Urban Food Production and Greening:

Best Practices for Minimizing Exposure to Brownfield and Background Contaminants

A Directed Study for Groundwork USA

Rebecca Harnik
Friedman School of Nutrition Science and Policy
Tufts University
August 11th, 2016

Table of Contents

Introduction

This research is the culmination of a semester long one-credit directed study course at Tufts University, with the intent to support Groundwork USA in understanding risks and best practices associated with urban gardening and farming on former brownfields and other urban sites with contamination.

Groundwork USA works to bring about sustained environmental improvement and build community capacity in distressed cities through collaborative transformation of neglected land and waterways and stewardship of newly created assets. Groundwork USA is a federation of local organizations that turn brownfields into parks, gardens, and greenways; restore urban waterways and water systems; create neighborhood infrastructure for active living; expand local food production and access; and advance equitable development. Groundwork USA leads Environmental Protection Agency (EPA)-sponsored technical assistance programs on Brownfields Area Wide Planning; and on issues surrounding brownfields, equitable development and environmental justice.

The report used literature from studies based largely in the United States, emphasizing government research, peer-reviewed literature, and extension services. The aim of this literature review is to examine resources and guidance for gardeners and farmers seeking to utilize best practices to protect themselves and their communities from contaminants and to distill it into a usable framework.

Urban Food Production and Brownfields

The benefits achieved from urban gardening and farming are extensive. A multitude of studies have demonstrated associations between urban food production and human health, including improved nutrition, greater levels of physical activity, and increased community food security. Further, children who garden are more likely to try vegetables, enjoy them and eat more of them; and gardening can lead to increased access to fresh food and healthier food choices. Social benefits include increased social interaction, improved understanding of natural processes, and job creation. Gardening and food production in an urban landscape can offer significant ecosystem services, including habitats for urban animals and pollinators, nutrient cycling, and water cycling. (Brown et al, 2015; Kim et al, 2014; Kaiser et al, 2015; EPA Land Revitalization 2015)

Unfortunately, the reality of the urban environment is that contamination is prevalent in the landscape. Many contaminated properties, known as brownfields, have presence or suspected presence of hazardous substances, pollutants or contaminants. According to the US Environmental Protection Agency, there are over 450,000 brownfields in the United States. Brownfield testing requires more in-depth research on site history and testing than typical soil tests, and may require additional cleanup and more intensive soil management. Still, the benefits of cleanup can be significant – remediating and reinvesting in these properties can improve and protect the environment, increase tax base and neighborhood investment, and offer significant opportunities for food production. (US EPA, 2011; US EPA, 2015)

Contaminants are linked to a range of land uses, including former industrial sites, vacant lots with remnants of demolished and/or burned buildings, and residues from illegally dumped materials. The most commonly found contaminant in cities in the United States is lead, but a host of other heavy metals including arsenic, cadmium and barium are often present. Other toxic compounds such as asbestos, solvents, and polycyclic aromatic hydrocarbons (PAHs) are also commonly found concentrated in urban areas, among others. (Clark et al, 2006; MISA, 2010; Mitchell et al, 2014; Kaiser et al, 2015).

After a brownfield or contaminated site is tested and/or cleaned up, it can still be utilized to cultivate food, but gardeners and farmers must take steps to ensure that they are minimizing exposure to contaminants. This research works to build an understanding of contamination and its risks in urban spaces for gardeners, farmers and others working to transform contaminated spaces for greening in the US; and documents best practices to minimize exposure to urban contaminants.

Understanding the Risks

While food production offers many opportunities for improved health, growing food in cities can present health risks from exposure to contaminants. When assessing costs and benefits, these risks must be weighed carefully so as to protect gardeners adequately without discouraging beneficial food production. (Kim et al, 2014). Many agencies including the Centers for Disease Control and Prevention (CDC), the Environmental Protection Agency (EPA) and the World Health Organization (WHO) have developed risk analyses for different exposures to contaminants – and results often vary, based on factors including the intended audience to be protected, expected activities carried out near contaminants, and local and regional land characteristics and history.

