Technical Briefing: March 9, 2016

A review of exposure risks through direct garden soil ingestion or through consumption of plants grown in gardens with soil metal contamination

Background

The Oregon Health Authority (OHA) has received several requests from private citizens, daycares, schools, and neighborhood gardeners about the risks for gardening and consuming garden grown foods in areas nearby two artisan colored glass manufacturing facilities in Southeast Portland (Bullseye Glass) and North Portland (Uruboros Glass). The U.S. Forest Service released validated data for cadmium concentrations in moss sampling that they conducted throughout the city of Portland. Cadmium was the highest nearby the two glass facility sites in Portland. Cadmium results in the moss data prompted air monitoring by the Department of Environmental Quality (DEQ).

While the investigation of air and soil nearby glass facilities in Portland prompted a literature review, this paper was written to establish a scientific basis for response to gardening risks in urban environments in general.

Introduction

Gardens provide many benefits, including healthier lifestyles through increased physical activity, fresh produce, spaces to celebrate culture and community pride, and by nurturing social interactions and cooperation among people (EPA, Brownfields and Urban Agriculture: Interim Guidelines for Safe Gardening Practices 2011).

This document includes findings from review of the most recent and relevant scientific literature, as well as the input of leading experts from academia, and national geological, environmental and public health agencies (see Contributions section). Review was focused on studies, and agency guidance for protecting health when gardening in areas with known or suspected environmental contamination, with a specific focus on arsenic, cadmium, chromium, and lead.

Differences between "urban" soil and "garden" soil

Soil type and texture, moisture retention, pH, compaction, aeration, and many other factors influence the behavior of contaminants found in urban and garden soils (Pearson, 2013). All soils contain naturally occurring, background levels of metals, minerals and microorganisms. Contaminated soils contain concentrations of contaminants that exceed the natural background level for local soils (Peryea, 1999).

Urban soils are commonly contaminated with metals, petroleum by-products, pesticides, and other chemicals resulting from past or present land use and proximity to pollution sources (Alloway, 2004). The construction of urban infrastructure (e.g. homes, roads, and sidewalks) changes soil characteristics often resulting in compaction, poor drainage, and overall lower soil quality in urban areas (Bell, et al. 2003).

Due to the poor quality of most urban residential soils, urban gardeners are advised to improve soil quality in the areas where gardens are established (Bell, et al. 2003); (OSU-Extension, Improving garden soil 2016). Gardeners growing food in pots, raised beds and directly in the ground incorporate amendments to increase soil quality and nutrients available to plants. Common amendments include manure, peat moss, compost and fertilizer (OSU-Extension, Improving garden soil 2016). The addition of amendments changes the chemical properties and characteristics of soil (Brown and Cotton, 2011). Garden soil is a mixture of soil and amendments that are brought into the garden from outside sources, this makes garden soil very different from urban soil found in city parks, residential lawns, parking strips, private businesses, and other public spaces.

Key Terms

Bioaccessibility: "the amount of a soil contaminant that could potentially dissolve and would be available for absorption in the human digestive system" (Attanayake, Hettiarachchi and Martin, et al. 2015).

Bioconcentration: "A process leading to a higher concentration of a substance in an organism than in the environmental media to which it is exposed" (Chemistry 1993).

Field and laboratory studies found that garden soils amended with compost create healthier plants, make it harder for contaminants to get into plants, and lower bioconcentration and bioaccessibility of contaminants (Attanayake et al,. 2015); (Defoe, et al. 2014).

Key Terms

Exposure Pathways: the ways that contaminants can potentially harm people.

Direct: The three main exposure routes are ingestion, inhalation, dermal. For metals in soil the main direct exposure route is through ingestion of soil. Particle size is too large to be of concern for inhalation and metals are not dermally absorbed.

Indirect: consumption of plants with contaminated soil adhered to the surface.

Food-chain transfer: the movement of contaminants from soil to food crops and the subsequent transfer of contaminants into humans through food consumption.

Exposure risk - soil ingestion *(direct)*

Many scientific studies assess the risk for exposures to common urban contaminants directly through soil ingestion, as well as through consumption of food crops grown in such soils (Brown et al., 2016); (Attanayake et al., 2015); (Defoe et al., 2014). In a study of home gardens neighboring a superfund site researchers found concentrations of arsenic in soils that were 10 to 100 times greater than concentrations in the vegetables grown in contaminated soil (Ramirez-Andreotta, 2012).

In most urban gardening settings, the primary exposure risk is through ingestion of contaminated soil particles (EPA, Brownfields and Urban Agriculture: Interim Guidelines for Safe Gardening Practices 2011). For children this risk is a concern during gardening due to potential direct exposure to contaminated soils. Since it's uncommon for adults to ingest soil during gardening practices, the concern for exposure is primarily through consumption of soil particles that adhere to garden grown crops (Brown et al, 2016); (EPA, Brownfields and Urban Agriculture: Interim Guidelines for Safe Gardening Practices 2011).

