Introduction to advances in the toxicity of construction and building materials

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1.1 COVID-19, the toxicity of construction and building materials and the need for healthy built environments

The general population in North America and Europe already spent on average almost 90% of their time indoors [1,2]. To make things worse since COVID-19—that some believe is the pandemic that humanity deserves [3,4] although it can serve to drive innovations in several areas including in the built environment [5]—came along the confinement raised that percentage to as much as 100%. At least for people belonging to risk groups, people with certain underlying health conditions such as having one or more of the following health conditions: chronic respiratory or pulmonary problems, chronic heart problems, diabetes, kidney disease, or people who are less resistant to infection [6]. The threat of COVID-19 has increased the health risks of going to an office or factory and this will lead to an increase in the number of people working remotely from their homes [7]. Until social-distancing guidance due to COVID-19 ends, offices cannot work at full steam like they use to do [8]. Also not only using public transportation is a health risk but also many workers live very far from offices, too far to walk or cycle. No wonder then that according to Bartik et al. [9], more than one-third of firms that had employees switch to remote work believe that remote work will remain more common at their company even after a vaccine that stimulates the immune system to make antibodies to tackle the virus that causes COVID-19 (SARS-CoV-2) is found. One reason has to do with the fact that commuting was among the least enjoyable activities that people regularly did and the other reason is that home-working is actually more efficient than office-work [8]. The fact is that the time spent at home has increased but also that many people before COVID-19 used to spent 8−10 hours per day in the office and now they spend it at home. Recent studies show that a healthy environment is crucial to strength the immune system [10], which in turn is crucial to develop antibodies to tackle infections. No wonder then that traditional non healthy built environments and the potential toxic effects of building materials on health has gain a new importance in the context of the COVID-19 health crisis in in which

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more people spent more time indoors. Even because COVID-19 will continue to be a problem in coming years because according to The Serum Institute, the world largest vaccine manufacturer, there will not be enough doses to inoculate the entire world until 2024 or beyond [11]. It's worth remember that toxicity aspects have been a field outside the boundaries of the construction industry practitioners belonging to the realm of health professionals. That's why architects, civil engineers, and other professionals involved in the construction industry have so little knowledge about this area. Even despite the fact that many buildings suffer from many problems that can cause several health-related problems such as asthma, itchiness, burning eyes, skin irritations or rashes, nose and throat irritation, nausea, headaches, dizziness, fatigue, reproductive impairment, disruption of the endocrine system, cancer, impaired child development and birth defects, immune system suppression, and even cancer. Indoor pollutants may include volatile organic compounds (VOC) such as formaldehyde, benzene, toluene, xylene, styrene, acetaldehyde, naphthalene, limonene, and hexanes [12]. Some major sources of these pollutants are adhesives, sealants, paints, solvents, wood stain, wallboard, treated wood, urethane coatings, pressed-wood products, and floorings. They also include semivolatile organic compounds (SVOC), such flame retardant, and phthalates are also important toxic chemicals that can be found in the indoor environment [13]. Also concern in the context of the toxicity of building materials is the use of flammable building materials that can lead to catastrophic consequences that were seen in the Grenfell Tower tragedy, when a fire erupted on a block of flats in London on June 14, 1917 that had resulted in 72 casualties and 70 physically injured [14]. McKenna et al. [14] showed that the use of polyethylene-aluminum composites used in the Grenfell Tower showed 55 × greater peak heat release rates and 70 × greater total heat release, when compared to the least flammable panels on the market. A different problem is related to the fact that the use of flame retardant chemicals, like organ halogens, is associated with adverse health effects such as diminished immune function, endocrine disruption, and cancer [15]. Not to mention the fact that those chemicals will hinder the material recycling ability. Radon is another pollutant of indoor air. It is a colorless, odorless radioactive gas that comes from the ground in granitic-related areas but can also be sourced from granite floor materials or even from construction materials thus polluting indoor air. Radon was identified as a human lung carcinogen in 1986 by WHO. This gas constitutes the second cause of death after lung cancer [16]. To make things worse, the tendency of buildings constructed since the worldwide oil crisis in the 1970s to be sealed has exacerbated problems associated with pollutant concentration in indoor air. It Also helps to understand why the term "sick building syndrome" was coined in the early 1980s. Global health care and associated costs due to indoor air pollution for developed countries are likely to be just under US$90 trillion. Health costs associated with indoor air pollution may be as high as US$9.4 billion in the United States alone, leading to as many as 150,000 mortalities per year [17]. And recently, González-Martín et al. [18] mentioned that more than 5 million people die every year prematurely from illnesses attributable to poor indoor air quality. In 2018, Professor Bendell authored a dramatic piece warning that it is now too late to stop a future collapse of our societies because of the current climate emergency and that we must now explore ways in which to reduce harm (Bendell, 2018) [19]. He called for a “deep adaptation agenda” whose essence lies in “the four Rs”:

