cleaning the air for the new facility as well.

Material of concern: PVC

Polyvinyl chloride (PVC) or vinyl plastic avoidance has become one of the major material issues for HUMC—both to reduce immediate health impacts on patients and staff and because of its health impacts elsewhere in its life cycle. In taking steps to avoid the use of PVC in interior finishes and medical products, HUMC (the fourth largest hospital in the United States) is joined by Kaiser Permanente (the largest nonprofit health maintenance organization in the United States), Catholic Healthcare West, and many other hospitals, including three of the four healthcare projects[6] certified under Leadership in Energy and Environmental Design (LEED)[7] and two-thirds of the more than 100 projects from around the United States participating in the *Green Guide for Health Care* pilot program.[8]

Polyvinyl chloride or vinyl first became an issue of concern for the healthcare industry in the mid-1990s when the US Environmental Protection Agency (EPA) released data showing that medical waste incinerators were one of the largest single sources of dioxin emissions. The irony of hospitals emitting large amounts of this incredibly potent carcinogen triggered a strong reaction in the healthcare community. In addition to shutting down incinerators, the healthcare sector started reducing PVC use in disposable medical products, which are a source of chlorine—a necessary ingredient in the formation of dioxins in incinerators.[9]

Further study of PVC revealed it to be a plastic to avoid on many counts. Dioxin formation is not restricted to the burning of PVC, but is also one of a host of toxic byproducts of PVC manufacture. Hazardous additives may be added to give PVC its useful characteristics, including lead and organotins to stabilize it and phthalate plasticizers, like di-2-ethyl hexyl phthalate (DEHP), to give it flexibility. Lead is a neurotoxicant and DEHP is a reproductive toxicant—a particularly serious concern for neonatal intensive-care unit patients.[10]

Leveraging the building materials industry to get the PVC out

With growing success in creating markets for PVC-free medical devices, attention in the healthcare sector has turned to building materials where PVC is found in flooring, carpet backing, wall coverings, upholstery, pipes, and more. Environmental rating systems for buildings around the world, like the *US Green Guide for Health Care*,[11] Australia's *GreenStar,*[12] and Environmental Building News' *Green Spec*[13] have begun to acknowledge the value of PVC elimination. Today, healthcare project designers in the United States, Europe, and Australia are starting to deselect PVC materials.

Alternatives to PVC-based materials abound in construction in general. But finding alternatives that meet healthcare's exacting performance needs can sometimes be challenging, especially in areas where PVC has become the standard and options are limited and/or more expensive. Undaunted, some healthcare systems—most notably Kaiser Permanente—recognize their considerable purchasing power and are challenging manufacturers to develop products that have better environmental and health attributes with equal or better performance and cost (see "Changing the Course of Production: Kaiser Permanente"). The plethora of new products that have moved into the market in the last couple of years heralding their no-PVC content and other environmental-health attributes is a testament to the power of healthcare to shift markets.

Moving to green materials

Substitution unlocks bottom-line gains

When hospitals search for environmentally preferable alternatives, they can make a powerful discovery: doing the right thing for health and the environment can leverage sizable unexpected benefits to the bottom line. HUMC and Kaiser Permanente are two examples of a growing number of healthcare organizations to make the switch from vinyl (PVC) flooring plastic to other flooring materials, such as synthetic rubber, polyethylene, and polypropylene. While environmental concerns prompted the search for vinyl-free flooring, they soon discovered economic benefits as well.

As HUMC and Kaiser Permanente evaluated alternative flooring systems, they first discovered that most options were modestly more expensive per square foot to install than vinyl. Further analysis revealed that, while initial capital costs were higher, life cycle costs were lower for many PVC-free options. Rubber flooring, for example, provides better stain resistance and eliminates the wax-and-strip maintenance cycle of vinyl. Eliminating the wax-and-strip cycle not only reduces maintenance costs, but it also improves staff health by avoiding exposure to the chemicals used in stripping and waxing and solves the major logistical challenges of scheduling this maintenance in 24/7 facilities. Rubber has also been very popular with nursing staff due to its better acoustics and tendency to be easier on staff feet when standing on it for long hours. Very significantly, it also looks like the higher friction coefficient of many PVC-free flooring alternatives may dramatically reduce slip/fall accidents with the potential for significant payoffs in reduced staff and patient injuries.

Changing the Course of Production: Kaiser Permanente

Environmental activism emerged within Kaiser Permanente four decades ago when the organization invited Rachel Carson, author of *Silent Spring*, to deliver the keynote address to a large symposium of physicians and scientists. Today, the 8.5 million member organization with 145,000 employees and $31.1 billion in annual revenues has become a national environmental leader in the healthcare sector. Driving Kaiser Permanente to invest in the environment is the recognition that the health of its members is affected by the health of the communities they live in.

Purchasing specifications and partnerships

In the mid-1990s Kaiser Permanente began incorporating environmentally preferable purchasing specifications into contracts for medical, chemical, and building products. Mercury-free thermometers, PVC-free medical and building products, latex-free examination gloves, greener cleaners, and recyclable solvents are among the many product changes implemented over the past ten years. The power of large-scale purchasing to drive changes in the market is demonstrated in the case of how Kaiser Permanente catalyzed innovation in the carpet sector.

In the summer of 2002, Kaiser Permanente set out to find a high-performance, environmentally preferable carpet. To evaluate whether a carpet is indeed environmentally preferable, Kaiser Permanente asked leading manufacturers detailed questions about the impacts of their products from cradle to grave. For product content, Kaiser Permanente evaluated the carpets for PVC content, other persistent bioaccumulative toxics (PBTs), carcinogens, and postconsumer recycled content. For sustainable manufacturing practices, Kaiser Permanente assessed the progress carpet-manufacturing facilities are making in minimizing waste, water use, nonrenewable energy, and air emissions. For the use stage, the company examined whether the carpets posed problems to indoor air quality, including off-gassing volatile organic compounds—that new carpet smell. For the end-of-life stage, carpets were evaluated on whether they can be closed-loop recycled (carpet to carpet) or down-cycled (carpet to other products of lower value). This scale of investment in evaluating the environmental performance of products sets Kaiser Permanente apart from its peers.

The decision: Catalyze innovation

After evaluating the products and the company responses, no carpet emerged that was both PVC-free and met Kaiser Permanente's demanding performance specifications. The ideal product, it turned out, did not yet exist. Lacking the ideal product, Kaiser Permanente added an innovation question to evaluate the interest, commitment, and capacity of suppliers to develop a new product that met its needs. "Kaiser Permanente," Tom Cooper of Kaiser Permanente's Standards, Planning, and Design team emphasized, "is seeking to develop long-term partnerships with companies that are committed to developing the products we need."

With the goal of creating a new product, Kaiser Permanente chose two vendors on the understanding, specified in a contract, that they would develop a PVC-free product with the necessary performance characteristics at the same cost as existing products within two years. The contract required each firm to submit quarterly reports, including indicators of progress toward PVC-free backing. One of the firms ran into difficulties, fell behind schedule, and stopped communicating with Kaiser Permanente. The other firm, Collins & Aikman (C&A), met the challenge.

"In direct response to our request, C&A developed a new durable, low-emission, PVC-free carpet with backing made primarily from postconsumer recycled plastic," said Cooper. The achievement earned C&A a sole source contract with Kaiser Permanente. In responding to Kaiser Permanente's challenge, C&A created a new carpet line for the firm and for other healthcare and institutional uses. The C&A trademarked "ethos" carpet is made with a PVB [polyvinyl butyral] backing, a chlorine-free material that is recovered from PVB laminate in automobile safety glass. The C&A carpet backing is made from more than 75 percent postconsumer recycled product, which can be recycled into more carpet backing at the end of its life. The combination of mission, capacity to evaluate products, willingness to partner with suppliers, commitment to reducing PVC use, and market size of Kaiser Permanente led C&A to design a new carpet product.

Excerpted with permission from Clean Production Action, Healthy Business Strategies for Transforming the Toxic Chemical Economy, *http://www.cleanproduction.org/Publications.php*.

