

# Introducing “embedded toxicity” – a necessary metric for the sound management of building materials

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Global building and infrastructure stocks have increased 23-fold between 1900 and 2010, and are expected to grow further in the next decades—as will their already large environmental footprints.<sup>1</sup> The mining and manufacturing of building materials, for example, leads to significant greenhouse gas emissions, biodiversity loss, and diminished water quality and quantity. Recognizing these considerable impacts, action has been taken to address some aspects of the environmental footprints of building materials. For example, the concept of “embedded carbon” (also known as “embodied carbon”), or the upfront greenhouse gas emissions associate with producing building materials, has garnered attention as policymakers formulate plans for large-scale building renovations and retrofits to address the climate emergency.<sup>2</sup> Yet, building materials also mobilize numerous other chemicals with associated adverse human and/or environmental health impacts. Despite its centrality to the Sustainable Development Goals, the embedded toxicity of chemicals in building materials has not received the same attention as that of the embedded energy, water, and greenhouse gas emissions. We draw attention to the concept of “embedded toxicity” to aid in the sound management of building materials, as a needed addition to “embedded carbon.”

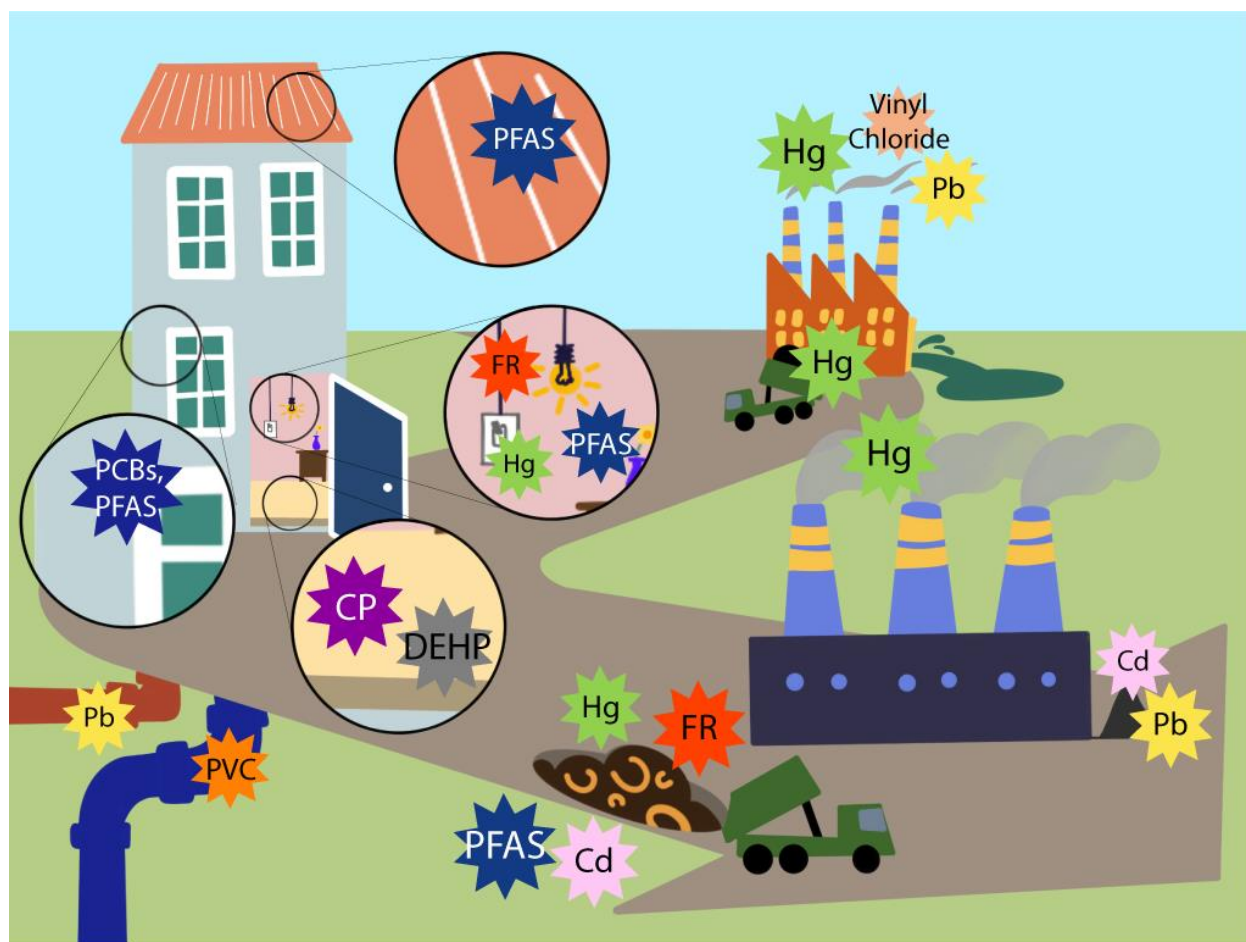
### **Why the concept of embedded toxicity matters**

