Everything Will Become Soil

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Pollution is not an objective condition but a social and legal fiction, one that emerges from negotiated thresholds of biological tolerance and modes of inhabitation. Elements that naturally occur in the earth's crust become pollutants once they exceed socially and legally defined thresholds of acceptability. Yet in most cases, pollution is not a geological anomaly but an anthropogenic condition, produced through extractive practices, industrial processes, and destructive events triggered by human action. Pollution names the moment when matter exceeds the limits of what society is willing – or able – to manage.

In Ukraine, these limits have been violently breached. Russia's ongoing war of aggression has not only annihilated cities, infrastructures, and lives, but has also accelerated environmental degradation on a continental scale: scorched forests, disrupted aquatic systems[1], and unprecedented soil disturbances[2]. Reconstruction thus unfolds on contaminated ground. That is why we argue for regenerative construction practices that operate within the most damaged territories accepting their polluted resources. Rather than treating contamination as a condition to be externalized, removed, or deferred to landfills, the project asks how architecture might confront pollution directly: absorbing, containing, and transforming it as a material and political reality of post-war rebuilding.

The current shift towards regenerative materials is driven not only by their reduced embodied carbon[3,4], but also by its positive impact on human health and their capacity to reduce pollution across all stages of the building life cycle[5,6]. Thus, current regenerative building strategies typically rely on *"clean"* feedstocks, with more and more toxins being expelled from contemporary construction practice. Meanwhile potential resources classified as polluted are commonly landfilled, while excavated soils with traces of contaminants are treated in energy-intensive washing, thermal treatment or other processes that still result in waste residue destined for disposal.

CONTAMINANTS ON THE GROUND AND ON PAPER

In November 2024, we collected soil samples in the Ukrainian region of Kharkiv to analyse war-related pollution. Our aim was to determine whether this contaminated soil could be treated to produce safe local material for reconstruction efforts. Selected in collaboration with geologists, the sites met two key criteria: they had been previously studied, providing a baseline for comparison, and they had experienced direct military activity while remaining distant enough from urban areas to isolate potential sources of contamination [fig.1,2]. Soil samples taken from various strata were tested for heavy metals, polycyclic aromatic hydrocarbons (PAHs), and per- and polyfluoroalkyl substances (PFAS). The results indicate elevated concentrations of heavy metals, particularly cadmium and arsenic, prompting a sharpened focus on the challenge of heavy metal contamination.

Figure 1. Agricultural land in Fedorivka, Kharkiv Oblast. Used as a launch site of the multiple rocket launcher “Grad”.

Figure 2. Abandoned farmland in Mala Rohan, Kharkiv Oblast. Site of the military helicopter crash.

These findings also initiated a central question: What thresholds should govern contamination assessments? Our research evolved into an inquiry about the very nature of pollution: how it is defined, regulated, and treated by society. We have studied and compared limit values for heavy metals set by the standards of different European countries and international organisations [fig. 3]. For example, in Ukraine, documents regulating contamination for building materials refer to the general value of the maximum permissible concentrations in soil. In Germany, there are different regulations that determine the concentrations of heavy metals for different classes of landfills, the reuse of mineral waste in construction, as well as new standards for sustainable materials (such as natureplus). In the Netherlands, target values in soil are used to define a generally accepted norm, and intervention limits determine the need for soil remediation. In some countries, such as Estonia, in addition to general targets, there are also reference values for residential and industrial areas.