1. Resilience
2. Relinquishment
3. Restoration
4. Reconciliation

A healthy built environments contribute to the first R and it is therefore an important goal to be pursued. More recently, Gill [4] called for a deep restoration of the awareness of the necessity for maintaining ecological balance within the context of earth system dynamics. A deep restoration of the ethics of harmony with the web of life, including not only all species of creatures but also with the water, the oceans, the forests, and the soils of the earth, in which we are deeply embedded and mutually interdependent. Recently, Carmichael et al. [20] also referred to the need of considering health impact in future building regulations. Fig. 1.1 presents a summary of the healthy building concept and how it affects the physical, mental, and social well-being of occupants. Still Horve et al. [22] recalled the anecdotally fact that, when architects describe “healthy building” principles, they routinely speak of access to daylight and outside air, and this is supported by the prioritization of daylight in building performance rating systems. The United Nations’ Sustainable Development Goals (SDGs) offer an overarching framework for improving the

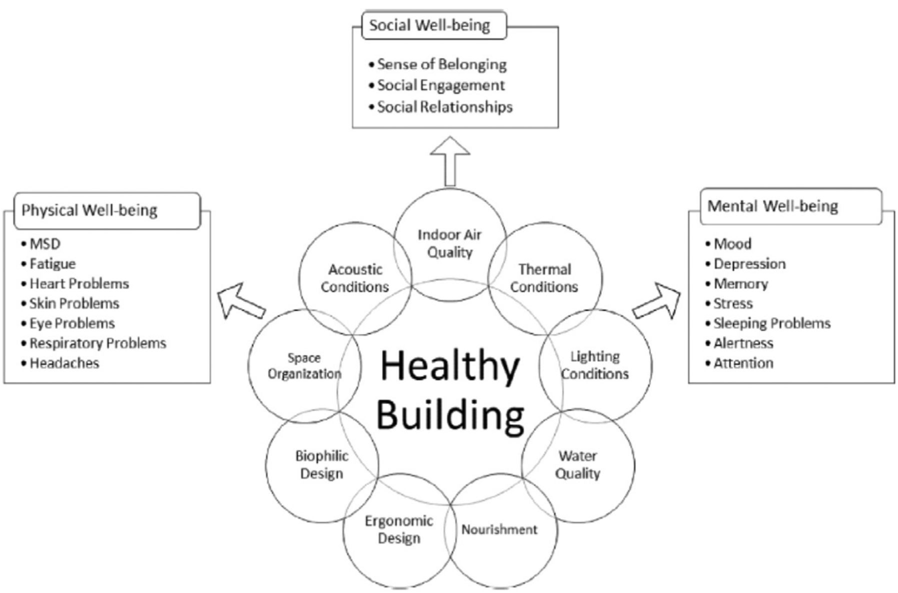

Figure 1.1 Healthy buildings concept [21].

environment and health in cities and the SDG indicator 11.1.1 explicitly refers to the need for adequate housing standards.

Worden et al. [23] recognized that green buildings were focused on environmental sustainability topics like energy use and water utilization, so health issues had not been given enough importance. Still theses authors claim that in what concerns the LEED v4 rating system many of health related credits require practitioners to possess some degree of public health expertise in order to recognize and implement the credits in a health-oriented manner. Be there as it may Knoll [24] recall that the Code of Ethics and Professional Conduct of the American Institute of Architects demands those professionals to "select and use building materials to minimize exposure to toxins and pollutants in the environment to promote environmental and human health...." A different issue however is the growing gap between expert knowledge on design of green and healthy buildings and lay knowledge of house builders and householders, as design and construction of housing become more sophisticated knowledge gaps widen between different groups. In terms of health impact, a more holistic approach to both policy and skills training could lead to more considerate building practices where there is greater knowledge of the links between building design and health. Also improved access to education materials on green and healthy buildings and how to use them could help [20]. And that goal is the purpose of this book

1.2 Outline of the book

This handbook provides an updated state of the art on the field of the toxicity of Construction and Building Materials

The first part encompasses indoor air contaminants (Chapters 2−4).

Chapter 2, Assessment of Hazardous Compounds in Building Materials Accumulated by the Action of the Atmospheric Pollution, concerns the assessment of hazardous compounds in building materials accumulated by the action of the atmospheric pollution using test methods like spectroscopic techniques for nondestructive analysis, quantitative analysis of the accumulated pollutants, ionic chromatography for the soluble salt analysis, heavy metal analysis, and the relevance of the sequential extraction methodologies.