The concept of embedded toxicity can be understood from the perspective of material flows and life cycle analyses, which seek to trace the path followed by resources from production to end-of-life. In the past, the embedded toxicity of building materials has often be interpreted literally, to mean the chemicals physically present in building materials during use.<sup>3</sup> Here we recommend a wider scope for the concept of embedded toxicity, to also capture all the related chemicals present in upstream and downstream life-cycle stages starting from the extraction process up to the point of end-of-life treatment, but not including the use stage. The rationale for this extension is in line with the concept of “embedded carbon,” given that many chemicals may pose risks throughout their life cycle.<sup>4,5</sup>

We recommend that embedded toxicity be used as a means to understanding how to “detoxify” our long-overlooked building infrastructure (note that we constrain the concept to building materials, but not the contents of buildings such as home furnishings and personal care products, which have relatively short lifespans and are already under more regulatory scrutiny). This detoxification can happen immediately, as building codes are updated and large-scale retrofitting projects commence, and in the long-term, as we develop plans to reduce the embedded toxicity of building stocks during construction.

A prime example of how policy has overlooked embedded toxicity comes from the Montreal Protocol, which phased out the production and use of ozone-depleting substances. Despite its success in limiting damage to the ozone layer and putting it on the slow path to regeneration, the Protocol does not provide for environmentally sound management of existing stocks of ozone-depleting substances in building materials. This represents a blind spot for the Protocol. According to Obernosterer and Brunner (1997), one-third of all chlorofluorocarbons ever used in Austria are stored in various building materials, with half in insulation, and the other half in cooling systems and miscellaneous applications.<sup>4</sup> On a global scale, this represents a significant stock of still-unreleased ozone-depleting substances (significantly larger than that in household refrigerators) for which there is no plan in place to prevent further release to the environment—and which therefore represents a threat to the health of the ozone layer.<sup>4</sup>

Many other problematic chemicals are similarly prominent in building stocks (see Figure 1). For example, polychlorinated biphenyls (PCBs) have left a legacy from use in caulking, adhesives, and electronic equipment,<sup>6</sup> while asbestos is infamously used for insulation and fireproofing.<sup>6</sup> Per- and polyfluoroalkyl substances (PFAS) are used extensively in building materials ranging from concrete flooring and sealants to indoor, low-VOC (volatile organic compounds) paints.<sup>7</sup> Other chemicals found in building materials include lead to solder water pipes and in paint, mercury in electrical switches, isocyanates used in building materials, polybrominated diphenyl ethers (PBDEs) and other halogenated flame retardants used extensively in insulation, phthalates and chlorinated paraffins (CPs) in flooring made from polyvinyl chloride (PVC), and a variety of VOCs.<sup>6</sup> Many of these chemicals are well-known for widely posing significant human and environmental health risks from indoor exposures,<sup>6,7</sup> whereas for others, concerning scientific evidence is emerging.



**Figure 1.** Examples of (potentially) hazardous chemicals and materials that may be present in the life cycle of building materials. Cd = cadmium; CP = chlorinated paraffins; DEHP = di(2-ethylhexyl) phthalate; FR = flame retardants; Hg = mercury; Pb = lead; PCBs = polychlorinated biphenols; PFAS = per- and polyfluoroalkyl substances; PVC = polyvinyl chloride.

While some of these are legacy chemicals (depending on the jurisdiction), the long lifespan of buildings has ensured that they persist in buildings that are in use today, even decades after the hazardous effects of these chemicals were discovered, or their use and production restricted.<sup>8</sup> This reflects a major motivation and urgency for addressing embedded toxicity: due to the long lifespan of building materials, the high costs of renovation (both fiscally and in terms of convenience), and the lack of a tracking system for chemicals in building materials in most jurisdictions, it is almost prohibitively expensive and practically impossible to identify and then remove chemicals from buildings after they are found to be problematic. A case in point here is the continued risk posed by exposure to PCBs used in some schools in the United States (US).<sup>9</sup> These aforementioned shortcomings also make it inherently challenging to manage waste building materials in a sound manner and to minimize environmental and human exposure to problematic chemicals (particularly occupational exposure for those in the building and demolition trades), while also complicating the transition to a safe circular economy.