Exposure to contaminants follows three primary pathways and varies by type of contaminant. Exposure routes include:

- **Inhalation**, through breathing;
- **Direct contact with skin**, through touching;
- **Ingestion**, which can occur through direct consumption of soil through hand-to-mouth contact. as well as indirect ingestion through the consumption of garden-grown produce. Contaminants including lead, cadmium and arsenic can accumulate in tissues of vegetables grown in contaminated soils, at varying levels (EPA, 2011; Kim, Poulson et al, 2014) although research suggests that the majority of ingestion-based exposure comes from ingestion of the dust itself, rather than actual uptake by the plant. (Clark et al, 2006)

Factors to consider when evaluating risks due to contamination

Substantial variability exists in types of contamination in any given urban parcel, and each scenario may be distinct based on soil-related characteristics, farming practices, historical land use, and interactions between contaminants. (US EPA, 2011). These variations can make it very challenging to issue specific risk analyses, and guidelines also can serve to be directed to improve human health, groundwater supplies, or ecological health. (Shayler et al, 2009, *Guide to soil testing*) Risk assessments may work to consider any or all of the following:

Historical Property assessment

How much is known about the site's historical uses can inform the types of testing that gardeners should pursue to minimize exposure to contamination. Sites that were home to industrial uses, sustained a structural fire, or had underground storage tanks on site, among other uses, should be considered for more robust testing for heavy metals beyond what a typical soil test might detect. It is important that brownfield assessments (with site soil and/or groundwater sampling) be pursued when historic site uses appear to warrant more sophisticated soil investigation. (US EPA, 2011)

Distribution:

Concentrations of contaminants, even in a single parcel of land, can vary based on runoff, spills, and aerial deposition as well as horizontal movement. (US EPA, 2011; Brown et al, 2015) A study of community gardens in New York City found tremendous variation even within a single parcel – on average there was an 11-fold difference between the lowest and highest lead concentrations on each site; and an 8-fold difference in barium concentrations within a garden. (Mitchell, et al, 2014)

Contaminant characteristics:

The tendency of contaminants to hold in soil or move can vary by compound, and may influence the long-term contamination of a parcel. Movement can occur to groundwater through leaching; volatility (evaporation) in the air; and capacity to bind in the soil movement of contaminants. Additionally, aerial redeposition can occur through particles being deposited over short distances off-site -- this can occur even after compounds are no longer being used. (Shayler et al, 2009; Mitchell et al, 2014; Kaiser et al, 2015)

Plant properties:

Different classes of plants take up different contaminants to plant tissue in varying ways – some are more likely to absorb contaminants while others are relatively unlikely. The part of the plant being consumed also has an impact on contaminant loads. Additionally, the height of plant also comes into play in risks to consumers, as shorter plants are more vulnerable to direct splash from the soil. (WHO, 2006; US EPA, 2011; McBride et al, 2014)

Human body response and vulnerability:

Age and susceptibility will impact the body's reaction to contaminants. This includes gardeners, those on site (eg children), and food consumers. (US EPA, 2011)

Children face a particularly high risk from all pathways, as they may swallow more soil than adults due to increased hand-to-mouth contact; and have higher absorption and increased sensitivity. (Kim et al, 2014; Kaiser et al, 2015). Youth gardeners are more highly susceptible to exposures, and as a result in assessments cannot simply be considered "small adults" when risks are calculated. Between conception and adolescence, developing bodies have increased susceptibility – and pregnant women must also exercise caution as a result of transferability to the fetus. (Clark et al, 2006).

Further, residents (especially children) from low income areas, urban environments and communities of color are more likely to face exposure due to the cumulative burdens of multiple sources of exposure, including higher in-utero exposure, more independent playtime, homes with higher levels of lead dust, and residential proximity to areas with contamination and toxins. (Gochfeld and Burger, 2011) *See "Environmental Justice and Contaminant Exposures" below for more information.*

Human activities:

Amount of time spent and how much direct contact with soil gardeners have can make a difference in what kinds of exposures gardeners have; as well as practices taken to exercise precaution, such as wearing gloves, washing hands, and cleaning produce (US EPA, 2011; Shayler et al, 2009, Guide to soil testing)

Management and growing approaches

Management plays a substantial role in modifying exposure. How many and which types of practices are selected to control volatility and movement of compounds in the air and soil; amount of carbon-rich amendments and compost is added to the soil, and how is the site management plan tailored towards the community specificities (Clarke, 2006; US EPA, 2011)

Soil Characteristics:

Soil types and characteristics vary tremendously by region and prior land use. Characteristics include pH of soil, type of soil, soil horizons, amount of organic matter, presence of clay, temperature, background levels of contaminants in soil based on non-human regional soil characteristics, presence of other chemicals, and soil mineralogy. These factors will impact the reactions with chemicals, likelihood of retention, and changes over time (Shayler et al, 2009, Guide to soil testing; Mitchell et al, 2014).