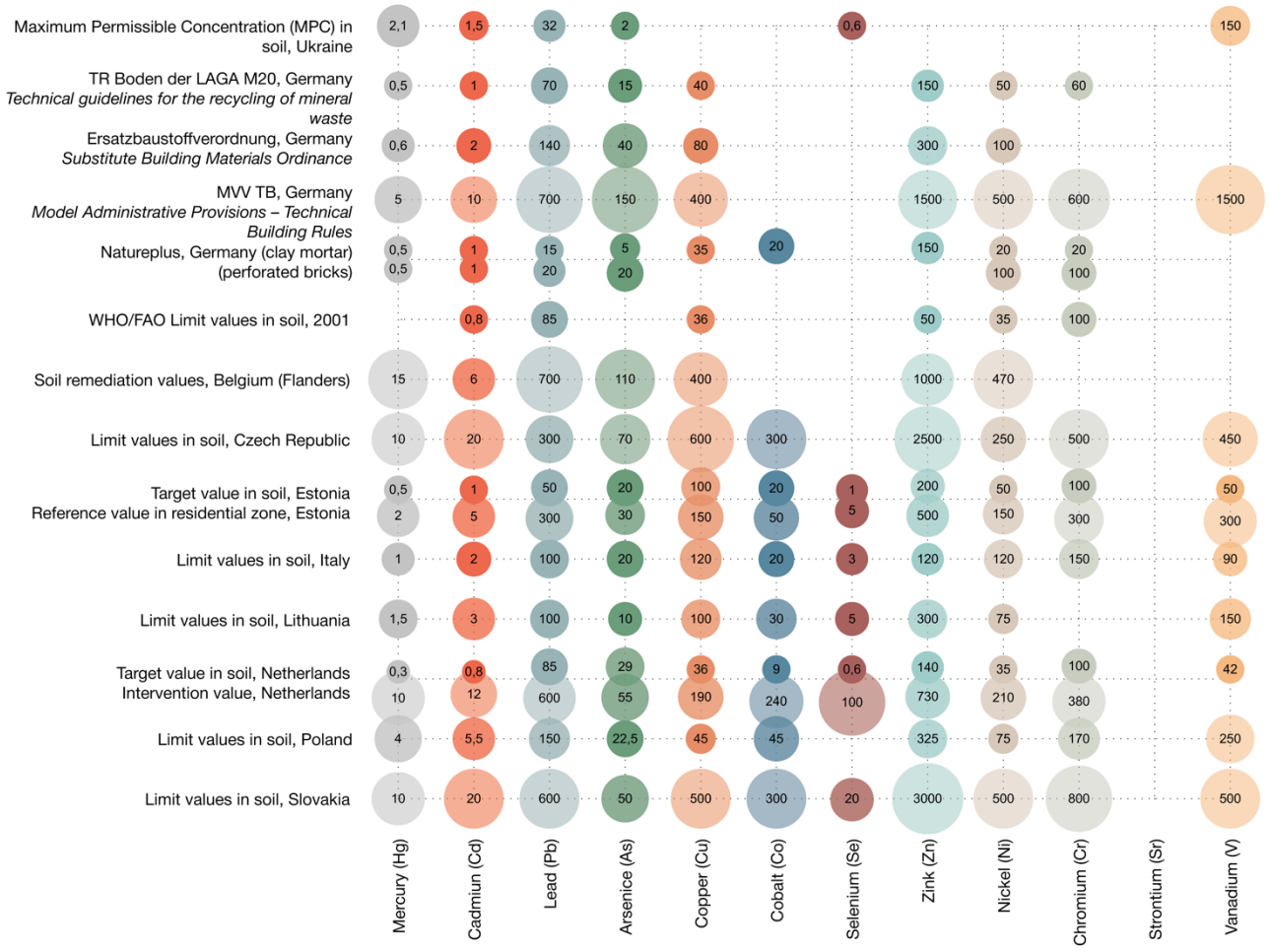

Figure 3. Diagram comparing limit values of heavy metals in soil in different European countries.

To interpret the principles underlying this spectrum of regulations, we turned to the anthropocentric perspective that has historically structured modern environmental standards. We sought to understand how specific elements affect human biology, and how exposure is distributed in space.

Heavy Metals in Our Bodies

Heavy metals enter the human body through inhalation of toxic dust, ingestion of contaminated food and water. Building materials can be substantial contributors to this exposure. While many construction materials appear stable, they can release heavy metals over time as dust, fumes, or leachates, contaminating indoor air, water supplies, and surrounding soils. These pollutants infiltrate air, food, and water supplies, increasing the risk of exposure. Cadmium, lead, and mercury, commonly found in building materials, have been linked to cancer. Additionally, certain metals,

including antimony (Sb), arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), tin (Sn), and vanadium (V), are classified as metal–oestrogens due to their ability to mimic oestrogen activation, potentially increasing the risk of hormone-related cancers, such as breast cancer[7].

Cadmium, for instance, is absorbed from contaminated soil by grass and fodder crops, accumulating in the liver and kidneys of animals before reaching humans through meat and dairy consumption[8]. Lead exposure occurs via soil, water, industrial emissions, equipment, pipelines, lead-based pesticides, packaging materials, and household items. Arsenic, another highly toxic element, can enter the human body through contaminated food and drinking water. Its sources include industrial emissions, copper smelters, lignite-fired power plants, arsenic-containing pesticides, and feed additives[9].

Tracing the metabolism of heavy metals across ecosystems inevitably brings us back to soil as both the primary entry point and ultimate sink of pollutants moving into food and water systems. It is therefore unsurprising that most regulatory frameworks ultimately anchor their limit values in soil, even those governing construction materials. And so it raises a question: how does architecture become soil? The most immediate, and least desirable, answer is the landfill.