Getting started: Setting goals

Whether an organization is just starting or is already incorporating environmental priorities into material purchasing policies and facility-design protocols, it is important to set overarching organizational goals. Kaiser Permanente, for example, framed its environmental goals for building design in terms of community health in March 2002 in the "Kaiser Permanente Position Statement on Green Buildings":

> "Kaiser Permanente's mission is to improve the health of the communities we serve. In recognition of the critical linkages between environmental health and public health, it is Kaiser's desire to limit adverse impacts upon the environment resulting from the siting, design, construction, and operation of our healthcare facilities. We will address the life cycle impacts of facilities through design and construction standards, selection of materials and equipment, and maintenance practices. Additionally, KP will require architects, engineers, and contractors to specify commercially available, cost-competitive materials, products, technologies, and processes, where appropriate, that have a positive impact, or limit any negative impact on environmental quality and human health."

Important elements of this vision include examining the life cycle of the facility and the materials used inside. The life cycle of a facility includes design through construction, operation, and maintenance and, ultimately, demolition. The life cycle of a material differs in that many stages, including extraction of raw materials, manufacture, and usually disposal, all occur outside of the hospital's boundaries. Only installation, use, and maintenance of a material's life cycle occur within the hospital. Thus, a comprehensive approach to materials requires a broader perspective.

HUMC is an example of a growing number of healthcare organizations that are explicitly making the connection between their healing work and the causes of the potential diseases they treat. In its mission statement, Deirdre Imus Environmental Center for Pediatric Oncology states: "The Deirdre Imus

Environmental Center for Pediatric Oncology at Hackensack University Medical Center represents one of the first hospital-based programs whose specific mission is to identify, control, and, ultimately, prevent exposures to environmental factors that may cause adult, and especially pediatric cancer, as well as other health problems with our children."

With this mission, HUMC has made improving indoor air quality and avoiding materials responsible for some of the worst toxic chemicals released into the global environment its top priorities when evaluating the environmental performance of building materials.

Defining green materials

The work of HUMC, Kaiser Permanente, and other businesses inside and outside of healthcare reveals an emerging path for defining and selecting environmentally preferable or green materials. We define a green material[14] as having the following key properties:

- No toxic chemistry: Uses only green chemicals in production, use, and disposal. Green chemicals are those that are healthy to humans and the environment and are produced in accordance with the twelve principles of green chemistry (see Appendix 2).
- Biobased or recycled content: Is manufactured from sustainably grown and harvested plant resources or postconsumer recycled content.
- Reusable, recyclable, or compostable: Avoids disposal at the end of its useful life through refurbishment, reuse, recycling into an equivalent product (closed-loop recycling), or composting into soil.

Other properties relevant to the sustainability of a material across its life cycle include: efficiency of water, energy, and materials use; use of renewable energy sources; and maintaining and supporting labor and human rights. Some healthcare organizations such as Kaiser Permanente have made the important first step of questioning suppliers about their consumption of resources, generation of waste, and labor practices when evaluating products.

Our definition of green materials is informed and supported in part by the US Green Building Council's Leadership in Energy and Environmental Design system[15] and the *Green Guide for Health Care*.[16] LEED, for example, prioritizes recycling, renewable materials, and materials that reduce the off-gassing of VOCs into the building. The GGHC expands upon LEED's priorities on materials to address community and global health issues, strengthen the standards on indoor air quality, and broaden the range of chemicals addressed.

Criteria for the transition to green materials

Since green chemistry is practiced by few companies and few materials on the market come close to fully meeting our definition of a green material, attaining truly green materials on a large-scale basis will require patience, persistence, and constant demand from consumers large and small. Progress is being made toward greener materials by consistent signaling to manufacturers about the environmental health priorities of the healthcare industry. Kaiser Permanente and HUMC, for example, are helping move markets to greener materials by developing environmental specifications and partnering with suppliers that are willing to meet them.

The Green Materials Hierarchy for Healthcare defined in Table 1 represents our synthesis of the developing consensus in the healthcare industry on what constitutes greener materials. The hierarchy provides an initial set of criteria, a version 1.0, for defining greener materials that are achievable today.

They are not a comprehensive set of directions to achieving truly green materials—rather they define an initial set of steps that start us along the path to green materials. These guidelines are deeply influenced by our concerns with the use and exposure of humans and the environment to toxic chemicals. For this reason, they start with screening to eliminate materials that contain or contribute to the release of highly hazardous chemicals.

Criterion 1: Persistent organic pollutants

At the top of the hierarchy is the elimination of the use of materials that contribute to the formation of persistent organic pollutants (POPs) as specified by the Stockholm Convention on Persistent Organic Pollutants.[17] Such materials are the top priority because POPs are a set of chemicals so hazardous to human health and the environment that the international community has agreed on the need to eliminate their production, use, and release into the environment. The persistent and bioaccumulative nature of these chemicals makes them a hazard to the entire world community regardless of where they are produced. Under article 5(c) of the convention, ratifying nations agree to "Promote the development and, where it deems appropriate, *require the use of substitute or modified materials, products and processes to prevent the formation and release of the chemicals listed in Annex C [*emphasis added*]*" (which includes dioxins and furans)."[18]

Dioxins and furans are the POPs of greatest relevance to materials because both the production and incineration of some materials, especially those containing chlorine, unavoidably contributes to their formation.[19] The *Green Guide for Health Care* prioritizes avoidance of *chlorinated compounds, especially PVC and cement from kilns fired with hazardous waste* to avoid dioxin emissions.[20] PVC plastic is by far the largest volume plastic made with chlorine and is the only plastic whose production is listed by the US EPA in its inventory of dioxin emissions.[21] Cement kilns fired with hazardous waste (much of it chlorinated) rate in the US EPA's top ten sources of dioxin.[22]

Criterion 1 is a baseline requirement, a prerequisite, to starting on the path to green materials. If the manufacture, use, or disposal of a material creates as a waste product any chemical on the list of Stockholm POPs, then it is not an environmentally preferred material. To use the contracting language of Kaiser Permanente, criterion 1 is a go/no-go criterion: to go forward in the contracting/purchasing process the specification, in this case meeting criterion 1, must be met.

Criterion 2: Highly hazardous chemical content and emissions

Eliminating materials that *contain or emit* highly hazardous chemicals is the next level in the hierarchy because the use of such materials can result in patient and worker exposure to toxic chemicals in hospitals. At the top level is criterion 2a, eliminating the use of materials that contain persistent, bioaccumulative, and toxic (PBT) or very persistent and very bioaccumulative (vPvB) chemicals. These chemicals are similar to POPs—being persistent, bioaccumulative, and toxic in nature means they very are likely to pose global problems; additionally, national governments are targeting them for elimination. Appendix 3 lists PBT and vPvB chemicals as identified by governments. If a material contains a PBT or vPvB chemical above one hundred parts per million (i.e., 0.01 percent), then it is not allowed on the path to green materials.

Plastics, for example, trigger criterion 2 when a highly hazardous chemical additive is used to give them a particular performance characteristic. The flame retardants polybrominated diphenyl ethers (PBDEs) are such an example. Added to plastics to enhance their fire resistance, PBDEs are PBTs and are of significant concern in the United States because Americans have the highest concentrations of PBDEs in their bodies. A plastic that contained PBDEs would fail criterion 2.

At the next levels of criterion 2—2b and 2c—are avoiding materials that *contain or emit* other highly hazardous chemicals, including carcinogens, reproductive toxicants, neurotoxicants, endocrine disruptors,

Table 1: Green Materials Hierarchy for Healthcare

Criterion 1: Do not use materials that contribute to the formation of persistent organic pollutants (POPs) as defined by the Stockholm Convention.

Criterion 2: Do not use materials that contain or emit highly hazardous chemicals, including:

a. Do not use materials that contain
   1. Persistent, bioaccumulative, toxics (PBTs) or
   2. Very persistent, very bioaccumulative (vPvB) chemicals

b. Avoid materials that contain
   1. Carcinogens
   2. Mutagens
   3. Reproductive or developmental toxicants
   4. Neurotoxicants
   5. Endocrine disruptors

c. Avoid materials that emit criteria levels of VOCs.