Biologic availability of contaminant:

The presence of a contaminant found in soil may not mean that it is biologically available to be taken up by human/animal bodies. Some contaminants can "age" and have a lower bioavailability or bioaccessibility over time; others react with contaminants, which increases or decreases the availability to the plant or human body. (EPA, 2007; Shayler et al, 2009; Kaiser et al, 2015).

Environmental Justice and Contaminant Exposures

Risks from environmental contaminants are not distributed uniformly across populations. Research demonstrates that populations including children, people of color, Native Americans, and low-income urbanites often face disproportionate exposures to hazardous compounds. (Brulle and Pellow, 2006; Gochfeld and Burger, 2011)

Lead, the most common contaminant, has been found in high concentrations in proximity to communities of color, particularly in Black and Hispanic/Latino communities; and research has demonstrated that children at 100% of the federal poverty level may have substantially higher risk for exposure than those above the poverty level (Aelion et al, 2013). Because exposure to lead and other compounds in the soil disproportionately impacts urban poor and minority communities, it is considered to be an environmental justice issue (Clark et al, 2006).

Increased susceptibility to risks may also occur as a result of a higher likelihood of living near environmentally hazardous facilities, an increased cumulative burden of risk factors, and lesser access to health care. At-risk communities often face multiple factors layered upon each other, which can cumulatively result in greater susceptibility. Risk assessment methods often fail to adequately identify the elevated risks of such populations, and when calculating population-wide average risks, they may underestimate risks to some of the most vulnerable communities. As such, it is important that in evaluating contaminants that all populations are served equitably under environmental justice laws, which must evaluate all people and communities fairly under public health laws and regulations. (Brulle and Pellow, 2006; Gochfeld and Burger, 2011)

Given that these environmental risks and cumulative burdens are higher in communities that are low income, urban and/or have a high proportion of residents of color, when urban agriculture is carried out in such areas, extra precaution may be considered with testing and selecting best practices to prevent exposure and poisoning – and remediation and site planning must be designed to target specific needs of demographics and environmental justice issues. (Clark et al, 2006)

Contaminants of Concern: An Overview

This section delves into classes of contamination to offer an understanding of the range of contaminants associated with different land uses, and the importance of tailoring testing towards previous land uses and knowledge around the history of the area.

As discussed above, there is a great deal of variability in risks posed by contaminants in urban spaces. Further, each class and subtype of chemical carries its own distinct risks. This section will work to draw trends in distribution of chemicals, as a foundation for practitioners and researchers who may wish to evaluate their specific contexts. Because many chemicals, metals, and compounds are typically invisible in soil, it emphasizes researchable details in order for anyone wishing to develop or use a site to pursue, with the end goal choosing good testing and exposure reduction plans. It also offers suggestions on some physical signs of how someone may be aware of the land's history.

In the below chart, the US EPA offers a division of common contaminants by land use history; and this research further expands on this chart in the rest of the section by offering more specifics on each of these general land uses. Many broad categories of contaminants are listed in the chart, but the reader should understand that these categories encapsulate a range of contaminants. "Metals," for example, includes nearly a dozen different compounds, including arsenic, cadmium, calcium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, selenium, thallium and zinc. While some of these metals are actually biologically necessary for healthy humans and plants, concern arises when they exceed certain levels. Examining general sources of compounds and their associated classes can be helpful to understand a site's risks and develop strategies for mitigation. Many of these compounds are carcinogenic and may pose serious health threats in situations of high exposure. For further information on individual compounds, follow the section at the end of the paper on *Resources for Urban Farmers and Gardeners*.

