WELL V2:

EVIDENCE BEHIND THE MATERIALS CONCEPT

FEATURE X01: FUNDAMENTAL MATERIAL RESTRICTIONS

OVERVIEW

Part 1: Ensure that newly installed building materials contain less than 1% asbestos by weight.
Part 2: Ensure that newly installed, thermostats, illuminated exit signs, switches and electrical relays are mercury-free, and fluorescent and high-pressure sodium lamps meet specified mercury content limits.
Part 3: Ensure that drinking water systems and plumbing products are lead-free, and indoor paints and surface coatings contain less than 90 ppm total lead.

SCIENTIFIC BACKGROUND

- Some materials that were widely used in the past, such as lead-containing pipes and asbestos roofing, have demonstrated health effects that have triggered restrictions or bans on the sale, import and use of certain materials in many countries.[1]
- Increasing literacy about the ingredients in building materials is a key step for proper materials selection and handling to protect occupants from known toxins.[2]
- Over the past decade, considerations related to construction materials have shifted away from an almost exclusive focus on durability and mechanical effectiveness to include a greater emphasis on the potential impact of building materials on human health and the environment.[2]

KEY HEALTH AND WELL-BEING EFFECTS

- Historical use of hazardous materials in construction and furnishing, specifically asbestos, mercury and lead, has presented serious and negative health impacts on humans. Disease caused by exposure to these chemicals, such as asbestosis, developmental issues in children and various forms of cancer, still affect millions of people.[3,4]
- Lead is a potent chemical that has pervasive effects on the human body.[4]
    - Children are especially vulnerable to lead and exposure can result, often irreversibly, in learning and memory problems, lower intelligence quotient (IQ) and delayed growth.[4-6] Pregnant women exposed to lead can transfer lead to their children.[4]
    - Elevated blood lead levels (BLL) have been found in children living in locations where high levels of lead from water pipes have been found in drinking water.[7]
    - Since phasing out lead in gasoline, the main source of lead exposure in children is now through the ingestion of paint chips and dust containing lead particles. Children absorb four to five times more lead than adults in their bloodstream.[8]
- The International Agency for Research on Cancer classifies all forms of asbestos as carcinogenic to humans.[9]
    - Asbestos exposure is associated with lung cancer, and malignant mesothelioma is almost exclusively linked to asbestos exposure.[9-11]
    - Other effects of asbestos exposure include chronic inflammation of the lungs (i.e., asbestosis) and calcification and thickening or fluid buildup of the lung lining.[12,13]
- While less ubiquitous in the built environment than other toxins, mercury is known to be persistent, bioaccumulative (i.e., over time, with continued exposure, levels build up in the body) and toxic.[14,15]
    - Mercury exposure from non-food sources can occur from compact fluorescent lamps (CFLs) and other mercury-containing bulbs, some products that might be found in scientific laboratories, electrical switches, antique or vintage items or in old thermometers (which contain about 500 mg of mercury, equivalent to over 100 CFLs).[14,16,17]
    - The most significant impact of chronic elemental mercury exposure is kidney damage.[18] In addition, animal studies demonstrate that chronic exposure causes changes in testicular tissue and compromised and lower sperm count, while acute mercury exposure can result in acute renal damage.[18,19]
    - Acute effects of mercury exposure also include tremors, slowed sensory and nerve function, mood changes and impaired cognitive function, while chronic effects can include further negative impacts on the central nervous system.[18]

- While these compounds have been restricted or banned in buildings in many countries, they still pose threats in countries that have not enacted the necessary limitations. As a result, exposure to these hazardous materials should be limited and, if possible, eliminated.

HEALTH PROMOTION BENEFITS AND STRATEGIES

- One of the most effective ways to protect people from exposure to toxic chemicals is through legislation that restricts allowable content in materials and products.
- The sale, import and use of asbestos in construction has been fully or partially banned for buildings in most countries and alternatives are widely available.[20]
    - Asbestos exposure has been greatly reduced through policy-level limitations on its manufacture and use, but individuals who work with building materials, especially in older buildings, are at increased risk of exposure.[21]
- Lead content in building materials that may pose a risk to humans – particularly children through aspiration of lead-containing dust and the ingestion of paint chips – is restricted in many national regulations.[22,23]
    - The Global Alliance to Eliminate Lead Paint, a voluntary partnership formed by the United Nations Environment Programme and the World Health Organization, sets the maximum allowable total lead content of paint at 90 ppm, representing the strictest concentration limit in the world.[23]
    - Since trace amounts of lead are common throughout our environment, achieving zero lead content is assumed to be practically infeasible, and regulating authorities agree that 90 ppm represents a realistically achievable upper limit.[23]
    - While the ultimate remedy to prevent lead in drinking water is to remove all lead-containing pipes and fixtures, this is both time-consuming and expensive.[24] In lieu of remediating existing infrastructure, many countries have regulations for new pipe and fixtures in contact with drinking water to minimize the lead content in these products and/or to prevent lead from leaching into drinking water.[25]
- Eliminating the use of fluorescent and compact fluorescent light bulbs (CFLs) removes a potential pathway for release of mercury.[26]

ADDITIONAL NOTES

- In the absence of laws or in regions where laws allow for higher concentrations than is indicated as safe by developing research, voluntary efforts must fill the gap. For instance, only 38% of all countries have laws restricting lead content in paint, and concentration limits in those countries range from 90 ppm to 10,000 ppm or higher.[23]

FEATURE X02: INTERIOR HAZARDOUS MATERIALS MANAGEMENT

OVERVIEW

Part 1: Assess existing buildings for the presence of asbestos and implement a strategy to remove contaminated materials or to prevent spread of asbestos fibers.
Part 2: Assess existing buildings for the presence of lead in paint and implement a strategy to remove lead-containing paints or to prevent the spread of lead-containing dust and paint chips.
Part 3: Ensure that all PCB-containing materials to be removed during renovation activities are properly assessed and removed.