Criterion 3: Use sustainably sourced biobased or recycled and recyclable materials.

a. Prefer sustainably produced biobased materials that are:
   1. Grown without the use of genetically modified organisms (GMOs).
   2. Grown without the use of pesticides containing carcinogens, mutagens, reproductive toxicants, or endocrine disruptors.
   3. Certified as sustainable for the soil and ecosystems.
   4. Compostable into healthy and safe nutrients for food crops.

b. Prefer materials with the highest postconsumer recycled content.

c. Prefer materials that can be readily reused or recycled into a similar or higher value product and where an infrastructure exists to take the materials back.

Criterion 4: Do not use materials manufactured with highly hazardous chemicals, including those described in criterion 2.

acute allergens (for example, latex), and VOCs. VOCs have been related to sick building syndrome and a range of bronchial and other chronic problems.

The use of DEHP in PVC medical devices is an example of the need for criterion 2b.[23] It is a reproductive toxicant that is added to the material PVC. When used in medical devices, DEHP leaks from the product and exposes the patient. Yet alternative materials to PVC are widely available, none of which contain DEHP. People should not be exposed to highly hazardous chemicals from materials or products in a place of healing when safer alternatives exist. A challenge to implementing criterion 2 is learning which chemicals are contained in or emitted from a material or product and determining the hazards they pose. Strategies for addressing these challenges are discussed below.

Criterion 3: Biobased or recycled and recyclable

The third criterion in the hierarchy moves to specifying the materials we want, rather than the materials we don't want. These are the renewable materials produced from crops and forests and recycled materials.

Biobased materials are desired because, if sustainably produced, they will be available for generations, unlike materials based upon the use of virgin fossil fuels, which we are rapidly depleting. The significant clause here is, *if*, since the majority of current farming and forestry practices are unsustainable and unhealthy for multiple reasons. Current practices depend upon a high consumption of fossil fuel for energy and chemical inputs. They degrade and deplete the soil and ecosystems on which they depend. They use large amounts of toxic pesticides and other chemicals as well as increasing amounts of genetically modified organisms (GMOs).

To address the *if* issue, we specify in Table 1 conditions that will put renewable materials on the path to sustainability, including: grown without the use of GMOs and highly hazardous pesticides, grown with sustainable soil and ecosystem practices, and manufactured so as to be safely compostable. Compostability means the material can be biodegraded in a short period of time into healthy nutrients—containing no hazardous substances—for soil and crops.

Recycled materials are desired because they avoid the significant environmental impacts of extracting and producing virgin raw materials. In addition to saving limited virgin raw material resources, recycling processes typically release fewer toxic chemicals and require less energy than virgin production. The greater the percent recycled content of a material the less impact from virgin material production.[24] The most desirable recycled content is postconsumer content—meaning material that is recycled after used by end users. Postindustrial (or preconsumer) recycled content is material recycled after manufacturing but before consumer use. Note that recycling alone is insufficient to make a material green; it must be combined with the reduced use of toxic chemicals (criteria 1, 2, and 4).

Recyclable means that the material can be recycled into a similar product. Material recycling should be closed-loop, meaning the material can be turned into a product of similar or higher value. This usually requires designing the product to enable separating the different materials at the end of its life. To be meaningful, the technical design to be recyclable must be accompanied by manufacturer take-back programs or other local development of infrastructure to support recycling.

Table 2: Rationales for Green Material Hierarchy for Healthcare

Criterion	Reasons for Action
1. Do not use materials that contribute to the formation of Stockholm Convention Persistent Organic Pollutants (POPs).	• POPs are highly hazardous. • POPs circulate and accumulate globally. • Governments have identified POPs as a top priority for action and agreed to a global treaty for elimination (Stockholm Convention on POPs).
2. Do not use materials that contain or emit highly hazardous chemicals.	• Government agencies have identified these as priority health hazards. • These highly hazardous chemicals escape from materials in the healthcare environment. • Patients and healthcare workers may be exposed to these chemicals.
3. Use sustainably sourced biobased or recycled and recyclable materials.	• Create sustainable material supply systems. • Reduce environmental impacts from virgin material production and from agriculture.
4. Do not use materials manufactured with highly hazardous chemicals.	• Reduce exposure of communities outside the hospital walls to high hazard chemicals. • Improve wider community and ecological health.

Criterion 4: Highly hazardous chemicals in manufacturing

The fourth criterion in the hierarchy focuses on eliminating the use of highly hazardous chemicals in the *manufacture* of the material, whether they end up in the final product or not. Here the concern is with exposures to communities—human and ecological—beyond the walls of the hospital. Take the example of the plastic material, polystyrene. The primary building block of polystyrene is the chemical styrene—which is a possible carcinogen. When styrene is converted into polystyrene, it is no longer carcinogenic. Yet the workers manufacturing styrene and polystyrene, and the communities adjacent to these facilities, are exposed to styrene. Hospitals as healing centers have a responsibility to use materials that are safe and healthy—not only for the patients they serve, but also for the broader community of which they are part. The plastics spectrum in Figure 1 will help in implementing this criterion.

Table 2 summarizes the reasons for action for each of the four criteria in the Green Materials Hierarchy for Healthcare. The placement of each criterion is a function of our values of prevention, precaution, and concerns for environmental health as well as the practice of healthcare today, where leading organizations are already implementing the hierarchy. In the following sections, we apply the criteria to a group of materials widely used in healthcare—plastics—as well as materials that contain VOCs.

Putting the criteria into practice

Specifying preferable plastics

Since many products used for interior finishes, furniture, and medical products are made from plastics, plastics are the largest consumer of organic chemicals,[25] and many threats to health and the environment are related to plastics production and use, plastics provide a good place to start in implementing the Green Materials Hierarchy in a healthcare facility. The criteria in the hierarchy can be applied to plastics to provide guidance on selecting the healthiest options.

Figure 1 provides a guide for purchasers and specifiers on plastics, ranging from the worst plastic (PVC) through increasing preferability of the fossil fuel-based plastics to the most preferred plastic (sustainable biobased plastics). Shifting specifications to plastics further to the right on the spectrum will reduce health impacts and increase sustainability.

Plastics whose production or disposal contributes to the formation of Stockholm Convention POPs (criterion 1)

PVC is the least preferred plastic of the plastics listed in Figure 1. Because of its chlorine content, PVC production, inadvertent fires, and waste incineration result in emissions of dioxins (a Stockholm Convention POP).[26] Hence PVC triggers the critically important criterion 1. PVC also has problems under the other criteria. Many types of PVC may contain additives that fail criterion 2, including lead, cadmium, and DEHP. With its very low recycling rates—essentially zero recycling in the municipal solid waste stream (see Table 3)—PVC does not score well under criterion 3. Made from the carcinogens vinyl chloride monomer and ethylene dichloride, PVC also triggers criterion 4.[27]

Plastics that contain highly hazardous additives (criterion 2)

Plastics contain many different types of additives: chemicals that are added to a polymer to improve manufacturing and material performance (e.g., durability, flexibility, longevity, aesthetics, etc.). Some of these additives are highly hazardous. For example, PVC coatings used on electrical wire and cable typically contain lead compounds and some end uses of polypropylene and polyethylene (which are typically preferred for reasons discussed below) contain the flame retardants, PBDEs, which are PBTs.

Figure 1. Plastics: Environmental Preference Spectrum

PVC	Plastics with highly hazardous additives	ABS EVA Polycarbonate Polystyrene Polyurethane Silicone	PEX PET	Polyethylene Polypropylene TPO	Biobased plastics — sustainably grown

AVOID → **PREFER**

ABS = Acrylonitrile Butadiene Styrene
EVA = Ethylene Vinyl Acetate
PET = Polyethylene Terephthalate
PEX = Polyethylene (PE) Cross-linked (X)
PVC = Polyvinyl Chloride
TPO - Thermoplastic Polyolefin

Plastics that otherwise would be highly rated on the spectrum for their relatively lower health impacts—such as polypropylene—become problematic materials when highly hazardous chemicals are added. For example, if a plastic contains an additive that is a PBT or vPvB chemical, triggering criterion 2a, it is no longer advancing toward a greener material and it becomes a material to avoid rather than prefer.