Common Land Uses and Associated Contaminants

Land Use	Common Contaminants
Agriculture, green space	Nitrate, pesticides/herbicides
Car wash, parking lots, road and maintenance depot, vehicle services	Metals, PAHs, petroleum products, sodium, solvents, surfactants
Dry cleaning	Solvents
Existing commercial or industrial building structures	Asbestos, petroleum products, lead paint, PCB caulks, solvents
Junkyards	Metals, petroleum products, solvents, sulfate
Machine shops and metal works	Metals, petroleum products, solvents, surfactants
Residential areas, buildings with lead-based paint, where coal, oil, gas or garbage was burned	Metals, including lead, PAHs, petroleum products creosote
Stormwater drains and retention basins	Metals, pathogens, pesticides/herbicides, petroleum products, sodium, solvents
Underground and aboveground storage tanks	Pesticides/herbicides, petroleum products, solvents
Wood preserving	Metals, petroleum products, phenols, solvents, sulfate
Chemical manufacture, clandestine dumping, hazardous material storage and transfer, industrial lagoons and pits, railroad tracks and yards, research labs	Fluoride, metals, nitrate, pathogens, petroleum products, phenols, radioactivity, sodium, solvents, sulfate

The above chart was published in EPA, 2011; adapted from Boulding and Ginn, 2004

Agriculture and Green space

(Shayler, 2009; US EPA 2011; Kaiser et al, 2015)

- **Pesticides:** In areas of agriculture and green space, pesticides may have historically been (or may still be) used on the property or surrounding areas; old orchards or farms may have persistent pesticide and arsenic residue in soils, too. Pesticides can include insecticides, herbicides, fungicides, rodenticides or other poisons. There is no single test for pesticide residues because there are hundreds of different varieties – the best way to examine a property is to historical use of the property – pesticides can vary in persistency in how long they remain on the land.

- **Fertilizers:** Fertilizers may be (currently or historically) used for lawns and gardens on the property, as well as in nearby farmland. Some fertilizers can contain waste materials, such as sewage biosolids or fly ash – these can contain a large array of heavy metals – copper, zinc, cadmium and lead, as well as Persistent, Bioaccumulative, Toxic chemicals (PBT's). Manure can contain high levels of heavy metals, with copper and zinc; and phosphate fertilizers may contain cadmium from the rock phosphate.

Automobiles and Machines

(Shayler, 2009; EPA 2011; MISA, 2010)

- **Automobile and machine repair:** may result in spillage, breakdown of car parts, and dumping. Contaminants associated: petroleum, PAHs from motor oil, which can stick to the soil; and solvents in rubber products; as well as a range of metals: lead, molybdenum or nickel; and lead and mercury from used batteries.

- **High Traffic areas:** being located near a high traffic area impacts amounts of chemicals in the soil, especially lead. Lead was used in gasoline until the late 1970s, and the particulate molecules from cars leeched into the soil. PAH's are a concern here too, as they relate to the in
- **Petroleum spills:** These can come from gas stations, and fuel tanks, and can include: benzene, toluene and xylene. Though volatile chemicals will likely not remain in the surface of the soil, they may remain deeper down in the soil if there is significant digging or a source of continued leaching.

Dry Cleaning

(MISA, 2010)

- Solvents produced as a product of dry cleaning may be toxic – Stoddard Solvents, and Tetracholorethenes are some solvents of concern.

Residential Areas, Dumping and Burning

(Shayler, 2009; Kaiser et al, 2015)

- **Paints** manufactured before 1978 are likely to contain lead. As they age and peels off, they can get into soil surrounding buildings. Concentrations tend to be highest right near buildings or pipes and decrease with distance from source. Lead testing is one of the most common contaminant tests offered, and is an important test to consider in areas with high traffic or homes built before 1980.
- **Landfills/garbage dumping**: Proximity to a garbage dump or former use as a garbage dump can lead to soil contaminants leaching into the groundwater including: petroleum, solvents, pesticides, lead and other heavy metals. These materials can vary dramatically, and historical contexts should be researched to get a more specific sense of exposures to such contaminants.
- **Burning/fires.** Intentional or unintentional burning of houses, garbage, synthetic substances such as vinyl siding, or other items or other materials can lead to the release of PAHs, dioxins, or other chemicals. PAHs come from burning of coal, gas, wood, garbage, and often stick to soil particles. Yard waste burning, such as branches or leaves, is less likely to release harmful contaminants.