SCIENTIFIC BACKGROUND

- Some materials ubiquitously used in building construction during the past century have been phased out in many parts of the world due to health concerns. However, buildings constructed prior to these regulations still pose a risk of exposure.[3,27]
- Legacy building contaminants, such as asbestos, lead and PCBs, pose risks for human exposure as materials containing these compounds degrade over time and can release fibers and dust into the environment.[3,27,28]
- Removing contamination sources or protecting hazardous materials from releasing toxins is a key step to maintain a healthier space and reduce exposure to known toxic compounds.

KEY HEALTH AND WELL-BEING EFFECTS

- Historical use of hazardous materials in construction, specifically asbestos, lead and PCBs, has presented serious and negative health impacts on humans.
    - The International Agency for Research on Cancer classifies all forms of asbestos as carcinogenic to humans.[9] Asbestos exposure is associated with lung cancer, and malignant mesothelioma is almost exclusively linked to asbestos exposure.[9-11]
    - Lead is a potent chemical that can affect almost every organ and body system.[4] Children are especially vulnerable to lead, and exposure can result in learning and memory problems, lower intelligence quotient (IQ) and delayed growth.[4-6] Pregnant women exposed to lead can transfer lead to their children.[4]
    - In countries where lead in gasoline has been phased out, the main source of lead exposure in children is now through ingestion of paint chips and dust. Children absorb four to five times more lead than adults in their bloodstream.[8]
- Occupational exposure to asbestos, other than in regions where it is extracted from the earth, occurs during remediation of asbestos-containing buildings.[9]
- In a survey of adults working in various industries with known exposure to lead, workers in the construction industry were found to have high blood lead levels compared to other industries.[4]
- PCBs were heavily used until 1970s when they were banned worldwide as persistent organic pollutants. PCBs were used in many products because of their chemical stability (including non-flammability), ability to transfer heat, and plasticizer and electric insulation properties.[28,29]
    - PCBs are known carcinogens, have genotoxic effects on the body and target the endocrine system.[30]
    - Their chemical inertness and pervasiveness make them a threat even decades after their phaseout. PCBs are semi-volatile and are present in air, they deposit in water sources and can bioaccumulate in fish. Inhalation of volatilized PCBs and ingestion of contaminated foods are the main sources for human exposure to PCBs.[28]

HEALTH PROMOTION BENEFITS AND STRATEGIES

- Many countries have bans on the import of asbestos and programs for phasing out asbestos containing materials (ACMs) during renovations and demolitions, with varying degrees of success in the implementation of these programs.[1,31,32]
    - The goal of these regulations is to contain the spread of asbestos fibers into the environment and to protect the health of building occupants as well as those involved in remediation activities.[33]
    - Regulations encompass remediation techniques, notification of works, workers' protection and handling of asbestos-containing waste.[33]

- Where asbestos cannot be removed, treatment interventions can be applied on-site to prevent ACMs from releasing asbestos fibers. These in-place management strategies require periodic inspection to maintain their effectiveness.[34]
- Many national regulations address remediation of surfaces coated with lead-containing paints with the goal of preventing the release of dust and paint chips.[35]
- Because PCBs are such a serious threat to human and environmental health, aggravated by their persistence and chemical inertness, remediation of buildings containing PCBs that considers protocols to reduce the generation and spread of contaminated particles protects workers from exposure to PCBs and allows for safer waste disposal.[36]
    - To supplement remediation strategies, many countries set legal requirements for places that can receive PCB-containing waste.[37]

FEATURE X03: CCA AND LEAD MANAGEMENT

OVERVIEW

Part 1: Assess existing buildings for the presence of wood containing chromated copper arsenate (CCA, also known as pressure-treated wood) in exteriors and implement remediation.
Part 2: Assess existing buildings for the presence of lead in soil and other surfaces and implement a strategy to remove lead-containing paints or to prevent the spread of lead-containing dust and paint chips.

SCIENTIFIC BACKGROUND

- Chromated Copper Arsenate (CCA) was heavily used in outdoor structures and furniture. However, its potential to leach arsenic prompted its phaseout.[38]
    - Wetting and bleach-cleaning of CCA-containing wood increases the dislodging of arsenic and chromium from the wood matrix into water runoff and adjacent soil.[39]
    - A three-year study of CCA-containing wood subject to rainfall events found that 10% of arsenic and 2% of chromium was released into the soil, showing the potential of arsenic to reach shallow underground water supplies.[40]
- CCA-treated wood, if burned, releases chromate, creating toxic fumes.[41]
- Lead from paint used for exterior structures and playgrounds, as well as from recycled tires, may be present in soil, rubber crumbs and fibers.[42,43] While surveys for lead in playgrounds and artificial turf have ubiquitously detected this compound, further research is being conducted to assess bioavailability of lead as well as routes and doses of exposure that lead to significant health impacts.[43-45]
- Surveys of paint in playgrounds have shown widespread presence of lead in older playground equipment.[46]