Halogenated flame retardants, such as PBDEs, are an example of additives that healthcare systems are beginning to screen from their products and some governments are beginning to regulate. Widely used in polyurethane, polypropylene, polyethylene, polystyrene,[28] and other plastics for flame resistance, PBDEs are PBTs. PBDE concentrations in Americans have been doubling every five years, and animal studies link them to immune suppression, cancer, endocrine disruption, and neurobehavioral and developmental effects.[29]

Other key additives and treatments that healthcare systems are targeting to screen include: phthalates (especially DEHP), stain treatments that require perfluorocarbons (PFCs, especially perfluorooctanoic acid or PFOA), and heavy metals like mercury, cadmium, and lead. Table 4 highlights additives of known concern. Leading systems like Kaiser Permanente and HUMC are moving beyond single chemical exclusions to demand that manufacturers fully disclose all of the chemicals and materials in their products so they can fully evaluate the health and safety of the products for their staff, patients, and the larger community.

Tracking down data on the additives used in plastics is a challenge because manufacturers consider the data proprietary. Healthcare systems and group purchasing organizations need to press manufacturers for the data on additives used in plastics as well as the hazards they pose and be willing to sign nondisclosure agreements if necessary to receive the data.

Use sustainably sourced renewable or recycled and recyclable materials (criterion 3)

The most preferred plastic is nontoxic in its chemistry and renewable. Instead of being made from limited virgin materials like fossil fuels, it is made from a sustainably sourced biobased resource, is closed-loop recyclable, and, ultimately, biodegradable into healthy nutrients for food crops when no longer useable. While few such materials exist, some are closing in on this goal.

Plastics made from plants, the biobased plastics, are the new generation of plastic materials. For example, the plastic polylactic acid (PLA) is manufactured from corn rather than fossil fuels. Biobased plastics like PLA have been in use for some time for select medical products and are now beginning to be used in fabrics and interior finish materials such as carpet and wall-protection systems. Linoleum flooring, wood cabinetry, cotton insulation, and other biobased materials can be placed on the spectrum similarly to biobased plastics. Biobased materials are preferred over fossil fuel-based products in criterion 3 for a wide range of reasons: from their potentially inexhaustible renewable nature to the reduced global warming impact and avoidance of the human and environmental health impacts of fossil-fuel exploration, extraction, and refining.

Whether these benefits are realized, however, depends upon how the crops they are made from are raised and how the plastic is then manufactured. Today modern agriculture uses vast amounts of fossil fuels, toxic chemicals, and novel biological organisms (GMOs), potentially making biobased plastic materials just as hazardous to our health as their fossil fuel-based cousins. Hence buyers are developing guidelines for biobased plastics to encourage more sustainable practices. Criterion 3 lists a set of principles that form the core of sustainability guidelines for biobased materials:

1. Grown without the use of GMOs.
2. Grown without the use of pesticides containing carcinogens, mutagens reproductive toxicants, or endocrine disruptors.
3. Certified as sustainable for the soil and ecosystems.
4. Compostable into healthy and safe nutrients for food crops.

Watch in the next few years for programs that will certify the sustainability of bioplastics and other biomaterials. For wood, Forest Stewardship Council[38] certification already provides some assurance that the wood was harvested in a sustainable manner avoiding many of the worst environmental practices that plague the timber industry.

Recycling is an important issue for both biobased and fossil fuel-based plastics.[39] Criterion 3 encourages maximizing recycled, preferably postconsumer, content. It also gives preference to those materials that are designed to be easily reused or recycled at the end of their useful life in a closed-loop cycle—meaning, recycled back into products of equal or higher value.

Recycling of plastics from building materials is at an early stage of development. Pilot programs targeted at recycling various specific building material plastics in isolation may demonstrate the technical ability to recycle, but large-scale recycling of these materials must integrate into existing commodity plastic recycling systems to achieve high percentages of recycled content. The current recycling rate of various plastics in the municipal waste stream is a useful indicator of the potential for large-scale recycling of plastics from the building-material waste stream. Among the commodity plastics,[40] PVC and polystyrene

Table 3: Plastic Recycling Rates in Municipal Solid Waste (MSW)

Plastic	Generation (thousand tons)	Recycling (thousand tons)	Recycling Level (percent by weight)
PET	2,870	410	14.3%
High density polyethylene (HDPE)	5,140	470	9.1%
Other plastics	5,080	350	6.9%
Low density polyethylene (LDPE) and Linear low density polyethylene (LLDPE)	6,210	150	2.4%
Polypropylene	3,610	10	0.3%
Polystyrene	2,270	0	0.0%
PVC	1,470	0	0.0%
Total plastics in MSW	26,650	1,390	5.2%

Source: US EPA, 2003, Municipal Solid Waste in the United States: 2003 Data Tables (http://www.epa.gov/msw/msw99.htm)

Table 4: Additives Watch List

Chemical	Type of Additive	Principal Polymers Used In	Hazards Posed
Bisphenol A	Antioxidant	Polyethylene, polypropylene, styrene	Endocrine disruptor[30]
Cadmium compounds	Stabilizer	PVC	Reproductive/developmental toxicant and mutagen[31]
Carbon black	UV light stabilizer	Polyethylene, polypropylene, polyurethane, styrene, PVC and others	Carcinogen[32]
Lead compounds	Stabilizer	PVC	Neurotoxicant[33]
Organotins	Stabilizer	PVC	Reproductive toxicants[34]
PBDEs	Flame retardant	Polyethylene, polypropylene, polyurethane, styrene and others	PBTs (see Appendix 3)
Perfluorinated compounds (Teflon chemicals)	Stain repellant or lubricant surface treatment	many	PFOS[35] (perfluorooctane sulfonates) is a PBT (see Appendix 3) PFOA (perfluorooctanoic acid or C8) is very persistent, possibly carcinogenic and an immunotoxic in animals[36]
Phthalates, especially DEHP	Plasticizer	PVC	DEHP is a reproductive/ developmental toxicant[37]

have the lowest recycling rates in the municipal solid waste (MSW) stream—essentially zero (see Table 4). Polypropylene and LDPE/LLDPE (two types of polyethylene: low density polyethylene and low density polyethylene) are recycled, but at low levels (less than 5 percent). Polyethylene terephthalate (PET) and high density polyethylene (HDPE) have the highest MSW recycling rates of the plastics.

PVC is also a contaminant in PET recycling. The presence of PVC in the reprocessing and remanufacturing of postconsumer PET can cause problems. At very low concentrations, PVC can form acids when mixed with PET. These acids break down the physical and chemical structure of PET, causing it to turn yellow and brittle. This renders the PET material unacceptable for many high-value end-use applications. In addition, the presence of PVC may result in hydrochloric acid emissions during PET reprocessing, which can increase the cost of control systems or regulatory compliance.[41]

The placement of fossil fuel-based plastics on the environmental preference spectrum (beyond those that do not fail criteria 1 and 2) depends upon their recycling rates and how they fare on criterion 4 below. Since acrylonitrile butadiene styrene (ABS), ethylene vinyl acetate (EVA), polycarbonate, polystyrene, polyurethane, and silicone are barely recycled, they are less preferable in terms of recycling than PET, polypropylene, and the polyethylenes (HDPE, LDPE, LLDPE).

Do not use materials manufactured with highly hazardous chemicals (criterion 4)

ABS, EVA, polycarbonate, polystyrene, polyurethane, and silicone follow plastics with highly hazardous additives on the environmental preference spectrum because they are manufactured using highly hazardous chemicals and, as discussed above, are seldom recycled. ABS is a copolymer made from three highly hazardous chemicals. Acrylonitrile (A) is an International Agency for Research on Cancer (IARC)-probable carcinogen.[42] Butadiene-1,3 (B) is an IARC- probable carcinogen,[43] as well as being a European Union Category 2 mutagen,[44] and reproductive/developmental toxicant according to the State of California.[45] Styrene (S), which is also the building block of polystyrene, is an IARC-possible human carcinogen.[46] EVA is made from the feedstock vinyl acetate, which is an IARC-possible human carcinogen.[47] Polycarbonate is manufactured from the suspected endocrine-disrupting compound, bisphenol A.[48] Thermoplastic polyurethane is manufactured from a variety of highly hazardous intermediary chemicals, including the IARC known carcinogen formaldehyde.[49] Silicone is manufactured from intermediary feedstocks that include quartz (also known as silica) and methyl chloride. Silica dust is an IARC-known human carcinogen,[50] and methyl chloride is reproductive/developmental toxicant according to the State of California.[51]

Polyethylene terephthalate is manufactured from the possible developmental toxicant ethylene glycol and hence also violates criterion 4.[52] PET is, however, somewhat more preferable to the plastics to the left of it on the environmental preference spectrum—which share similar concerns over highly hazardous chemicals inputs—because it is more readily recycled (criterion 3).