THE LANDFILL

The post-World War II era led to a significant escalation in waste management challenges due to two primary factors: the rise of consumerism and the advent of the chemical age. Together, these developments dramatically increased waste volumes, altered waste composition, and introduced new toxicity concerns, necessitating stricter regulations on landfilling. However, it was not until 1978 before the USEPA first published a list of 24 deleterious substances which comprised several HMs such as Pb, Hg, Cd, As, and so on[10].

As of 2021, in Europe, 24% of waste was recycled as secondary raw materials, while 18% was processed into compost. In contrast, Ukraine faces a critical waste management issue, with over 90% of waste being landfilled[11]. Since solid waste is disposed of in both regulated and unregulated landfills – either dumped on the soil surface or buried – national standard on the *Maximum Permissible Con-*

centration in Soil is used to assess toxic substances in building materials before disposal[12]. Currently, Ukraine has approximately 300 hazardous waste storage facilities, many of which were constructed without adequate technical safeguards, posing significant regional environmental risks[13].

A substantial portion of landfilled solid waste originates from the construction and demolition (C&D) sector, which accounts for 30% of total global waste production. On average, over 35% of C&D waste is disposed of in landfills annually[14]. In Germany, C&D waste that meets the criteria for inert waste under the *Waste Framework Directive* (2001) and the *Landfill Directive* (1999) can be deposited in specialised inert waste landfills. However, the first regulation on landfills in the country was only introduced in 1972. As a result, older landfills – such as those used for building rubble disposal in the post-WWII period – lack adequate environmental protection measures. Studies indicate that building rubble-based substrates exhibit significantly elevated concentrations of heavy metals and organic pollutants compared to natural soil[15], highlighting the long-term environmental consequences of inadequate waste management in earlier decades.

DISSOLVING BUILDINGS

While landfill offers the fastest route for architecture to become soil, a slower and less visible transformation occurs through the gradual degradation of materials themselves. Contaminants, such as heavy metals, contained in building materials may leach out over time, potentially degrading soil and groundwater quality, especially when these materials are applied directly to soils. Rainwater infiltration and percolation through building materials can facilitate the release of pollutants, which subsequently migrate into the underlying soil. The composition of the leachate, as well as the rate and total amount of contaminant release, varies depending on the material's composition. For instance, for many years, arsenic was a key component of chromated copper arsenate (CCA), a wood preservative that combines chromium, copper, and arsenic in various proportions. However, concerns about CCA-treated wood have grown, particularly due to the risk of arsenic inhalation when burned and the gradual leaching of chemicals into surrounding soil, water, and food sources[16]. Similarly, biocides often containing mercury, arsenic or copper are still added to façade paints to prevent algae growth[17].

Once contaminants enter the soil, their downward transport may be slowed due to adsorption onto soil constituents. The extent of this retardation depends on soil properties such as pH, organic matter content, and clay composition. Many of these factors vary spatially and temporally. For instance, alkaline soil conditions promote pollutant sorption, reducing the risk of leaching into groundwater.

Most of the conventional regulations were initially developed around linear material flows, linking limit values to disposal safety, and were later extended towards recycling practices. In the EU it is exemplified by the documents such as Germany's *Substitute Building Materials Ordinance (Ersatzbaustoffverordnung)*, or the Dutch *Soil Quality Decree conceptualized around the possibility of toxins leaching from building materials into the soil*[18]. That is why these frameworks primarily assess risk in relation to environmental exposure, not to continuous human contact inside or around buildings.

THERE IS NO "AWAY"

A shift toward alternative thinking about polluted matter is beginning to take shape. Instead of displacing contamination beyond the limits of the built environment, new approaches accept responsibility for its presence and consequences. *The UPMIN100* project in Germany explores the use of secondary aggregates from demolition waste (sometimes exceeding legal pollution thresholds) by blending them with cleaner materials from secondary aggregates[19]. Building upon this, our project *Grunt* demonstrated that polluted loam could be safely diluted with washed sand, though such methods face regulatory limitations such as the "mixing ban"[20]. Another German project initiated by the Federal Institute for Materials Research and Testing (BAM) showed that historic earthen structures (built of presumably polluted soil or accumulating pollution over time) can adsorb and immobilize heavy metals within their matrix, with minimal leaching beyond the surface layer of 0–3 cm[21]. These findings informed our encapsulation strategy: to immobilize heavy metals within contaminated earthen materials by enclosing them with protective layers composed of uncontaminated materials [fig. 4].