KEY HEALTH AND WELL-BEING EFFECTS

- Arsenic is an element naturally found in the soil of many countries.[47] Inorganic arsenic, either as the trivalent arsenite (AsO_2^-) and pentavalent arsenate (AsO_4^-), is significantly more toxic than organic arsenic.[48] While arsenite is more toxic, reduction of arsenate by environmental microorganisms or upon entering the human body is well documented.[38,48]
    - Arsenic can accumulate in the liver, kidney, lungs and heart and cause a myriad of health effects, including cancer, diabetes and cardiac dysfunction, among others.[47]
    - Children playing around wet and recently bleached CCA-containing wood structures may ingest or absorb arsenic through the skin beyond maximum daily doses accepted by regulation authorities.[39]
- Lead is a potent chemical that can affect almost every organ and body system.[4] Children are especially vulnerable to lead, and exposure can result in learning and memory problems, lower intelligence quotient (IQ) and delayed growth.[4-6] Pregnant women exposed to lead can transfer lead to their children.[4]
    - There is no “safe” level of lead exposure, particularly for children.[42] Aspiration and ingestion of lead-containing dust can occur via contaminated soil. In a study in the United States, bioavailable soil samples from single family homes were correlated with blood lead levels in resident children.[49]
    - Lead in soil poses a particular burden to children in neighborhoods near present or past industrial activities.[42]

HEALTH PROMOTION BENEFITS AND STRATEGIES

- Since the early 2000s, CCA-treated woods have been banned in many countries where they may come in contact with humans, animals and food crops.
    - The inspection of purchasing records or chemical analyses can help identification of CCA-containing wood, which has a characteristic pale green color.[41]
    - Once identified, CCA-treated woods can be sealed to prevent arsenic from leaching.[39,41] Best practice to prevent further exposure and environmental degradation suggests that CCA-treated wood should not be chipped or burned.[41]
- The primary objective and benefit of testing for lead in soil and structures is to inform the need for remediation. Once identified, replacement of soil and artificial turf containing lead above allowable thresholds is recommended.[43,50] Likewise, if playground equipment is found to contain lead, the safest alternative is to remove the equipment.[44]

FEATURE X04: SITE REMEDIATION

OVERVIEW

Part 1: Assess sites for contamination and, if likely, test and remediate pollutants.

SCIENTIFIC BACKGROUND

- Many environmental regulations are relatively new. Therefore, many sites with past industrial activities are likely to be contaminated.[51]
- Development of contaminated sites without a proper remediation strategy may expose building occupants and surrounding communities to hazardous chemicals.[52,53]
- While there is no singular definition, the term "brownfields" is widely used to define segments of derelict, vacant, contaminated or previously developed land.[54] Their location and size span from abandoned buildings inside cities to swaths of developed land in rural locations. Due to the risk they pose to nearby residents, before being brought back to use or redeveloped, brownfield sites require intervention.[54]

KEY HEALTH AND WELL-BEING EFFECTS

- Contaminated soil can spread pollutants in the environment (e.g., via dust or water sources) which can result in human exposure to hazardous chemicals.[51]
- In a study performed in the United States, elevated levels of cancer and other health impacts such as respiratory and heart diseases were associated with proximity to brownfields with higher concentrations of heavy metals, PCBs and aromatics, among other contaminants.[55]
- A similar study conducted in England suggested strong correlations between the proportion of brownfield areas and health aggregates (limiting long-term illnesses and premature mortality).[54]
- Children may be especially vulnerable to heavy metal exposure due to their low body weight. In children, exposure may negatively impact physical and intellectual development.[27,53]
- Brownfields associated with low-quality prior developments (contaminated or not) also may trigger deleterious consequences in the psychosocial health of surrounding communities due to stigmatization associated with living in or within the vicinity of these areas.[54]

HEALTH PROMOTION BENEFITS AND STRATEGIES

- Brownfield remediation strategies are embedded in many legal codes, usually accompanied with public subsidies to attract private investment.[56]
- Including neighboring communities (those impacted by brownfield contamination) in the decision-making process associated with development may provide a degree of fairness and balancing of interests along with the environmental benefits associated with remediation.[57]
- Fostering re-development of land slows down urban sprawl and reduces pressure to develop agricultural land and green space.[58,59] Experts agree that developers should consider tradeoffs between developing new buildings and providing green space in remediated brownfields and forcing out existing communities due to increasing property values.[60,61]

FEATURE X05: ENHANCED MATERIAL RESTRICTIONS

OVERVIEW

Part 1: Restrict certain classes of chemicals in furniture, electrical and electronic components.
Part 2: Restrict chemicals in architectural and interior products.

SCIENTIFIC BACKGROUND

- There is often scientific uncertainty about the causes and effects of specific chemicals on health or environmental outcomes. The relationship between exposure to chemicals and health effects are often complex and nuanced, and are dependent on specific exposure conditions, characteristics and vulnerabilities of populations exposed, properties of the chemical in question and more.
- Orthophthalates are a group of chemicals comprised of functionally and structurally similar molecules used as plasticizers (i.e., used to soften and increase the flexibility of plastic) . They are commonly added to plastic Polyvinyl Chloride (PVC). Orthophtalate compounds have been found ubiquitously in indoor air throughout the world.[62-64]
    - Lower-income homes were found to have significantly higher concentrations of these compounds in air (two to 18 times) compared with homes in higher social strata.[62]
    - Some countries have moved to phase out and ban certain orthophthalates from some products, including personal care products.
- The per-and polyfluorinated substances (PFAS) are a group of chemicals, in which fluorine atoms are bounded to carbon chains.[65] These compounds are monomers used in the making of fluoropolymer coatings and products that resist heat and repel oil, stains, grease and water.[66] PFAS encompass more than 4,000 related compounds, of which perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) have been the most studied.[65] PFAS pose significant environmental and public health concerns because they do not break down and can accumulate in water bodies, including drinking water supplies, and bioaccumulate in fish and wildlife.[65-67]
    - Sources of human exposure include industrial emissions, house dust and PFAS-containing consumer products.[68]
    - While PFOA and PFOS are being phased out from production, humans can be exposed to these compounds for many years due to their chemical stability.[67]
    - PFAS can travel through air and water, in some cases over long distances, as evidenced by the presence of these compounds in the Arctic ice cap.[67]
- Halogenated (brominated or chlorinated) flame retardants are often added to upholstered furnishings but are not always chemically bound to the products, allowing them to be released into the surrounding environment.[69] While some of these compounds are banned in certain countries, they still can be found in existing housing stock.[62]
- Heavy metals are defined as high-density metallic elements. Some of them, like copper, cobalt, zinc and selenium, are essential for the human body in small concentrations. Others such as Cadmium, Lead and Mercury are toxicants at very small doses. These metals are found in nature and are used in many industrial applications and consumer products.[67]