Polypropylene and polyethylene are the most preferred of the fossil fuel-based plastics because their feedstocks, propylene and ethylene, have not been identified as meeting any of our criteria for highly hazardous chemicals—they are not listed as carcinogens, mutagens, reproductive or developmental toxicants, neurotoxicants, endocrine disruptors, or PBTs in any of the governmental databases we searched. Additionally these plastics are, along with PET, the more widely recycled plastics in both municipalities and industries. Thermoplastic polyolefin (TPO) is a blend of polypropylene and polyethylene and is also highly preferred among the fossil fuel-based plastics for similar reasons—less hazardous and recyclable in commercial applications. Note that for polypropylene, polyethylene, and TPO to be highly preferred they must meet criterion 2, contain no highly hazardous chemical additives.

Another polyethylene, cross-linked polyethylene (PEX), is somewhat less preferable than the other polyethylenes because it is a thermoset plastic; which means it cannot be melted down and converted into a high-value product. It can only be ground down and used in filler for generally low-value applications.

Specifying low VOC materials

Paints, stains, adhesives, and other wet-applied products will emit VOCs after application, with emissions tapering off rapidly in the weeks that follow. Furniture, carpets, flooring, and other interior finish products release VOCs more gradually over time. VOCs are the chemicals most commonly associated with sick building syndrome in new buildings or after renovations. Many green building material-rating systems already include screening procedures for interior finish materials based either upon quantities of VOCs *contained* in the product or upon levels of VOCs *emitted* into the indoor air after installation.

A large (and growing) number of standards and certification systems exist that address the release of VOCs from different building materials or products. They include government standards—such as the South Coast Air Quality Management District VOC content regulations for paints, coatings, and adhesives and the California 01350 emissions standard for solid finish materials—and independent third-party certification programs—like GreenSeal for paints, Indoor Advantage and GreenGuard for furniture and finish materials. A recent trend is that an increasing number of green building product-certification programs are being established and managed by trade associations, such as Green Label Plus for carpets by the Carpet and Rug Institute and FloorScore for resilient flooring by the Resilient Floor Covering Institute. This trend is being viewed with increasing skepticism and concern by many observers, given that the associations promulgating these standards were formed to promote the products being tested and to protect the interests of that product's industry.

The most health-protective standards address a large number of individual VOCs using health-science-based criteria with a strong precautionary approach; others just set a total VOC limit and monitor a small number of individual VOCs. It is important to note that there is no material-certification program yet that addresses all potential chemical hazards that a building material can present to occupants. Most of them only address immediate postinstallation exposure to VOCs and a limited set of VOCs at that. Generally, they do not address semivolatile organic compounds (SVOCs) such as phthalates and brominated flame retardants that are released more slowly later in the life of the material, nor do they generally limit heavy metals and other toxic components of materials that may be released as particulate rather than volatilizing.

The ideal indoor health certification program for green building materials will be

- developed with participation of consumer and public health interests and independent of industry control;
- transparent, meaning that the protocols are publicly available;
- not proprietary, usable by multiple certifiers;
- third-party certified;
- incorporating the full range of chemicals of concern related to indoor exposures; and
- clearly related to other standards that address the wider range of green material issues (such as recycled content or lifecycle PBT emissions) or be clearly identified as limited only to indoor exposure issues.

No standard yet exists that meets these criteria. Intense discussion is under way in the certification community to reduce the confusion of different standards currently on the market and develop more comprehensive standards.

VOC standards and certification programs are useful tools for screening building materials for health, but must be approached with awareness of the limitations of current programs and combined with the chemical screening described elsewhere in this paper to truly protect the health of occupants or of the community.[53]

Challenges on the path to green materials

Gaining the benefits of the 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.

A particular challenge to evaluating the toxicity profile of materials is gaining access to data on the chemical constituents of a material. In fact, many product vendors do not know the materials included in their products nor do they know the chemicals that are in those materials. Gaining data on the chemical and material constituents of products will require deeper partnerships with vendors. Kaiser Permanente's work with C&A on carpets and HUMC's Greening the Cleaning product exemplify how it is possible through persistence to understand the toxics in products and eliminate them.

Some suppliers, such as Herman Miller and Interface, have worked to gain detailed knowledge of the chemicals used in their products as well as the hazards posed by those chemicals.[54] Herman Miller, for example, requires its suppliers to disclose the chemical constituents of their materials down to 100 parts per million.

As a result, Herman Miller knows the chemical composition of all of the parts down to 0.01 percent by weight of some products like its Mirra office chair. But Herman Miller does not disclose publicly or to its customers the chemicals contained in its products.

Once data is collected on the chemical constituents of a material/product, the next challenge is understanding the hazards posed by that chemical. Unfortunately, the majority of chemicals on the market have not been comprehensively tested for their hazards.[55] To acquire comprehensive hazard data requires government action to mandate and coordinate. This reality is leading some healthcare systems such as Kaiser Permanente to actively support government chemical policy reform.

After an organization commits to selecting green materials, the next challenge is finding products that contain them. Do not be surprised if the product does not exist. But, do not be discouraged either. Kaiser Permanente's journey in search of PVC-free carpet illustrates how persistence and a willingness to partner with a supplier can result in new product development that meets price, performance, and environmental concerns. Vendors need to be engaged in the search for solutions and rewarded with contracts when they deliver the product. Of course, as new green materials are developed, it is critical that no standards of performance or patient care be sacrificed. Recent evidence shows that healthcare's huge purchasing volume puts it in a strong and potentially unique position to shape the course of material development by catalyzing manufacturers to market materials that are good for healthcare and the environment.

Finally, once a new material is in place, workers need to be engaged to maximize the benefits of the greener material. For example, both HUMC and Kaiser Permanente have found that, in initial tests, they were not capturing the potential benefits of the reduced maintenance needs of new floorings. Maintenance staff continued to use the old vinyl-floor wax-and-strip methods on the new floors, particularly in areas where the old and new floors coexisted in the same building. Both organizations had to institute a careful training and monitoring program with maintenance staff to help them through the transition, to understand the changes, why they are taking place, and how to work with the new materials.

In another such transition, HUMC found installers were initially skeptical about the switch from fiberglass insulation batts to the recycled cotton. The cotton handles differently, and installers were resistant to try the new product, with which they had no experience. After trying it out, however, the installers discovered that, in addition to avoiding carcinogenic formaldehyde, they didn't get the skin irritation typical of fiberglass handling and felt much better after installing it. Now some of the installers are active proponents and don't want to go back to fiberglass.

Reaping the big bottom-line benefits

Potentially even more powerful than the individual attribute benefits of change in flooring or insulation or paints or blood bags or cleaners can be the effect on staff relations. Creation of a comprehensive approach to addressing the health impacts of the facility on staff, patients, and the community can be framed to highlight the organization's philosophy. This can provide a powerful message of the organization's caring and concern and support gains in professional staff allegiance and retention and in patient satisfaction.

Will greening materials cost more? The answer will vary—some materials substitutions will cost no more, some may even save money. Others may have a higher initial price tag but can leverage tremendous returns. The organization that can break down the barrier between capital and operating budgets and can make links between environmental decisions and staff and patient effects can reap major economic rewards while doing good.

Recommendations

Healthcare organizations can establish a progression of measured steps to steadily improve the health impact of their material purchases.

First steps

- Adopt purchasing policies that clearly state a preference for green materials that are protective of health and maintain the highest standards of patient care.
- Incorporate green building material preferences into design goals early in capital projects.
- Use the Plastics Environmental Preference Spectrum as a guide when specifying plastic-based products.
    - Prefer polypropylene and polyethylene plastics that do not contain hazardous additives and sustainably-sourced biobased materials.
- Give preference to low VOC products.

Next steps

- Require suppliers to disclose chemical and material content of products.
- Avoid materials that contain highly hazardous chemicals. Start with chemicals listed in Appendix 3.
- Prefer materials and products with high recycled content and end-of-life recycling programs.