Exposure risk - consumption of plants grown in contaminated soil *(indirect)*

Soil fertility can impact contaminant uptake in vegetables (Attanayake et al. 2015), it is for this reason that maintaining healthy garden soil is important to reducing exposure risks for gardeners.

Recent studies of garden soils identify higher soil levels of contaminants, including metals, when compared to levels of contaminants found in plants grown in gardens with contaminated soils (Brown et al. 2016); (Attanayake et al. 2015); (McBride, et al. 2014); (Defoe, et al. 2014); (Chaney, et al. 2010). A variety of factors are responsible for the variability in plant and soil contaminant level, ranging from plant species and varieties to chemical forms of contaminants in soil, soil properties, climate, and soil and plant management practices. It's important to note that most of the detected contaminants measured "in plants" (stored inside edible plant tissue) were not at levels that would cause harm to health; many studies identified contaminants measured "on plants" from soil residues adhered to the waxy surface of plant tissue (Attanayake et al. 2015); (Brown et al, 2016) (McBride, et al. 2014); (Codling, 2014); (Defoe et al. 2014). In studies referenced, some plants demonstrate higher potential for soil adherence and accumulation of contaminants from soil (Alexander et al. 2006). These studies do not address air emissions of metals and deposition onto garden grown plants.

Washing plants thoroughly removes a significant amount of soil and reduces the risk of indirect exposure (EPA, Brownfields and Urban Agriculture: Interim Guidelines for Safe Gardening Practices 2011); (Attanayake et al. 2014); (Brown et al. 2016).

Manage risks from soil splash by avoiding overhead watering and covering bare soil with mulch, or other material to avoid soil splash contamination of leafy vegetables, herbs, and other low growing plants.

Key Term

Soil Splash: the ability of water droplets from rain or watering of garden plants to fall and splash up soil onto the surface of plants.

Arsenic (As)

Arsenic occurs naturally in all soils and waters and is found most everywhere in the environment (Peryea, 1999). Food-chain transfer can occur, plants absorb As through their roots and all plants contain small amounts of As (Peryea, 1999). However, scientific studies of commonly grown garden foods indicate that most plants do not take up As at levels that are harmful to health (Mitchel et al., 2014); (Defoe et al., 2014); (Attanayake et al., 2015). Rice accumulates As into edible plant tissues when grown under submerged conditions, however growing rice in this way is not common in urban gardens.

***Cadmium (*Cd)**

Cadmium concentrations in urban garden-grown vegetables in a 2014 study were detected at levels too low to cause harm to human health (McBride et al., 2014); leafy green vegetables appear to contain the highest Cd concentrations; (ATSDR, Cadmium ToxProfile, 12). Soils with near neutral pH reduce the ability for Cd to uptake into plants, adding normal limestone to garden soils with low pH improves plant production and also reduces levels of Cd detected in plants (R. L. Chaney, 2015). Nearly every Cd source for garden soils has 100-200 times more zinc (Zn) than Cd. Zn inhibits Cd uptake by garden crops and reduces absorption by mammals when the crop is consumed. Only the rare case of Cd contamination without Zn is believed to comprise garden soil Cd risk (R.L. Chaney, personal email, 2016) supported by 2015 study (R. L. Chaney, 2015). Cd concentrations in vegetables were not correlated to soil Cd concentrations in a 2014 study; this was probably because of the near-neutral pH of most soils which limits plant uptake of Cd (McBride et al., 2014). In healthy, near neutral pH (non-acidic) garden soil, Cd has a low likelihood of exceeding soil guidance values based on residential soil cleanup levels, and a low likelihood of uptake by garden grown crops (McBride et al., 2014) (R. L. Chaney, 2015). Rice accumulates Cd (R. L. Chaney, 2015), however rice is not commonly grown in urban gardens.

Chromium (Cr)

Chromium (Cr) is a naturally-occurring element found in rocks, animals, plants, and soil, where it exists in combination with other elements to form various compounds. The two forms of Cr found in soils in the environment are Cr3+ (chromic) and Cr6+ (chromate, hexavalent chromium, chromium +6). Small amounts of Cr3+ are needed for human health. Chromium changes from one form to another in water and soil, depending on the conditions present (ATSDR, Chromium ToxProfile, 2). Cr6+ is only stable in alkaline, low organic matter soils. In neutral and acidic soils, with organic matter, Cr6+ is reduced to Cr3+. When soils are moderately contaminated with Cr6, the addition of compost, manure, biosolids, or biodegradable organic matter and microbes rapidly reduce and precipitate Cr6+ to Cr3+ (Chaney et al., 1997). "There are several areas of natural Cr in very rich serpentine soils in the US (MD, NC, CA, OR) where soils contain 1000 to 10000 or higher ppm Cr as the insoluble mineral Cr-Fe-oxide "chromite". Plants do not accumulate Cr from this mineral/these soils. Actually, plants hardly accumulate Cr from any soil. In the high Cr soils, plant Cr concentration was explained by soil/dust contamination of the plant samples" (R.L. Chaney, personal email, 2016); confirmed by (Chaney et al., 1997).