KEY HEALTH AND WELL-BEING EFFECTS

- A meta-analysis of indoor dust studies shows the ubiquitous presence of orthophthalates, halogenated flame retardants and PFAS inside homes. Further analysis suggests that inhalation of some of the most volatile compounds may be an important source of exposure, particularly for children.[64] These contaminants were found to be even more prevalent in lower-income housing.[62]
- Evidence of health effects has been shown for some orthophthalates (e.g. di(2- ethylhexyl) phthalate, DEHP), whereas for others (e.g., DINP), there is more debate. Due to the knowledge gaps and the structural variety of these compounds, further research is needed to establish explanations for the health effects of orthophthalates based on their chemical structure.[70]
    - An evaluation of DEHP evidence by the International Agency for Research in Cancer (IARC) concluded that there is sufficient evidence of the carcinogenicity of DEHP in animals and classified this compound as category 2B (possibly carcinogenic to humans).[71] Studies have also associated DHEP with reproductive toxicity and respiratory diseases, including asthma.[72]
    - Orthophthalate exposure may induce or exacerbate allergic diseases in children.[73,74]

- Prenatal exposure to orthophthalates and metabolites produced in the human body upon maternal intake of orthophthalates has been associated with poorer cognitive development in in boys.[75,76] Endocrine disruptive effects of orthophthalate exposure have been found in several studies, including in gene expression analyses of exposed pregnant mothers.[77] A prospective cohort study found a dose-response association between maternal exposure to mono-benzyl phthalate (a metabolite of Benzyl butyl phthalate, BBP) and diastolic pressure.[75,78]

- PFAS are found ubiquitously in human blood serum samples.[67,68] In humans, PFOA and PFOS have an estimated half-life of 3.8 to 8 years.[67,68] They can cross the placenta and have been measured in maternal and cord blood and breast milk.[67]
    - The most-studied PFAS chemicals are PFOA and PFOS. Studies suggest that PFOA and PFOS exposure can increase risk of liver and kidney damage, thyroid disease, increase levels of serum lipids (including cholesterol) and decreased antibody response to vaccines.[68]
    - Chronic exposure to PFAS can also result in endocrine disruption and has been linked with decreased fertility in women.[75]
    - PFOA is classified as possibly carcinogenic to humans (group 2b) by the IARC.[67]
- Cadmium and lead are known carcinogens. They pose significant health hazards for children though ingestion of contaminated particles and water and for adults through occupational exposure, smoking and ingestion of contaminated food.[27,79]
- Flame retardants are lipophilic (able to dissolve in fats and oils) and have been found human blood, breast milk and scalp hair.[75,80] Occupational exposure has been documented in firefighters and in workers in the foam and carpet industries. Among adults, exposure commonly occurs through ingestion of contaminated food and dust, inhalation and dermal absorption. Toddlers may become exposed through their micro-environment which includes products such as flooring, infant furniture and toys that may contain these chemicals.[81]
    - Polybrominated Diphenyl Ethers (PBDEs), a group of flame retardants, are associated with thyroid hormone disruption.[81] Metabolites of tetrabromophthalate, a substitution for PBDEs, are a cause of concern due to potential cardiovascular health effects.[82]

HEALTH PROMOTION BENEFITS AND STRATEGIES

- One way to better protect humans and the environment from potential harms associated with hazardous ingredients in building materials is by promoting materials that are designed to minimize, if not eliminate, such components without compromising functionality.
- In certain countries, some compounds within the chemical classes addressed in this feature are being banned (e.g., REACH and RoHS regulations in Europe). In others, phase-out programs are in place to remove them from fabrication and the manufacturing ecosystem.[83,84]
    - Because of the relevance of European regulations in international trade, technical specifications of most electronic products state compliance with Europe's RoHS, which bans certain chemicals in electronics.
- Due to incomplete and sometimes contradictory data at a compound class level, a precautionary approach in selecting building products is recommended.[70] This approach favors, where technically feasible, selecting products with compounds that are better characterized and less toxic than the products being substituted.
- Orthophthalates are commonly found in vinyl building materials (e.g., flooring, plastic wall base, wallcovering), electric wire jacket, paints, adhesives, detergents, solvents, blinds and plastic pipes and upholstery. Depending on the use and function, alternative formulations of these products, that are not made with orthopthalates, can be found in the market such as:[85]
    - Flooring: Rubber, Linoleum and Phthalate Free Plastics.
    - Wall Base: Vulcanized Rubber Base, MDF and Wood Base.
    - Wallcoverings: Poly-Olefins and cellulose based products.
    - Pipes: Copper, galvanized Steel and polypropylene.
- PFAS are commonly found in water-repellant fabrics (e.g., upholstery, carpets, curtains), paints and nonstick products. Products without or that use alternative formulations are available in the market such as:
    - Textiles and carpeting without water- and stain-repellency.
    - Products with "perfluor-", "polyfluor-", and "PTFE" on the label.
    - Some products labeled as "PFOA free" products may contain other PFAS chemicals.