Fully engage

- Partner with suppliers who manufacture and develop products using green materials.
- Require suppliers to provide comprehensive hazard data on the chemicals contained in materials and products.

Transitioning to greener materials is part of a journey to creating safer and healthier products. It is a journey that will take time, experimentation, adjustments to error—in short, continuous improvement. As the experiences of Kaiser Permanente, HUMC, and others show, however, the potential rewards for the healthcare system are huge. Patient outcomes, staff satisfaction and retention, and operating costs all stand to gain. Healthcare with its large purchasing volume is uniquely positioned to shape the future of material development and reap substantial benefits to the bottom line while improving global health and the environment.

Author Biographies

Mark Rossi, PhD, is the research director at Clean Production Action and co-chair of Health Care Without Harm's Safer Materials Workgroup. He is also a research fellow at the Lowell Center for Sustainable Production at the University of Massachusetts Lowell. The purpose of Rossi's work is to change the course of production away from the dependency on hazardous chemicals to alternatives that are healthy for humans and the environment. Currently he is developing tools for identifying safer chemicals and materials. Rossi's work on safer materials began in the 1980s when he performed life-cycle assessments on plastics for Tellus Institute. He earned his doctorate in environmental policy from MIT, where he focused on green technology development and diffusion.

Tom Lent is technical policy director for the Healthy Building Network, a national network of design professionals, environmental health specialists, and activists working together to advance the use of ecologically superior building materials that are safer throughout their life cycle. Lent helped develop the Green Guidelines for Healthcare Construction (GGHC) as one of the coordinators on the GGHC Steering Committee and serves on the LEED for Healthcare Committee. He has consulted on the development of a variety of other model green building projects and corporate and governmental construction guidelines with the City of San Francisco, Kaiser Permanente, and others around the country with an emphasis on materials and health issues. Lent was honored in 2004 with Environmental Award for Outstanding Achievement by Region 9 of the US Environmental Protection Agency for his work to bring health concerns into green buildings.

Notes

1 US Department of Health & Human Services (USHHS). 2005. Centers for Medicare and Medicaid Services, Office of the Actuary, National Health Statistics Group. "National Health Expenditure Data, Table 2—National Health Expenditures Aggregate Amounts and Average Annual Percent Change by Type of Expenditure: Selected Calendar Years 1960-2004," http://www.cms.hhs.gov/NationalHealthExpendData/downloads/tables.pdf. *Structures and equipment* includes the value of both new construction and new medical equipment," accessed July 7, 2006.

2 Geiser, K. 2001. *Materials Matter: Toward a Sustainable Materials Policy*. Cambridge, MA: The MIT Press.

3 US Census Bureau. 2006. "Manufacturing, Mining, and Construction Statistics, Construction Spending," May, http://www.census.gov/const/C30/total.pdf.

4 Haughey, J. 2006. "Healthcare Spending Grows Faster in 2006–07," *Building Design & Construction News*, April 1, http://www.bdcnetwork.com/article/CA6323272.html.

5 Information for this section on HUMC is from: Miles Z. Epstein, "A Conversation with Deirdre Imus: A Champion of Children's Health," *Commerce Magazine*, Commerce and Industry Association of New Jersey, April 2005, http://www.cianj.org/magazines/uploads/242678.pdf; and an interview by Tom Lent with Suzen Heeley, director of design and construction, Hackensack University Medical Center, June 15, 2006.

6 Boulder Community Hospital (Colorado), The Patrick H. Dollard Discovery Health Center (New York), and Richard J. Lacks, Sr., Cancer Center (Michigan).

7 See US Green Building Council, Leadership in Energy and Environmental Design (LEED), www.usgbc.org.

8 See *Green Guide for Health Care*, www.gghc.org.

9 For a summary of the relationship between PVC and dioxin, see Health Care Without Harm, "Dioxin, PVC, and Health Care Institutions," October 16, 2002, http://www.noharm.org/library/docs/Going_Green_3-1_Dioxin_PVC_and_Health_Care.pdf.

10 For a summary of the life-cycle hazards of PVC see: Health Care Without Harm, "Why Health Care Is Moving Away from the Hazardous Plastic: Polyvinyl Chloride (PVC)," April 6, 2006, http://www.noharm.org/details.cfm?ID=1277&type=document. For the patient populations vulnerable to DEHP exposure see US Food and Drug Administration, "Public Health Notification: PVC Devices Containing the Plasticizer DEHP," 2002.

11 See *Green Guide for Health Care*, www.gghc.org.

12 See Green Building Council Australia, http://www.gbcaus.org/gbc.asp?sectionid=88&docid=952.

13 See BuildingGreen.com, http://www.buildinggreen.com/.

14 By materials we mean the basic matter—wood, plastics, metals, paper, minerals, ceramics, cotton, wool, etc.—from which physical products (such as flooring, IV bags, roof coverings, oxygen masks, computers) are made. Note that all materials are comprised of chemicals—chemicals and their atoms are the building blocks of materials. Some materials—such as plastics—are manufactured directly from chemicals synthesized by humans. Other materials—such as wood—consist of chemicals synthesized into unique combinations by nature.

15 US Green Building Council, Leadership in Energy and Environmental Design (LEED), www.usgbc.org.

16 See *Green Guide for Health Care*, www.gghc.org.

17 The text of the Stockholm Convention can be found at http://www.pops.int.

18 Ibid.

19 The POPs list includes twelve chemicals. The majority of these chemicals are pesticides: aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene (also an industrial chemical and industrial byproduct), mirex, and toxaphene. Only hexachlorobenzene and polychlorinated biphenyls (PCBs) are industrial chemicals—manufactured for use in products that are not pesticides. The remaining two chemicals—dioxins and furans—are unintended byproducts of industrial activity.

20 Any building material can be associated with dioxin releases across its life cycle due to diesel-fuel combustion (for transportation) and coal combustion (power generation) in the manufacturing process. These dioxin releases are not uniquely nor intrinsically related to the material itself. Action to reduce these releases must happen by changing the transportation and power sectors—not the topic of this paper. Other building materials that the US EPA has indicated may have significant direct dioxin releases include: aluminum, copper, and lead smelting (recycling) operations and iron (from sintering operations). Dioxin releases from copper recycling are dropping dramatically as chlorine sources, particularly PVC wire sheathing, are removed from the recycling stream. Lead is already deselected due to criterion 2. Aluminum and iron operations require more analysis to determine the nature of the dioxin formation and whether these operations can be cleaned up to remove chlorine-based contaminants to bring dioxin releases down or whether material avoidance is warranted.

21 US Environmental Protection Agency. 2005. "The Inventory of Sources and Environmental Releases of Dioxin-Like Compounds in the United States: The Year 2000 Update," External Review Draft, published March 2005, http://www.epa.gov/ncea/pdfs/dioxin/2k-update/.

22 Ibid.

23 See, Health Care Without Harm, "The Weight of the Evidence on DEHP: Exposures are a Cause for Concern, Especially During Medical Care," April 6, 2006, http://www.noharm.org/details.cfm?ID=693&type=document.

24 It should be noted that recycling can sometimes result in higher net energy impacts than virgin materials due to transportation if the materials need to be shipped long distances to centralized plants for recycling. In some cases, it still makes sense to purchase recycled content materials despite high transportation energy costs for a period of time to stimulate investment in the infrastructure to recycle materials locally, eventually reducing impacts for the long haul.

25 Organic chemicals contain carbon. Chemicals manufactured from fossil fuels and living matter contain carbon—making organic chemicals a significant segment of all chemical production.

26 Other chlorinated plastics used in construction that also trigger this criterion include: chlorinated polyethylene (CPE), chlorinated polyvinyl chloride (CPVC), chlorosulfonated polyethylene (CSPE), and polychloroprene (chloroprene rubber, also brand name Neoprene). PVC is targeted for priority action because it is far and away the largest end use for chlorine and, hence, the most significant dioxin contributor among plastics. The PVC manufacturing process is the only plastic thus far quantified in the EPA's dioxin assessment. Other chlorine-based plastics, however, are likely dioxin sources and would be placed in the same column as PVC on the plastics spectrum.

27 For more information on PVC, refer to Health Care Without Harm's fact sheet "Why Health Care Is Moving Away from the Hazardous Plastic Polyvinyl Chloride (PVC)," http://www.noharm.org/details.cfm?ID=1277&type=document and the Healthy Building Network's fact sheet "PVC in Buildings: Hazards and Alternatives," http://www.healthybuilding.net/pvc/facts.html.