Wood Preserving and Furniture Refinishing

(Stehouwer, 2002; US EPA, 2005; Shayler, 2009, Rails to Trails Conservancy online)

- **Pressure treated wood** has historically been used to prevent lumber from rotting. Though pressure treating is no longer allowable by the Environmental Protection Agency for residential purposes, it may be still used for industry. Arsenic can leech from wood to soil, usually in a close range. It may have been used in decks, swing sets, play areas or other structures.
- **Furniture refinishing:** Chemical strippers may be used in refinishing furniture, including methylene chloride and solvents such as toluene and methanol. These can contaminate soils and groundwater.
- **Railroad tracks and ties:** Many railroad tracks and storage areas may have contamination from herbicides, PAHs, metals, fly ash, and creosote. Due to toxic compounds, rail ties should not be used as a part of raised bed gardens.

Storm water Drains and Water Retention

(Wortman and Lovell, 2013)

- Urban agriculture sites may face contaminated runoff from roads and industrial areas – this may lead to exposure of PAHs, heavy metals and pathogens. The "first flush" from rain often contains the highest contamination, and management techniques should consider impacts from heavy runoff. PAHs may stick to soil particles or spread widely in surface water.

Lead: The Most Common Soil Contaminant

Nationally, the most commonly found contaminant in soil is lead, and research indicates that lead is often highest in urban centers due to its historical use in gasoline and leaded paint (Kaiser, et al, 2015). As such, this literature review dedicates a section specifically to lead. Many resources exist to learn more about lead, including the CDC, the EPA, and the National toxicology program, among others. This document offers an overview of these concerns to contextualize the mechanisms and importance of reduce exposures.

Many cities across the country have elevated levels of lead (Pb). Lead is an element, which doesn't degrade; and a meta-analysis of 62 urban areas in the US from 1970 – 2012 indicated that there has been no significant change in lead concentrations in the last 4 decades (Datko-Williams et al, 2014), demonstrating that the metal's longevity persists, despite regulation on its usage. In Boston, MA, for example, 88% of urban gardens sampled across the city had soil lead concentrations above the EPA soil screening level of 400 mg kg^{-1} (Clark et al, 2006). Additionally, the presence of lead may be closely correlated with other urban contaminants because they frequently originate from common sources (Wortman and Lovell 2013). Because other contaminants may be present, it is important that gardeners test for lead in their soils as well as compounds beyond lead.

Health Concerns

Lead exposure can have impacts that are broad and far reaching. It is a neurotoxin, and impacts include cardiovascular, immunological and endocrine effects (Betts, 2012), as well as liver, kidney, and nervous system issues. High exposures may even cause seizures, coma or death. It is classified by the World Health Organization's International Agency for research on Cancer as "probably carcinogenic to humans" (Kaiser et al, 2015; Kim et al, 2015).

The risk of cognitive damage from lead is particularly high for children, as they are in the developmental stage and may be sensitive to behavioral problems and learning disabilities. Even low levels of lead in the blood have been shown to affect IQ, attention capacity, and academic achievement. Effects of lead exposure cannot be corrected – and are often not directly detected. (CDC, Lead, 2014; Datko-Williams, et al, 2014; Kaiser et al, 2015; Kim et al., 2015) Urban children are the most vulnerable to lead exposure through ingestion of household dust and soil. Pregnant women are also a population of concern, as maternal blood lead levels can be transferred to the fetus. (Clark et al, 2006)

No levels in the blood are considered to be safe, and untreated effects are irreversible. The CDC has set the blood level of concern at 5mcg/dc, having recently lowered it from historically-set levels of 10mcg/dc; recognizing even low levels to be a substantial concern. Blood lead levels can be identified through a blood test for cases of chronic exposures. Symptoms of lead poisoning aren't always clear, which makes it even more challenging to diagnose and treat promptly. (CDC, Blood Lead Levels in Children)

Sources of Lead

Lead was historically used in paint and gasoline, which has caused a widespread prevalence of the metal, particularly in dense, urban areas with more housing and higher car traffic (Datko-Williams, et al, 2014). Lead has also been used widely in industry, particularly in construction materials, batteries and piping, and as well as industrial releases to soil from nonferrous smelters, battery plants, waste incineration, coal and oil combustion, and chemical plants. Disturbance of older structures containing lead-based paints are major contributors to total lead releases, such as burning and demolition. Lead is transferred continuously between air, water and soil by natural chemical and physical processes such as weathering, run-off, precipitation, dry deposition of dust and stream/river flow; however soil and sediments appear to be important sinks for lead. Lead is extremely persistent in both water and soil. (WHO IARC, 2006; Datko-Williams, et al, 2014; Mitchell et al, 2014, Kim, et al 2015).