- Flame retardant chemicals may be used in commercial and consumer products (e.g., foam furniture cushions) to meet flammability standards. Furniture, cushions and carpet padding containing polyurethane foam are most likely to contain these compounds. Strategies to select products less likely to contain halogenated flame retardants are listed below:
    - In the United States, consumers can look for the California TB117-2013-compliant label that states whether an upholstered product contains flame retardants or not.[86]
    - Alternative materials such as polyester or wool are unlikely to contain added flame retardants and may be appropriate alternatives.

FEATURE X06: VOC RESTRICTIONS

OVERVIEW

Part 1: Select paints, sealants, adhesives and coatings (wet-applied products) with low VOC emission or low VOC content.
Part 2: Select furniture, millwork, architectural and interior products with low or no VOC emission.

SCIENTIFIC BACKGROUND

- Volatile organic compounds (VOCs) encompass a large range of chemicals, both of natural and artificial origin, that readily vaporize at room temperature due to their low boiling points.[87]
    - Examples of VOCs include methane, formaldehyde, ethanol, benzene, toluene, isopropanol, isoprene, acetone, chloroform and styrene.
- VOCs are used as solvents in adhesives, paints and coatings. Part of these solvents volatilize after their application, leaving a bond or a solid structure behind. Furnishings and construction materials contain VOCs in glues, varnishes, paints and the like.
    - Some VOCs can be naturally emitted by plants or wood (biogenic emissions), such as isoprene, pinenes and d-limonene. Isoprene appears to be the dominant VOC emitted by vegetation and its release is somewhat proportionate to photochemical activity in plants.[88]
- VOCs participate in complex reactions within indoor environments, sometimes undergoing adsorption onto surfaces or the formation of other VOCs or particle material (PM). These processes are commonly catalyzed by surfaces, light or other compounds in the air (e.g., ozone).[89,90]
- High VOC emissions of building products when they are installed or applied during construction or renovation phase be followed by continuous emission long after installation.[91,92]
    - There are two types of VOC emission: Primary emissions are driven by the evaporation of solvent and non-chemically bounded VOCs, typically lasting for about one year. Secondary emissions are primarily driven by the mechanical or chemical breakdown of materials, lasting for longer time periods.[93] Some VOC-emitting paints may re-adsorb part of these emissions and re-emit them, at a lower rate, for a prolonged period of time.[94]

KEY HEALTH AND WELL-BEING EFFECTS

- Inhalation of VOCs emitted inside buildings can produce a wide range of effects, from olfactory annoyance to acute health and comfort issues, such as headaches, nose and throat irritation, dry or itchy skin, nausea and fatigue.[87,95] When these symptoms do not have a clear causal relationship and disappear shortly after exiting the building, they are collectively known as sick building syndrome (SBS).[96]
- Increased reporting of sensory irritation may be triggered by weak odors caused by VOC emissions, as humans have difficulty separating olfaction from sensory irritation. These odors can trigger annoyance and decreased performance among occupants.[89]
- Some VOCs, such as benzene, trichloroethylene (TCE) and formaldehyde, are classified by the International Agency for Research on Cancer (IARC) as group 1 carcinogens, meaning that there is sufficient evidence that exposure to these compounds increases the odds of developing cancer.[97]
- Exposure to airborne formaldehyde can result in respiratory tract irritation and inflammation.[98] Because its threshold for sensory irritation (0.6-1 mg/m^3) is only five to ten times larger than the olfactory threshold (0.11 mg/m^3), sensory irritation is sometimes reported more frequently than odors.[89]

HEALTH PROMOTION BENEFITS AND STRATEGIES

- Research has shown that installation of low-VOC materials is associated with lower indoor VOC concentrations compared to traditional building materials and products.[98,99]
- Many materials used in construction and furnishing are inherently non-emitting as they do not contain organic carbon. Examples are stone, metals, concrete and ceramic.
- The first year of a product's life after installation is commonly when the most VOCs will be emitted.[93] Therefore, used furniture may be considered as long as no new wet-applied products are added.[99]
- One of the best ways to reduce exposure to VOC's is to purchase or specify products labeled as low-, no or VOC-free. Further, it is recommended that consumers purchase only the quantity which will be needed, to limit or reduce the stockpiling of these chemicals.

    - Increasingly, manufacturers are testing and disclosing the emissions of their products. As a result, technical specification sheets, certifications, labels and scores that help consumers understand the contents and composition of building materials are more widely available.
    - Technical specification sheets may state compliance with various low-emission VOC standards including, California's CDPH, and CalGreen, Germany's AgBB or European Union's LCI emission standards. Many product certification programs include adherence to one or more of these standards.
- Low-VOC materials selection may complement other means for indoor air VOC control such as ventilation systems.[91]
- Low-VOC policies and regulations that improve product labeling, ventilation standards, and consumer education are critical to foster the design and operations of healthier indoor environments.[91,100]

FEATURE X07: MATERIALS TRANSPARENCY

OVERVIEW

Part 1: Select products that have all ingredients disclosed down to 1,000 ppm.
Part 2: Select products that have all ingredients publicly disclosed down to 100 ppm.
Part 3: Select products that have disclosed ingredients verified by a third party.

