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# Influence of heavy metal contamination on urban natural enemies and biological control

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Urban agriculture is increasing worldwide. A history of contamination within urban landscapes may negatively impact the biota necessary for sustainable crop production, including arthropod natural enemies. This investigation revealed that heavy metal contamination can influence the composition of natural enemy communities and exposure can have reproductive, developmental, immunological and behavioral impacts on predators and parasitoids. Natural enemies exposed to heavy metals typically live shorter lives, take longer to develop and exhibit a reduced reproductive potential. Further, they may incur significant energy costs though the production of detoxification enzymes. This is a new and relatively unexplored area for biological control research, with important implications for our understanding of urban agricultural food web interactions.

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## Introduction

Agriculture has long been part of the urban landscape, from home gardens to small scale farms [1••] but in recent decades, interest in producing food in cities has grown dramatically [2••]. It is estimated that more than 30% of the global urban population is engaged in some form of urban agriculture (UA) [3]. Furthermore, households with limited access to fresh produce are more likely to engage in UA [4], resulting in greater acquisition of fruits, vegetables, eggs, and other agricultural products within low income communities. Urban greenspaces, including community gardens and farms, have also been demonstrated to reduce human health risks via provision of additional biophysical ecosystem services [5] including filtration of pollutants from the air, reduction of the heat island effect, supplying space for physical activity, and improved neighborhood aesthetics [1••,2••].

UA often occupies vacant land that formerly supported industrial, commercial, or residential land use (Figure 1). These habitats frequently have a history of contamination [6••] by heavy metal (HM) pollutants, with soils serving as the major sink [6••,7•]. HM's include both nonessential elements (arsenic, cadmium, chromium, lead, mercury, and nickel) and elements essential to life that become toxic at higher concentrations (cobalt, copper, manganese, selenium, and zinc) [8•]. There are a multitude of routes to contamination that have facilitated HM pollution including vehicle exhaust, coal combustion, interior and exterior paint, smelting and waste disposal [6••]. HM thresholds for UA sites has focused on lead (Pb) caused by its ubiquity as an urban soil contaminant, correlation with the presence of other HM contaminants, and the documented exposure risks to human health [2••]. Worldwide Pb thresholds vary widely from 85–500 ppm [2••], with differences found between countries, and in some instances even among regions of a country. These thresholds are aimed at limiting human exposure to Pb via the consumption of contaminated produce or accidental soil ingestion or inhalation.

Research and regulations to ensure UA produces food safe for human consumption is paramount, but these contaminants also have important environmental impacts which are less clearly understood or regulated. Key among these is how HM contamination influences the beneficial arthropod fauna that support the ecosystem services necessary for sustainable UA. HMs can impact UA by influencing both top-down and bottom-up processes [9••]. In this article, we examine the impacts of HM contamination on crop plant – pest – natural enemy food webs. In particular, we focus on how HM contamination influences the composition and fitness of natural enemies foraging in contaminated landscapes and identify the potential impacts of HM exposure on biological control within UA.

## Heavy metals, crop plants, and herbivores

Production of crops in HM contaminated soils can result in decreased seed germination, reduced growth and development, abnormalities in morphology, altered enzyme activity, disruptions in metabolic pathways, reduced ability to uptake essential nutrients and water, chlorosis, early senescence and phytotoxicity [10•]. Given

**Figure 1**

**(a)** Urban agricultural production is growing worldwide, particularly in cities where protracted economic decline and home foreclosure have resulted in a significant amount of vacant land [22•]. (a) When foreclosed or abandoned homes hold little to no property value they are eventually torn down by municipalities. **(b)** Demolition involves removal of debris from the site, but this process could be a source of additional HM soil contamination from materials such as lead-based paints. **(c)** Following demolition, a vacant lot plant community establishes that may contain seeded grasses and/or grasses and forbs from the existing seed bank. Vacant lots are maintained as early-successional habitats with periodic mowing. **(d)** Communities are reimagining a portion of available vacant land as a resource for agricultural production.

the potential human and plant health consequences, urban growers employ several strategies to limit HM uptake by crop plants. These actions can be extensive, including upper level soil removal or 'capping' wherein a barrier is applied to a site and soil for plant production is added above it, although the latter approach is typically cost prohibitive [2••]. More typical recommendations involve the use of raised beds, frequently with HM free potting medium and compost added [11], or amending existing soil to reduce the bioavailability of HMs. Soil properties including pH, cation exchange capacity, oxides and organic matter can affect plant uptake of HMs [6••]. For example, soils with high organic matter content and neutral or alkaline pH generally have a lowered bioavailability of HM to flora and fauna [6••]. Thus, the application of phosphorus-based fertilizers or organic amendments such as biosolids or compost are recommended to reduce the likelihood for uptake of Pb [2••]. Management practices such as soil tillage to mix surface and subsoil can reduce bioavailable HM [6••,12] as can the presence of earthworms and mycorrhizal fungi [13]. Establishing turf or mulching areas between UA plantings can also limit recontamination of managed areas with HM dust from unmanaged areas of an urban farm.

The exposure of herbivores to HM contaminated host plants can alter weight gain, growth, survival, fecundity and eclosion success [9••]. Interestingly, the strength and direction of these relationships are influenced by the concentration of HM contamination. In some cases, predictable negative impacts of HM exposure on herbivore population growth have been documented. For example, the net reproductive rate of the English grain aphid, *Sitobion avenae* (Hemiptera: Aphididae), and the number of offspring per female decreased with increasing cadmium (Cd) concentration [14]. However, at low