### **Recommended measures for ways forward**

Several initiatives address specific aspects related to the embedded toxicity of building materials in specific regions. These include the Proposition 65 List in California and the Health Product Declaration (HPD) open standard for more transparent reporting of (hazardous) chemical content in materials and products,<sup>10</sup> and building codes in specific regions for addressing some well-known hazardous chemicals such as lead and asbestos in building materials.<sup>11</sup> While these are important initiatives, we need more. As large-scale renovation plans are put into place (e.g., the Renovation Wave of the European Green Deal) and a construction boom is occurring in many countries in Africa and Asia, it is critical to more systematically and efficiently integrate the concept of embedded toxicity into the current management frameworks of building materials around the world as follows.

**New building materials.** The most efficient approach to minimizing environmental and human exposure to problematic chemicals is to prevent their use in the first place—anytime after becomes a financial and logistical nightmare (although even that is better than allowing for building wastes disposal without management). Not all problematic substances can be immediately identified, as knowledge about chemical pollution is still evolving. Thus, proper disclosure of the chemicals in new building materials is needed so that stakeholders (e.g., architects, contractors, owners, and tenants) are informed of the known embedded toxicity of their choices and can take steps to minimize use of building materials with known problematic chemicals. Such transparency also enables future activities to reduce the embedded toxicity when new evidence regarding chemical safety emerges, as well as safe end-of-life handling. Up-front disclosure can be achieved through regulatory and non-regulatory initiatives (e.g., the Sustainable Products Initiative in Europe, the Healthy Building Alliance in the US). Governments can lead the way by, for example, setting stricter procurement guidelines on embedded toxicity for publicly funded building projects. Concerted action can be taken to establish knowledge bases that compile known upstream and downstream impacts of individual chemicals to enable better oversight of the embedded toxicity beyond the use stage.

**In-use building materials.** Proactive measures such as monitoring can reveal the order of magnitude of embedded toxicity and identify especially problematic sites for remediation and “detoxification.” However,

monitoring should take a targeted approach—connecting chemical analysis of building material archetypes with building stocks characterization (e.g., through both traditional material flow analysis and emerging sensing and imagery analysis) to identify the scale of the problem efficiently and effectively.

**End-of-use building materials.** At end-of-life, pre-demolition audits, a quality control mechanism before the building is torn down, are advisable. These should test for chemicals of particular concern, such as PCBs and asbestos, to inform the demolition team and subsequent waste managers (including recyclers) where special precautions should be taken.

**Action is needed now.** We now have a critical “window of opportunity” for communities experiencing construction or renovation booms world-wide to efficiently and effectively implement the concept of embedded toxicity in order to prevent and minimize future harm to human and ecosystem health from toxic building materials. We call for urgent policy and scientific attention to incorporate the embedded toxicity discussion into the building industry, starting with learning from the momentum behind discussions of embedded carbon.

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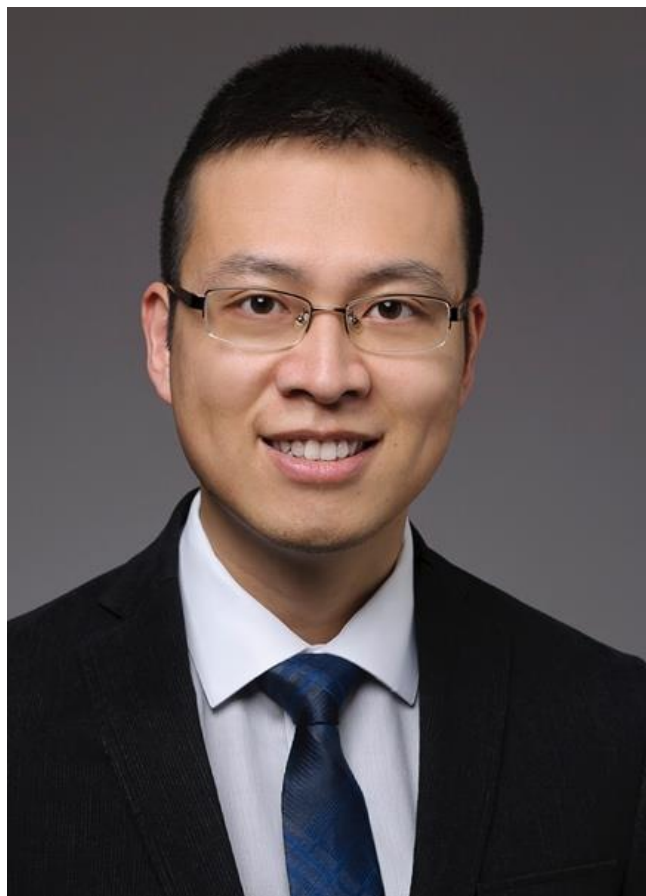


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