SCIENTIFIC BACKGROUND

- Materials transparency refers to manufacturers disclosing the ingredients, chemicals and materials needed to make a given consumer product. Knowing what is inside a product allows for better assessment of its potential health impact.[101]
- Data gaps and the lack of harmonized data may hinder the adoption of healthier and more sustainable materials.[102]
- One of the primary challenges in the manufacturing of safer products is a lack of data and knowledge about the composition of the numerous parts of a product. This is made more difficult, in part, by confidentiality clauses and proprietary formulations that may prevent a manufacturer from knowing all of the ingredients that make up their products.[103]
  - Historically, suppliers of chemicals, plastics and other component materials have been protective of their proprietary formulations, and there has been little incentive for them to share their ingredients with their customers.[103]
- Manufacturers need cooperation from the entire supply chain in order to inventory all the ingredients added upstream in the fabrication process to fully achieve materials transparency.
- The initial costs involved on reaching materials transparency may be high, but there are long-term benefits that may offset the cost of inaction.[101] For instance, transparency brings nimbleness in the formulation of a product, as it prepares a company to respond to regulatory shifts, protects the reputation of a brand and increases the reliability of the supply chain.[104]

KEY HEALTH AND WELL-BEING EFFECTS

- Transparency enhances the communication between a manufacturer and its supply chain, allowing for the verification of product claims. When not in place, the consequences can be deleterious. For examples, due to the lack of communication between a manufacturer of an end product and the supplier, a product was found to contain chemicals deemed as absent by the manufacturer but unknowingly introduced earlier in the manufacturing chain by the supplier.[105]
- Unknown materials in a product can compromise its safety and introduce potential health hazards to consumers.
  - A salient example of how these issues translate to consumers is with the case of lead in children's toys. Between 2006 and 2007 alone, millions of children's toys suspected to present lead paint hazards were recalled by manufacturers.[106]
- Lack of transparency in the supply chain may also results in effects on environmental and human health upon disposal, as certain products may become hazardous waste.[101]

HEALTH PROMOTION BENEFITS AND STRATEGIES

- Materials transparency is one of the many tools for manufacturers to proactively develop a chemical management strategy (i.e., a framework to address the uses and safety of chemicals in the manufacturing and formulation of a product). Value drivers include expanding brand recognition, limiting exposure to liability, aligning with company values, meeting societal expectations of safety or addressing concerns from non-governmental organizations (NGOs) about certain ingredients.[107,108]
- Many manufactures have found that simply asking questions leads to change. This aids in progress towards materials transparency particularly while manufacturers work towards a more rigorous target such as a transparency label, which requires time and thorough disclosures.[109]
- With the rise of voluntary disclosures, there are now a plethora of tools available to assist manufacturers in conducting a thorough inventory of ingredients and to support those who will disclose their proprietary formulations. Databases that compile transparency documents for manufacturers, organized by type of product, are growing in number and volume of indexed products.

- Knowledge of a product's content also can inform strategies for its reuse and recycle, helping improve human and environmental health and well-being.[104,110]
- It is important to complement materials transparency with literacy about their potential health effects, so users can properly assess the risk posed by the material's ingredients and draw technically accurate conclusions from the information received.[111]

FEATURE X08: MATERIALS OPTIMIZATION

OVERVIEW
Part 1: Select products with expanded chemical restrictions.
Part 2: Select products best positioned to support human and environmental health.

SCIENTIFIC BACKGROUND

- There is often scientific uncertainty about the causes and effects of specific chemicals and potentially related health or environmental outcomes. The relationship between exposure to chemicals and health effects is often complex and nuanced, determined by the specific exposure conditions, the characteristics and vulnerabilities of populations exposed, the properties of the chemical in question and more.
- A guiding tenet in addressing hazards of unknown consequence is the application of the precautionary principle, which states that a lack of full, scientific certainty on cause and effect relationships should not be a reason to delay taking precautionary actions in the threat of potential serious or irreversible harms.[112]
  - The precautionary principle was first widely popularized through the Rio Declaration of 1992 from the United Nations Conference on Environment and Development: "where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." The principle is also applicable to the protection of human populations and the environment.[112,113]

KEY HEALTH AND WELL-BEING EFFECTS

- Exposure to certain building materials may negatively impact human health. Insulation, paint and dust from materials applied across rooftops, walls, floors, pipes or other components in the built environment, all represent potential pathways through which humans can be exposed to potentially toxic substances, resulting in recorded health effects spanning impaired development in children and several types of cancer and lung disease.[114]
- For many compounds present in building materials, our knowledge of possible adverse health outcomes are derived from animal studies or through public health epidemiological data, and range from reproductive and developmental effects, endocrine disruption and increased risk of various cancers.[115-118]
- There is a history of regrettable substitutions for substances in the building industry. The replacement of polybrominated flame retardants with bis-(2-ethylhexyl) tetrabromophthalate (TBPH) has drawn some concern due to potential cardiovascular effects of its metabolite.[82] A more widespread example is bisphenol A (BPA), commonly used as a liner in cans, which has been replaced with structural analogs bisphenol S (BPS) and bisphenol F (BPF). Both substitutions appear to have similar endocrine disruption effects as the original component.[119]

HEALTH PROMOTION BENEFITS AND STRATEGIES

- One way to better protect humans and the environment from potential harms associated with hazardous ingredients in building materials is by promoting materials that are designed to minimize, if not eliminate, such components without compromising functionality.
- Overall, cleaner production practices can help to minimize the use of hazardous materials and reduce pollution, providing safer, alternative products in the market.[113]
- For manufacturers and their suppliers, a list of restricted chemicals, which includes at a minimum chemicals limited in applicable regulations, can be useful to help avoid adding such compounds.[103] However, chemical restrictions may not consider the effect of newly available, but regrettable, substitutions.
- Third-party-certified building products and materials have been independently assessed to verify that ingredients that pose known or suspected harms to human health or the environment under certain exposure conditions and durations have not been intentionally added to the end product.[120]
- Many building products or furnishings manufactured to meet chemical restrictions are listed by product verifiers, such as eco-labels or product certification programs. These verifiers usually have a database with products that meet their chemical avoidance criteria. In addition, many databases aggregate information from manufacturers to select for products that meet one or more certification criteria, usually filterable by certification or by adherence to building rating systems.
- Materials transparency databases, in which product composition is disclosed, can also help with selecting healthier materials.