The majority of human exposure to lead comes from household dust from lead-based paint, for both children and adults (Betts, 2012); and indoor lead sources have been shown to contribute more strongly to elevated blood levels than outdoor soil sources. (Brown et al, 2015)

Urban Agriculture and Lead

In the garden, evidence shows that the risks from inhaling dust or ingesting the actual soil are higher than eating properly washed crops, particularly for children. Soil metal chemistry causes most particles to be insoluble or strongly attached to soil particles or plant roots so that they don't reach the edible portions of most plants. (Datko-Williams, et al, 2014; EPA, 2011). In soil, lead concentrations are often highly variable over short distances, often impacted by factors such as proximity to a roof drip line, distance to a busy road, and age/distance from housing (Brown et al, 2015), and it is important that gardeners test to understand areas of high concentration.

While research suggests that lead in agriculture is a lesser concern than water and indoor lead sources, lead exposure from plants to be considered "both quantifiable and nontrivial component" as a pathway (Clark et al, 2006). Lead follows similar patterns to heavy metals - direct exposure occurs when soil is ingested – such as hand-to-mouth contact and inhalation of lead particles from soil or paint; and indirect exposure from consumption of crops that have been grown in lead-contaminated soils. (EPA, 2011; Brown et al, 2015)

Plant uptake

Plant uptake of lead is often an area of high concern by gardeners (Wortman and Lovell, 2013). Evidence has suggested that the highest lead levels in vegetables typically occur where soil lead levels are the highest, and the World Health Organization's International Agency for Research on Cancer (IARC) warns that lead present in soils can be taken up by food crops. Variations in uptake are substantial, and while some plants take up minimal contaminants, different parts of plants may take up significant amounts of lead. (WHO, 2006; Brown et al, 2015). Lead can be taken up through the plant's roots, and lead present in air may adhere tenaciously to leafy vegetables unless washed carefully. When determining relative risks in different crops, the following rules are suggested:

1. **Roots** typically contain *higher* levels of lead (WHO, 2006), especially hypocotyl root vegetables, such as carrots, radish, red beets, and turnips (Brown, 2015; Shayler, 2009)
2. **Stems** and **leaves** take up less lead than roots (WHO, 2006)
3. **Seeds and fruits** have the lowest concentrations (WHO, 2006). Specifically, tomatoes, eggplant, peppers, okra, squash (both summer and winter), corn, cucumber, melons, peas, beans (shelled) and onions; as well as tree fruits and berries. (Shayler, 2009)

Due to the variability in lead uptake by different plants, some high-uptake plants such as mustard and collards have been suggested as mechanisms to uptake lead in high quantities, and can be used for phytoextraction of lead in soils, accumulating lead in their tissues and taking it out of the soil. However, this technique may be very slow, and such efforts may require multiple strategies, including adjusting the soil pH to increase absorption of lead. In a study of lead-contaminated gardens in Boston, using such plants alone as an approach was not considered sufficient to be an adequate strategy to extract lead from the garden. (Clark et al, 2006)

While lead in plants is a concern, many factors influence lead uptake, including soil pH and presence of other compounds in the soil -- and the uptake of lead by plants is believed by many researchers to be somewhat limited. Human consumption of plants with lead may be less of a concern than gardeners tend to believe, especially if best practices are implemented. Further, plant uptake may be controllable by adding organic matter and nutrient-rich soil high in nitrogen, phosphorous and potassium (N,P,K) – this converts the lead to the mineral form of pyromorphite, which can reduce the uptake of plant lead, as well as cadmium and mercury. (McBride et al, 2014; Brown et al, 2015)

Further, in the long run, urban agriculture may have a positive impact on soils in urban areas, offering added net benefits to the community. Food production and addition of soil amendments typically results in a decreased bioavailability of soil lead, by reducing lead dust blowing or agitated in the community through settling and binding lead in the soil. (Brown et al, 2015)