Lead (Pb)

Lead occurs naturally in the environment, but it occurs at higher levels in urban areas or in soils affected by human activity. Some plants absorb Pb through their roots, all plants have small amounts of lead (Peryea ,1999). Recent studies of vegetable uptake of Pb show that plant absorption of Pb is relatively low and food crops grown in soils with high-Pb contamination do not increase exposure risks through food consumption (Brown et al., 2016). Gardening may increase exposure to lead if people swallow soil particles, track soil into the home where small children may pick up and eat soil particles, or eat unwashed vegetables grown in soil with high lead levels. Studies have shown limited absorption of Pb when ingested with food. Studies of concentrations of Pb in plant tissue do not reflect concentrations of Pb in soil (Brown et al., 2016). Low plant uptake in combination with low solubility when eaten as part of foods, suggests that eating plants grown in urban soils, including soils with elevated Pb, would not provide a significant risk pathway (Brown et al., 2016). Adding organic matter, amendments and phosphorous fertilizers to the soil over time can reduce total bioavailable Pb (Brown et al., 2016).

Conclusion

Several important factors affect the ability of metals to transfer from soil to vegetables, including soil pH, organic matter content, and other soil quality and nutrient properties (McBride et al., 2014). These are factors that gardeners can control to reduce and prevent risks of direct and indirect exposure. Based on the current science, the potential risk for exposure through direct and indirect exposure through consumption of food grown in soil contaminated with arsenic, cadmium, and chromium, the garden risks from metals emissions from the two glass manufacturing facilities investigated are not elevated beyond what is expected for gardening in urban environments.

The use of compost can be highly effective at making metals less available to plants grown in soil with metals contamination. Compost is readily available, reduces risk, and improves the soils. Thorough washing removes a significant amount of soil particles from plant surfaces.

For communities gardening in urban neighborhoods and other areas with contamination concerns, it is important to first determine the quality of the garden soil. To create fertile garden soil, first test the soil for characteristics such as pH and nutrient availability. Consider the garden site's land use history as well as current surroundings (industry, high traffic corridors, etc.) and test the soil accordingly for potential contamination. Building raised beds with clean soil significantly lowers risks in areas with known soil contamination. Knowledge of soil health and potential contamination are keys to helping communities identify and correct problems so that urban gardens are healthy and productive.

Recommendations

Gardens provide many benefits, including healthier lifestyles through increased physical activity levels, providing fresh produce, cultural outlets and community pride, and nurturing social interactions and cooperation among people.

OHA recommends that all gardeners growing food in urban environments, or in other areas where contamination might be of concern, follow healthy gardening practices. Avoid health risks by not allowing people to consume soil, either during gardening, by tracking soils into the home, or by eating soil particles stuck to garden crops. Cover bare ground with mulch or other materials to prevent soil splash onto food crops.

The Oregon Health Authority (OHA) Healthy Gardening website provides additional guidance and Oregon specific resources for soil testing, and best practices to learn how to reduce risks while working and playing in the garden.

As an urban gardener in areas nearby industrial facilities, it is important to be aware of the following.

- The primary risks from your garden are through eating the soil. To avoid the direct soil exposure pathway (eating soil) consider the following, along with guidance found on the OHA Healthy Gardening fact sheet:
  - Wash hands after gardening.
  - Do not track soil into the house.
  - Wash garden grown food before eating it to remove soil particles.

- It's important to ensure that soils, composts and amendments used to grow food are 'clean' and not sources of contamination. Standards are lacking for regulations on garden soil and amendments.
  - Ask if garden products are tested for contaminants and certified by a third party verifier.
  - The US Composting Council has a Seal of Testing Assurance (STA) for composts which meet the limits of their testing program (for nutrients, metals, and pathogens, and maturity of the compost as a soil amendment). Look for the STA stamp on compost products.
  - While the behavior of metals in garden soil is such that risks from exposure from eating garden grown food is low, it remains important to test soil in gardens in urban areas.
  - Testing garden soil is the only way to know for certain what the contaminant levels are.

Contributions

Literature reviewed for the creation of this technical briefing was provided by:

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These experts collectively have knowledge of metals (including arsenic, cadmium, chromium, and lead) physical and chemical properties, environmental fate, bioavailability, human exposure, and plant uptake. This acknowledgement should not be understood to imply its approval of final content within this technical briefing. The responsibility for the content lies with the OHA.

The Oregon Health Authority welcomes the sharing of recent research findings on this topic. Please send additional literature to ehap.info@state.or.us.

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