- These databases usually disclose the presence of materials considered hazardous if present.

FEATURE X09: WASTE MANAGEMENT

OVERVIEW

Part 1: Implement a waste stream plan for the management of hazardous waste, including compliance with specific procedures for the management of batteries, pesticides, mercury-containing equipment and electronics.

SCIENTIFIC BACKGROUND

- In 2012, it is estimated that globally there were approximately 3 billion urban residents generating 1.2 kg [2.6 lb] of municipal solid waste (MSW) per person per day, resulting in total of 1.3 billion tons of waste per year.[121] In the European Union alone, the 28 Member States discarded a reported 2.5 billion tons of waste in 2012, 4% of which was classified as hazardous waste.[122]
    - Researchers estimate that the proportion of hazardous waste to total waste may be increasing in Europe.[122]
- Wastes may be classified as hazardous if they pose one of the following characteristics: ignitability, reactivity, toxicity and corrosivity.[123] While industrial operations are widely recognized as the main source of hazardous waste, discarded domestic products, such as electronics and pesticides, are also problematic as they may become hazardous at the time of disposal.[124]
- Electronic waste (e-waste) is an increasing problem worldwide and increasingly effects disadvantaged communities in developing countries where the threats of e-waste impact the communities near which or in which they're dumped and recycled.[125,126]

KEY HEALTH AND WELL-BEING EFFECTS

- Contaminants released by hazardous waste can play a role in the development of adverse health effects or disease. For example, the inhalation of mercury vapor released from mercury-containing equipment or lamps may have harmful effects on the kidneys, including kidney failure.[127] In children, the inhalation of mercury vapor is associated with negative effects on the central nervous system, such as tremor and coordination difficulties, as well as mercurial erethism, which includes symptoms like excitability, memory loss, insomnia and extreme shyness.[128]
- Poorly executed and illegal waste management practices are critical potential source of hazardous waste and may be the most important contributor of soil and groundwater contamination around the world, as a result of emissions during storage, treatment, transportation and final disposal.[129] For example, one study found contaminated maize near a poorly managed battery landfill.[130]
- Pesticides and herbicides are chemicals used to control, kill, or repel insects, rodents and fungi and can eventually transfer up the food chain into fish and seep into groundwater affecting drinking water supplies, while also reducing soil quality and biodiversity.[131]
    - In fish, bioconcentration describes the process of contaminant uptake through gills and epithelial tissues. Bioaccumulation involves the uptake through the food chain, and biomagnification occurs when bioaccumulation goes two levels up the food chain.[132]
    - DDT is organochlorinated pesticide and known carcinogen largely banned worldwide. However, it is still used as an indoor pesticide for malaria control in certain countries and can persist in the human body for up to 50 years.[133] Exposure routes include inhalation in air, intake of contaminated food (through biomagnification from fish) and dermal contact.[133]

HEALTH PROMOTION BENEFITS AND STRATEGIES

- Managing hazardous waste should follow attempts first at source reduction, then recycling, treatment and disposal.[134]
- International cooperation on hazardous waste prevention, management and disposal are lacking, despite the potential risks from hazardous waste posed to populations around the world.[135] In the absence of legislation or in the case of illegal practices, which can be common despite legislation, intentional action is needed on the part of responsible generators of waste to enforce safe waste management practices.
- A system for hazardous waste management includes consideration of how waste is stored once generated, treatment of the waste—which depends on the waste type and can span physical, chemical, and biological treatment methods and practices like recycling – and disposal, which can involve landfills or incineration.[136]

- The disposal of some of these wastes is regulated in certain countries. For instance, universal waste regulations in the United States define how to handle pesticides, mercury-containing equipment and batteries, whereas Europe's e-waste directive establishes a framework to handle these byproducts.[124,137]

FEATURE X10: PEST MANAGEMENT AND PESTICIDE USE

OVERVIEW

Part 1: Implement a policy for managing indoor and outdoor pests that minimizes the use of pesticides and ensures their safe application when needed.

SCIENTIFIC BACKGROUND

- Pesticides (organic or not) are chemical substances used to kill, repel or limit pests such as rodents, insects, fungi and weeds or other types of unwanted vegetation.[138,139] They are extensively used in agriculture but are applied in smaller-scale contexts as well, such as in offices and homes.
    - Insecticides, herbicides, fungicides, rodenticides, bactericides and larvicides all are different types of pesticides.
- Pesticides contain both active and inert ingredients. Both ingredients can be toxic to humans, each with unique health effects.[140]
- Pesticides are commonly detected in streams and groundwater.[141] Therefore, pesticide runoff may end up in watersheds that feed drinking water treatment facilities or accumulate in the bodies of edible marine organisms (bioconcentration and bioaccumulation).[132]
    - For instance, dioxin-containing herbicides widely used in the past have long lifetimes and high bioaccumulation factors in fish and mammals (including humans), increasing cancer risks in those that consume them.[142]
- When evaluating the health effects associated with pesticide exposure it is critical to consider both extreme exposure in high concentrations as with occupational exposure (i.e., exposure experienced by landscapers, farmers and pesticide factory workers), as well as chronic, low-level exposure. For most indoor applications, where pesticides may be used regularly and may impact the people who live or work in those spaces, chronic, low-level exposure is more likely.