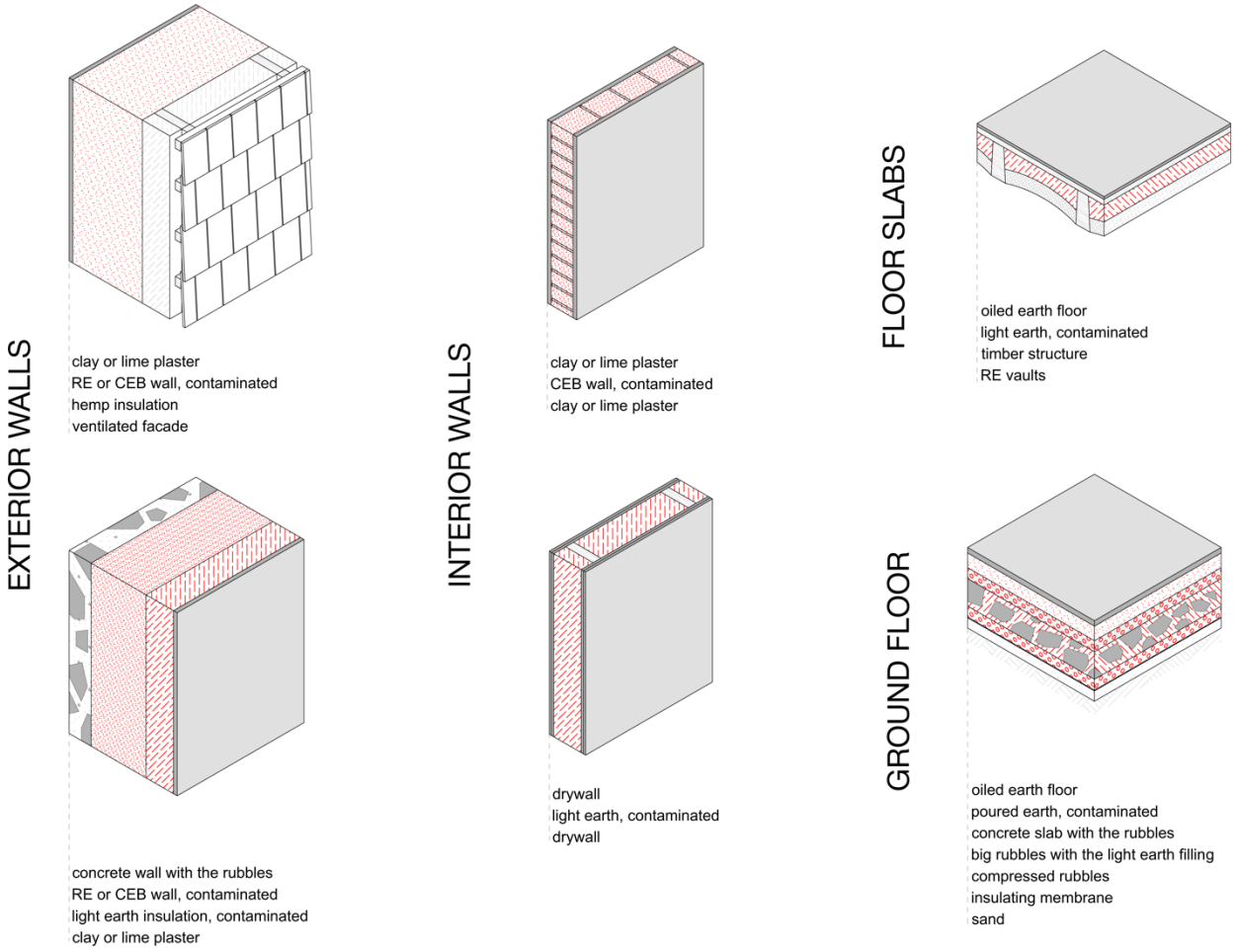

Figure 4. Encapsulation strategy, construction details.

The modernist pursuit of hygienic sterility, achieved through the systematic externalization of material hazards, has produced a carefully constructed illusion: the belief that human living spaces can be separated from their surroundings. In reality, by displacing the most harmful substances away from our settlements, we relocate them precisely where they pose the greatest threat to the soils that sustain us and the water we drink. The pathways of pollution make one thing unmistakably clear: there is no "outside," neither to architecture nor to our bodies. Contamination expelled from human habitats inevitably returns through food chains, water systems, and atmospheric cycles. In this context, the counterintuitive and unsettling proposition of retaining and encapsulating pollution within the built environment may represent not a solution, but the least violent option available. In a polluted world, taking responsibility for contamination may be the only architectural stance that remains intellectually honest and ethically defensible toward our shared planetary home.

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BIOs:

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