Managing lead exposure with nutrition

Following good nutrition practices can be a substantial means to manage lead exposure, because specific nutrients can reduce lead absorption and damage in the body. The value of nutrition in mitigation of lead uptake may make urban agriculture increasingly valuable in city environments where access to fresh and healthy food is limited, and this tradeoff may suggest that eating plants grown in urban soils may not provide a significant risk pathway. Consistent food access is also key - when lead is taken into the body along with foods, less lead is absorbed into the body than if exposure takes place on an empty stomach, because a more neutral stomach pH makes lead less biologically available. (EPA, 2014; Brown et al, 2015)

There are several vitamins, minerals and nutrients that are of particular value to reduce lead absorption. Vitamin C is the most widely studied antioxidant capable of removing free radicals; unsurpassed in its ability to bind and remove lead; highly effective in alleviating lead toxicity – and Vitamin C is commonly found in a range of fruits and vegetables. Calcium and Iron are also considered to be two primary and vital nutrients to reduce lead absorption and bodily damage, respectively. Combined, Vitamin C, Iron and Calcium are the primary priorities promoted by the EPA for children living in areas with high lead exposure. (Kim et al, 2013; EPA, 2014; Brown et al, 2015)

Other beneficial nutrients exist that can help prevent against negative impacts of lead. Research has demonstrated that Vitamin E is neuroprotective and has antioxidant effects; and it can reduce cognitive impacts and influences of lead-based memory impairment. Vitamins B1 and B6 can alleviate health problems caused by lead poisoning through antioxidant properties. Phytates, Flavenoids, fiber and herbs can also serve as preventative mechanisms to reduce uptake and prevent damage. **(**Kim et al, 2013; Brown et al, 2015)

Consuming Meat, Milk and Eggs Produced in Urban Areas: Preliminary research

Similar to humans, animals may face exposure to lead and other heavy metals, which can then be stored in their muscle tissues. Contaminants can pose a concern to animal well-being, and it is possible for human consumers of meat, milk, and eggs to be exposed secondhand to lead and other heavy metals indirectly through animal uptake and subsequent consumption of animal meat, milk and eggs.

Animals are often challenging to study because they may graze, forage, or move through a wide range of places, so amount of lead or other substances that animals are exposed to may vary substantially. Currently, studies evaluating contaminant concentrations in animals and the relative risks to humans are quite limited, however some initial research has offered preliminary evidence in this realm. This literature review highlights a study on chicken eggs to share mitigation measures that can be implemented to decrease the amount of lead or other contaminants that chickens are exposed to, and in turn the amount of exposure that humans will face.

Studies of Animal Uptake of Contaminants

Animal Meat
In studies of cattle that were exposed to very high levels of lead, transfer of lead from food source was seen to be possible into cattle muscle and milk tissue. However, studied animals were exposed to very high levels though remains of storage batteries that were burned and left in a pasture; more data need to be examined to understand impacts of exposure to low-to-moderate levels of lead, as well as with different types of livestock. (WHO IARC, 2006)

Research by *Horak et al, 2014* on wild Canada Geese meat was conducted to study health risks to consumers eating wild-caught meat in food pantries and feeding programs. The study collected data from geese across the Midwest, mid-Atlantic and Northeast of the United States, and assessed pesticides, metals, and PCBs; comparing contaminant concentrations with in commercially produced poultry.

The study found dramatic variation in contaminants seen in animal flesh. Some animals exceeded recommended FDA limits in their meat, while others did not. When risk to human consumers was modeled, more than 99% of adult consumers were found to fall below the exposure limits for the contaminants of concerns evaluated. The study indicates that wild animals can have quite high concentrations of lead in their muscle tissue, which could pose health concerns with sustained and regular consumption over time. However, if meat is consumed less frequently or is ground together with multiple meat sources (which is likely given the ways in which consumers tend to eat wild caught meat) it would be safe for most consumers. The birds in the study were likely not migratory, so future research might benefit from studying animals that migrate. (Horak et al, 2014**)**

Chickens and Egg Production

Research by *Spliethoff et al, 2014* in New York City in mixed-use residential/commercial neighborhoods examined eggs laid by chickens in community gardens with a range of levels of lead contamination. When measured across gardens, levels of lead found in eggs were found to be significantly associated with soil lead, indicating that chicken eggs reflect bird exposure to lead. Models utilized by researchers found that one in six eggs from a henhouse would exceed a 100 microgram per kilogram guidance value, at soil lead concentrations of 410mg/kg (above the EPA threshold of safe soil lead).