KEY HEALTH AND WELL-BEING EFFECTS

- Maternal exposure to pesticides, particularly in the case of occupational exposure, is linked to several birth defects in infants.[143-145]
    - One study found that the link between prenatal pesticide exposure and birth defects appeared to persist even when considering pesticides used in crops up to 500 m [1,640 ft] away from the maternal residence.[146]
- The use of pesticides in homes is associated with a higher risk of childhood leukemia and lymphoma. Further, associations have been observed between exposure to pesticides in infancy and childhood brain tumors as well as other adverse neurodevelopmental outcomes.[147-149]
- Effects on cognitive functions from chronic adult exposure to pesticides are non-negligible, particularly among farm workers. Exposure to pesticides was found to affect motor speed, motor and visuospatial coordination and memory.[150]
    - A case-control study linked prolonged and frequent use of household pesticides with increased odds of Parkinson's Disease, with particularly strong associations with usage of organophosphorus compounds such as chlorpyrifos.[151]

HEALTH PROMOTION BENEFITS AND STRATEGIES

- Adopting an integrated pest management (IPM) strategy for indoor and outdoor environments can help to reduce human exposure to pesticides, protecting people from the harmful effects associated with exposure, while still effectively limiting the presence of pests in the environment.[152-156]
- IPM involves the adoption of physical/mechanical and cultural controls as a means to prevent attracting pests, treating pesticide use as a last resort.[157]
    - Physical/mechanical controls refer to traps, walls, sealants and other design strategies to physically deter pests from entering a space.
    - Cultural controls refer to practices to deny water or food to pests (such as garbage collection).
- If pesticide use is determined as needed (e.g., due to an emergency or as a last resort when other methods have been unsuccessful), it is recommended to select products that are considered less harmful to human health and properly contain their application be properly contained.[157,158]

FEATURE X11: CLEANING PRODUCTS AND PROTOCOLS

OVERVIEW

Part 1: Develop and implement a plan for cleaning and disinfecting surfaces within the space.
Part 2: Select cleaning and disinfection products that are safer for cleaning staff and building occupants.

SCIENTIFIC BACKGROUND

- Like personal hygiene is essential for human health, regular cleaning is necessary to sustain a healthier built environment.
- Surfaces may host pathogens present in feces and body fluids released by sick individuals, or through contact with another contaminated surface.[159] Contaminated surfaces are known as fomites.
- Sick Building Syndrome (SBS) is a collection of symptoms, such as headaches, nose and throat irritation, dry or itchy skin, nausea and fatigue, associated with time spent in a building that tend to disappear after leaving.[87,96,160] Complaints about SBS symptoms by office workers have been correlated with the amounts of dust and VOCs inside buildings, among other factors.[161]
- Cleaning products are a common source of VOCs emission in indoor environments.[162]
    - Improperly stored chemicals, particularly ammonia and bleach-containing products, may combine and produce toxic byproducts, including hydrazine and gaseous chloramine.[162]

KEY HEALTH AND WELL-BEING EFFECTS

- Microorganisms present in dust mites are related to asthma and allergy development.[163,164]
- Cleaning products available in the market vary widely and the compounds that make up these products are equally variable, some with known negative health effects on humans.[165] This variability makes the decision-making process on which product to purchase more complex.[165]
    - In a survey of professional cleaning products, the most common hazards involved fragrances, glycol ethers, surfactants and solvents.[165]
- Interactions between humans and microbes are complex as is the relationship between microbes and the products with which we clean on environments.[166]
- Household cleaning sprays have been associated with asthma and other respiratory diseases.[100,162,167] Research also has associated allergies and respiratory issues to specific cleaning products.[167]
- Poor selection and indiscriminate use of products with anti-bacterial qualities may produce an effect to the built environment similar to antibiotic resistance in humans.[168]
    - Genetic mutations triggered by the ubiquitous presence of antibiotics confer environmental bacteria with resistance against these compounds.[168]
- Slips and falls were found to be the second-leading cause of missed workdays among hospital and restaurant employees, often producing long-lasting health effects.[169,170] In a survey of restaurant workers, improper mixing of floor detergent concentrate and water resulted in increased odds of slipping, highlighting the importance of following cleaning protocols to reduce these hazards.[170]

HEALTH PROMOTION BENEFITS AND STRATEGIES

- Developing a cleaning plan is key to enhancing the effectiveness of the cleaning operations.
    - Identifying the surfaces that require cleaning and disinfection, establishing thresholds for disinfection and responsibilities of various stakeholders promotes effective cleaning practices and also helps prevent the overuse of resources.[171]
    - The plan should consider the impacts to people and spaces that may be affected by the cleaning operations, holistically. For instance, the plan should address impacts to occupants and cleaning personnel, management of collected waste (including soiled personal protection equipment) and potential environmental impacts.[171]
- In a survey of cleaning staff, the utilization of cleaning products with substantiated environmental performance claims reduced the odds of dermal, respiratory and musculoskeletal symptoms.[172] Balancing respiratory health goals with cleaning and disinfection effectiveness was shown to be feasible when selecting these products in a comparison study in senior housing.[173]

- Safety precautions and composition information of cleaning and disinfection chemicals should be made available to cleaning personnel and conveyed in training to reduce occupational health risks. This is particularly critical for products that require dilution.[171]
- Selection of cleaning products with low VOC is an important factor for maintaining good indoor air quality during the operational phase of a building.[174]
- Many cleaning and disinfection products are less toxic than traditional alternatives. Such claims are often third-party verified by ecolabels meeting ISO standards for ecolabeling.[175]

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