Chapter 3, Toxicity of Semivolatile Organic Compounds, summarizes the characteristics of SVOCs in an indoor environment emitted from building materials and consumer products. Moreover, the health risks from multiroute and multimedia exposure to SVOCs are summarized alongside the combined health effects. Additionally, the approaches employed for the hazard assessment of chemical mixtures are briefly described.

Chapter 4, VOC Emissions in Building Materials, reviews volatile organic compounds (VOCs) in building materials. It includes VOC emission characteristic parameters of building materials and the control methods of building materials VOC emission (air purification, dilution ventilation, and source control)

Fire toxicity of building materials is the subject of Part II (Chapters 5–10).

Chapter 5, Toxicity of Toxic Gases Emitted during a Fire and Ventilation, covers the influence of ventilation conditions, on the toxicity of the environment during a fire. A review of the most important literature sources is included. Information on the toxic gaseous products emitted during a fire and their impact on human health and life is also included. Parameters related to the assessment of the degree of toxicity, such as FED (Fractional Effective Dose) or LC50 (compliant with the standard BS ISO 13344: 2004), are discussed. Theoretical foundations related to the influence of ventilation conditions on the toxicity of the fire environment are presented, and three selected experiments aimed at examining this relationship are discussed.

Chapter 6, Flame Retardant Wood Plastic Composites, reviews flame retardant wood plastic composites. It covers the combustion behavior and especially performance of the several the fire retardant chemicals.

Chapter 7, Fire Behavior of Sandwich Panels with Different Cores, (maciel) looks at the fire performance of sandwich panels with three different cores (mineral wool, polystyrene, polyisocyanurate foam). The decomposition temperatures of the cores used in sandwich panels, determination of the basic parameters determining the behavior of these materials in fire conditions, e.g., heat release rate, ignition time, smoke density are presented.

Chapter 8, Natural Radioactivity in Cement, analyzes the natural radioactivity of cement. In order to evaluate natural radioactivity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in cement samples and their radiological hazard indexes, worldwide cement sample data were gathered from literature then their radiological parameters such as radium equivalent activity (Ra_{eq}), the absorbed gamma dose rate in air (D_r), representative level index (RLI), the annual effective dose equivalent (AEDE), annual gonadal dose equivalent (AGDE), excess lifetime cancer risk (ELCR), gamma index (I_γ), alpha index, (I_α), external radiation hazard (H_{ex}), internal radiation hazard (H_{in}), and criterion formula (CF) were calculated. The activity concentrations and calculated radiological parameters of cement samples and raw materials were evaluated according to the comparison values given by European Commission Document (1999), UNSCEAR Report (2000), and recommended values for radiological parameters in literature

Chapter 9, Coal Bottom Ash Natural Radioactivity in Building Materials, is related to the use of coal bottom ash natural radioactivity in construction materials especially as sand replacement and as a cement replacement due to its pozzolanic properties.

Chapter 10, Recycling of Radioactive Phosphogypsum Wastes, focuses on the analysis of the environmentally friendly directions of phosphogypsum recycling. A cluster visualization of the uses of phosphogypsum with a focus on the binding of radioactive elements in it is considered. The main disadvantages of the existing methods of phosphogypsum recycling were identified and trends in this waste management were also considered.

Finally, part IV concerns the toxicity of metals, asbestos and of waste reuse (Chapters 11–14).

Chapter 11, Lead-Based Construction and Building Materials: Human Exposure, Risk, and Risk Control, analyzes human exposure, risk, and risk control of lead-based construction and building materials.

Chapter 12, Demolition Waste Contaminated with Asbestos, provides an overview of the knowledge in the field of hazardous waste, containing asbestos fibers, originating from demolition or renovation processes of older buildings. Attention is focused on an overview of the building materials in which asbestos could be used, asbestos minerals and asbestos-cement materials (ACMs) characterization, health effects and toxicity of asbestos fibers and methods for detecting of asbestos. Special attention is paid to a case study presenting the removal of asbestos-cement materials through a reconstruction process of the selected building, characterization of particular demolition waste with asbestos, and monitoring of airborne asbestos particles indoors during the reconstruction process.

Chapter 13, Recycling and Reuse of Bottom Ashes from Municipal Solid Waste Incineration (MSWI) Plants in Building Materials, is concerned with the recycling of bottom ash from a municipal solid waste. The characteristics and toxicity of the bottom ashes are discussed, as well as the possible recovery of metals.

Chapter 14, Leaching of Concrete with Mine Tailings, closes Part III with a review on the leaching of mine tailings. The chapter summarizes key physical and chemical properties of some of the most widely investigated mine tailings, such as Copper Mine Tailings, Gold Mine Tailings, Iron Mine Tailings, Phosphate Mine Tailings, and Tungsten Mine Tailings.

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