28 Specifically, high-impact polystyrene.

29 For more information on HFRs, refer to Health Care Without Harm's fact sheet, "What Health Care Purchasers Can Do to Reduce Flame Retardants," http://www.noharm.org/details.cfm?type=document&id=1108.

30 See, for example, Japan, Ministry of Environment, "Endocrine Disrupting Chemicals Database, Table of Chemicals Suspected of Having Endocrine Disrupting Effects," 1998, http://w-edcdb.nies.go.jp/HPEF/sp_Table3.html, accessed 7/24/06; and BKH Consulting (prepared for the European Commission DG ENV), Toward the establishment of a priority list of substances for further evaluation of their role in endocrine disruption—preparation of a candidate list of substances as a basis for priority setting (M0355008/1786Q/10/11/00), June 2000, http://ec.europa.eu/environment/docum/pdf/bkh_main.pdf, accessed 7/24/06.

31 For example, see European Communities, CONSLEG: 1976L0769—16/03/2004, Council Directive of 27 July 1976 on the approximation of the laws, regulations, and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations (76/769/EEC) (OJ L 262, 27.9.1976, p. 201), Consolidated Text produced by the CONSLEG system of the Office for Official Publications of the European Communities, 16 March 2004, http://ec.europa.eu/enterprise/chemicals/legislation/markrestr/consolid_1976L0769_en.pdf.

32 Carbon black is an International Agency for Cancer Research (IARC) 2B carcinogen, meaning it is possibly carcinogenic to humans, as well as a California Proposition 65 listed carcinogen (State of California, Environmental Protection Agency, Office of Environmental Health Hazard Assessment, "Chemicals Known to the State to Cause Cancer or Reproductive Toxicity," June 9, 2006, http://www.oehha.ca.gov/prop65/prop65_list/files/060906p65single.pdf).

33 For example, see US Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, "Draft Toxicological Profile for Lead," 1999, http://www.atsdr.cdc.gov/toxprofiles/tp13.pdf.

34 U.S. Department of Health and Human Services, 2003. Public Health Service, Agency for Toxic Substances and Disease Registry, "Toxicological Profile for Tin and Tin Compounds," http://www.atsdr.cdc.gov/toxprofiles/tp55.pdf.

35 Note that PFOS and PFOA or C8 are not necessarily ingredients in the final treatment product, but are used in manufacture and can be breakdown products—that is, the treatment can breakdown into PFOA or PFOS in the environment.

36 US Environmental Protection Agency. 2005. Office of Pollution Prevention and Toxics, Risk Assessment Division. "Draft Risk Assessment of the Potential Human Health Effects Associated with Exposure to Perfluorooctanoic Acid and its Salts," January 4, http://www.epa.gov/opptintr/pfoa/pubs/pfoarisk.pdf.

37 For example, see European Communities, CONSLEG: 1976L0769—16/03/2004, Council Directive of 27 July 1976 on the approximation of the laws, regulations, and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations (76/769/EEC) (OJ L 262, 27.9.1976, p. 201), Consolidated Text produced by the CONSLEG system of the Office for Official Publications of the European Communities, 16 March 2004, http://ec.europa.eu/enterprise/chemicals/legislation/markrestr/consolid_1976L0769_en.pdf, and State of California, Environmental Protection Agency, Office of Environmental Health Hazard Assessment, "Chemicals Known to the State to Cause Cancer or Reproductive Toxicity," June 9, 2006, http://www.oehha.ca.gov/prop65/prop65_list/files/060906p65single.pdf.

38 Forest Stewardship Council, http://www.fsc.org.

39 Land limits and competition for food and fuel mean that we cannot expand plastic production from plant matter without limit.

40 The commodity plastics are those plastics produced and consumed in the greatest quantities: PET, polypropylene, polyethylene, polystyrene, and PVC.

41 See Integrated Waste Management Board, 2003. "Plastics White Paper: Optimizing Plastics Use, Recycling, and Disposal in California," Sacramento; and Clean Washington Center (CWC), 1997, "Best Practices in PET Recycling: Contamination Issues," http://www.cwc.org/pet_bp/3-04-01.pdf.

[42] Acrylonitrile is listed by the International Agency for Research on Cancer (IARC) as a Group 2A carcinogen, meaning it is probably carcinogenic to humans.

[43] 1,3 Butadiene is listed by IARC as a Group 2A carcinogen, meaning it is probably carcinogenic to humans.

[44] European Communities, CONSLEG: 1976L0769—16/03/2004, Council Directive of 27 July 1976 on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations (76/769/EEC) (OJ L 262, 27.9.1976, p. 201), Consolidated Text produced by the CONSLEG system of the Office for Official Publications of the European Communities, 16 March 2004, http://ec.europa.eu/enterprise/chemicals/legislation/markrestr/consolid_1976L0769_en.pdf.

[45] California Environmental Protection Agency. 2006. Office of Environmental Health Hazard Assessment, "Chemicals Known to the State to Cause Cancer or Reproductive Toxicity," June 9, http://www.oehha.ca.gov/prop65/prop65_list/files/060906p65single.pdf, accessed 7/24/06.

[46] Styrene monomer is listed by IARC as a Group 2B carcinogen, meaning it is possibly carcinogenic to humans.

[47] Vinyl acetate is listed by IARC as a Group 2B carcinogen, meaning it is possibly carcinogenic to humans.

[48] See, for example, Japan, Ministry of Environment, "Endocrine Disrupting Chemicals Database, Table of Chemicals Suspected of Having Endocrine Disrupting Effects," 1998, http://w-edcdb.nies.go.jp/HPEF/sp_Table3.html, accessed 7/24/06; and BKH Consulting (prepared for the European Commission DG ENV), Toward the establishment of a priority list of substances for further evaluation of their role in endocrine disruption—preparation of a candidate list of substances as a basis for priority setting (M0355008/1786Q/10/11/00), June 2000, http://ec.europa.eu/environment/docum/pdf/bkh_main.pdf, accessed 7/24/06.

[49] Formaldehyde is listed by IARC as a Group1 carcinogen, meaning it is carcinogenic to humans.

[50] Silica dust is listed by IARC as a Group 1 carcinogen, meaning it is carcinogenic to humans.

[51] State of California, Environmental Protection Agency, Office of Environmental Health Hazard Assessment, "Chemicals Known to the State to Cause Cancer or Reproductive Toxicity," June 9, 2006, http://www.oehha.ca.gov/prop65/prop65_list/files/060906p65single.pdf, accessed 7/24/06.

[52] National Toxicology Program, Center for the Evaluation of Risks to Human Reproduction, U.S. Department of Health and Human Services. "NTP-CERHR Monograph on the Potential Human Reproductive and Developmental Effects of Ethylene Glycol," NIH Publication No. 04-4481. 2004 (Research Triangle Park: NTP).

[53] For more discussion on VOC certification programs and materials screening see the Healthy Building Network's fact sheet "Screening the Toxics out of Building Materials," http://www.healthybuilding.net/pdf/ Healthy_Building_Material_Resources.pdf.

[54] See Greiner, T., Rossi, M., Thorpe, B. Kerr, B. *Healthy Business Strategies*, 2006. (Spring Brook, NY: Clean Production Action), www.cleanproductionaction.org.

[55] United States Government Accountability Office. 2005. *Chemical Regulation: Options Exist to Improve EPA's Ability to Assess Health Risks and Manage Its Chemical Review Program* (GAO-05-458), June, http://www.gao.gov/new.items/d05458.pdf, accessed 7/24/06.

Appendix 1: Greening the Cleaning Must Not List

Greening the Cleaning is a cleaning protocol developed at the Deirdre Imus Environmental Center for Pediatric Oncology at Hackensack University Medical Center. The protocol guides users to eliminate to the greatest extent possible all cleaning agents containing hazardous ingredients and replace them with environmentally friendly products that utilize natural or naturally derived ingredients.

The Greening the Cleaning protocol uses the following guidelines—which were adapted from the US Department of Interior's "Guidance and Training on Greening Your Janitorial Business: Environmentally Preferable Attributes of Chemical Cleaners" and other standards—for formulating cleaning and related products.

They

Must not contain carcinogens, mutagens, or teratogens.

Must not contain any ozone-depleting compounds, greenhouse gases, or substances that contribute to smog.

Must not be corrosive or irritating to the skin or eyes.

Must not be delivered in aerosol cans.

Must not contain petrochemical-derived fragrances.

Must not contain toxic dyes.

Must not contain arsenic, lead, cadmium, cobalt, chromium, mercury, nickel, or selenium.

Must not contain hazardous wastes.

Must not contain petroleum distillates over .1 percent.

Must not be combustible.

Must not contain chlorinated solvents.

Must not contain persistent or bio-accumulative substances.

Volatile organic compound (VOC) levels must meet or be less volatile than the California Code of Regulations maximum allowable VOC level for the various categories.

Must be readily biodegradable.

Must be biobased.

Must be dispensed through automatic systems to reduce employee contact.

Must have a pH level between 4 and 9.

More information on Greening the Cleaning and the Deirdre Imus Environmental Center for Pediatric Oncology at Hackensack University Medical Center can be found at http://www.dienviro.com. Reprinted with permission.

Appendix 2: Green Chemistry

Twelve Principles of Green Chemistry

1. Prevent waste: Design chemical syntheses to prevent waste, leaving no waste to treat or clean up.
2. Design safer chemicals and products: Design chemical products to be fully effective, yet have little or no toxicity.
3. Design less hazardous chemical syntheses: Design syntheses to use and generate substances with little or no toxicity to humans and the environment.
4. Use renewable feedstocks: Use raw materials and feedstocks that are renewable rather than depleting. Renewable feedstocks are often made from agricultural products or are the wastes of other processes; depleting feedstocks are made from fossil fuels (petroleum, natural gas, or coal) or are mined.
5. Use catalysts, not stoichiometric reagents: Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once.
6. Avoid chemical derivatives: Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.
7. Maximize atom economy: Design syntheses so that the final product contains the maximum proportion of the starting materials. There should be few, if any, wasted atoms.
8. Use safer solvents and reaction conditions: Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals.
9. Increase energy efficiency: Run chemical reactions at ambient temperature and pressure whenever possible.
10. Design chemicals and products to degrade after use: Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.
11. Analyze in real time to prevent pollution: Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.
12. Minimize the potential for accidents: Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment.

Source: Anastas, P. T., and J.C. Warner. 1998. Green Chemistry Theory and Practice *New York: Oxford University Press. Also see Green Chemistry Institute Web site at www.greenchemistryinstitute.org.*

Appendix 3: Stockholm Convention Persistent Organic Pollutants (POPs); Persistent, Bioaccumulative, and Toxic (PBT); and Very Persistent and Very Bioaccumulative (vPvB) Lists

CAS	Chemical	POPs[1]	PBTs			vPvBs
			EU[2]	US EPA Priority PBTs[3]	WA[4]	EU[2]
87-61-6	1,2,3-trichlorobenzene		1			
120-82-1	1,2,4-trichlorobenzene		1			
84852-15-3	4-nonylphenol (branched)				1	
309-00-2	Aldrin	1		1	1	
120-12-7	Anthracene		1			
7440-43-9	Cadmium				1	
57-74-9	Chlordane	1		1	1	
3734-48-3	Chlordecone (Kepone)				1	
50-29-3	Dichlorodiphenyltrichloroethane (DDT)	1	1	1	1	
60-57-1	Dieldrin	1		1	1	
68515-49-1 and 26761-40-0	Di-isodecyl phthalate (DIDP)				1	
84-75-3	Di-n-hexyl phthalate (DnHP)				1	
several	Dioxins	1		1	1	
90640-86-1	Distillates (coal tar), heavy oils		1			
115-29-7	Endosulfan		1			
72-20-8	Endrin	1			1	
several	Furans	1		1	1	
76-44-8	Heptachlor	1			1	
1024-57-3	Heptachlor epoxide				1	
36355-01-8	Hexabromobiphenyl				1	
25637-99-4	Hexabromocyclododecane				1	
118-74-1	Hexachlorobenzene	1	1	1	1	1
87-68-3	Hexachlorobutadiene				1	
7439-92-1	Lead			1	1	
58-89-9	Lindane		1			
7439-97-6	Mercury			1	1	

CAS	Chemical	POPs[1]	PBTs			vPvBs
			EU[2]	US EPA Priority PBTs[3]	WA[4]	EU[2]
2385-85-5	Mirex	1		1	1	
1836-75-5	Nitrofen		1			
25154-52-3	Nonylphenol				1	
	Octachlorostyrene					
several	PAHs				1	
56-49-5	PAHs - 3-Methyl chlolanthrene				1	
218-01-9	PAHs - Benzo(a)phenanthrene (Chrysene)				1	
50-32-8	PAHs - Benzo(a)pyrene			1	1	
205-99-2	PAHs - Benzo(b)fluoranthene				1	
191-24-2	PAHs - Benzo(g,h,i)perylene				1	
205-82-3	PAHs - Benzo(j)fluoranthene				1	
207-08-9	PAHs - Benzo(k)fluoranthene				1	
189-55-9	PAHs - Benzo(r,s,t)pentaphene				1	
192-65-4	PAHs - Dibenzo (a,e)pyrene				1	
189-64-4	PAHs - Dibenzo (a,h)pyrene				1	
226-36-8	PAHs - Dibenzo(a,h)acridine				1	
53-70-3	PAHs - Dibenzo(a,h)anthracene				1	
224-42-0	PAHs - Dibenzo(a,j)acridine				1	
206-44-0	PAHs - Fluoranthene				1	
193-39-5	PAHs - Indeno(1,2,3-cd) pyrene				1	
198-55-0	PAHs - Perylene				1	
194-59-2	PAHs -7H-Dibenzo(c,g)carazole				1	
13654-09-6	PBDE - Decabromodiphenyl ether				1	
32536-52-0	PBDE - Octabromodiphenyl ether		1		1	
32534-81-9	PBDE - Pentabromodiphenyl ether				1	
1336-36-3	PCBs	1		1	1	
608-93-5	Pentachlorobenzene				1	
133-49-3	pentachlorobenzenethiol		1			1
1763-32-1	Perfluorooctane sulfonates (PFOS) Acid				1	
29081-56-9	Perfluorooctane sulfonates (PFOS) Ammonium salt			1		

CAS	Chemical	POPs[1]	PBTs			vPvBs
			EU[2]	US EPA Priority PBTs[3]	WA[4]	EU[2]
70225-14-8	Perfluorooctane sulfonates (PFOS) Diethanolamine salt				1	
29457-72-5	Perfluorooctane sulfonates (PFOS) lithium salt				1	
2795-39-3	Perfluorooctane sulfonates (PFOS) Potassium salt				1	
32241-08-0	Polychlorinated naphthalenes - Heptachloronaphthalene				1	
1335-87-1	Polychlorinated naphthalenes - Hexachloronaphthalene				1	
1321-64-8	Polychlorinated naphthalenes - Pentachloronaphthalene				1	
1335-88-2	Polychlorinated naphthalenes - Tetrachloronaphthalene				1	
1321-65-9	Polychlorinated naphthalenes - Trichloronaphthalene				1	
92061-94-4	Residues (coal tar), pitch distn.		1			
85535-84-8	Short-chain chlorinated paraffins				1	
79-94-7	Tetrabromobisphenol A				1	
95-94-3	Tetrachlorobenzene, 1,2,4,5-				1	
75-74-1	Tetramethyllead		1			1
8001-35-2	Toxaphene	1		1	1	
56-35-9	Tributyltin oxide (TBTO)		1			

[1] *Source: Stockholm Convention on Persistent Organic Pollutants, http://www.pops.int/documents/convtext/convtext_en.pdf.*

[2] *Source: European Chemicals Bureau, European Union, Status report on PBTs and vPvBs for New and Existing substances, http://www.defra.gov.uk/environment/chemicals/achs/060606/achs0614d.pdf*

[3] *Source: US EPA, Priority PBTs, http://www.epa.gov/pbt/pubs/cheminfo.htm*

[4] *Source: Washington State PBT list, http://www.ecy.wa.gov/programs/eap/pbt/pbtfaq.html*