Researchers modeled relative risks to consumers, given that home-hatched eggs are often consumed as only a portion of total egg consumption, and found that the estimates of health risk from consuming eggs with such lead concentrations were generally not considered to be significant at such levels. Based on the study's findings and additional research, the following recommendations were put forth to help NYC chicken keepers reduce lead concentrations in eggs (Spliethoff et al, 2014):

1. **Evaluate gardens for potential sources of lead,** and adjust gardening practices accordingly. Do not allow chickens to forage near these sources, including structures painted with lead-based paint and areas where the soil has higher concentrations of lead.
2. **Amend the soil to cover areas where chickens run/forage.** By adding clean soil,

mulch, or other cover material, gardeners can help reduce chickens' contact with and ingestion of contaminated soil. Inspect cover material regularly, adding or maintaining material to help keep chickens from coming in contact with underlying soil that may have higher concentrations of lead.

3. **Provide chickens with feed in feeders**, rather than scattering feed. This includes scratch grains and food scraps; on bare ground in areas where soil has higher concentrations of lead; or where lead concentrations are not well characterized.
4. **Avoid feeding chickens unwashed garden scraps** from areas where the soil has higher concentrations of lead.
5. **Offer a calcium supplement to chickens,** to reduce the amount of lead that gets into chickens' eggs.

One limitation of this study was that while soil in the study did contain high concentrations of lead, the soil in the study contained lead under 600 mg/kg, and such concentrations in urban settings may be significantly higher.

Gardener Awareness and Behavior

Studies examining urban gardener behavior in Cleveland and Columbus, Ohio have suggested that gardeners have high interest in gardens as a means for community food security, control, and health. (Kaiser et al, 2015). However, studies with urban gardeners in many cities show that gardeners may experience confusion or lack important knowledge or understandings of risks and management of risks. (Kaiser et al, 2015; Kim, Poulson et al, 2014)

Research with seventy gardeners from a range of gardens and socioeconomic census tracts in Baltimore found that 51% of gardeners cited soil contaminants as a concern; but on a scale of 1-5, 5 being the most severe, the average gardener only ranked the concern at 2.3. Further, this research showed that gardeners typically assume that once they've been gardening on a site for some time, contamination is no longer a concern. Major gaps were noted in knowledge of best practices to reduce exposure. (Kim, Poulson et al, 2014)

In Baltimore, it was found that among gardeners that there were substantial barriers that deter gardeners from testing their soil for contaminants: costs were perceived to be prohibitive, and additional need for knowledge was necessary; especially when a gardener wanted to test for a contaminant outside of a typical metals panel, like asbestos. Obstacles to testing included not knowing how to properly sample soil; where to send soil for testing; which contaminants to test for; how to interpret results. There was also a dangerous assumption noted by researchers that lead-free soils are considered safe. (Kim, Poulson et al, 2014)

Results from the studies with gardeners in Baltimore, MD and Cleveland and Columbus, OH recommended clear, locally-specific messaging for gardeners on risks and best practices; and better training for gardening experts on risks. Gardeners in Baltimore sought better collaboration between levels of government, increased face-to-face contact for education, and a central repository where gardeners could access information about soil contamination. (Kaiser et al, 2015; Kim, Poulson et al, 2014)

Best Practices to Promote Safety

Recommendations

There is a significant amount of literature on best practices for gardening on brownfields, and this list of 8 primary items works to distill it. Please see the two handouts, *Testing Your Soil* and *Best Practices for Food Production in Areas Suspected of Contamination* produced for Groundwork USA for a distillation of these themes.

1. **Research site's history.**
   (Clark, 2006; Minnesota Institute for Sustainable Agriculture, 2010; US EPA, 2011)
   Understanding the history of a property is a vital first step to be able to fully pay environmental due diligence to contaminants that may be present, and protect the community adequately – a systematic research report that interviewed local governance and academics by the Environmental Protection Agency emphasized the importance of this issue. Investigation can include: examination of Sanborn maps, which include building information since 1867 for 12,000 US towns and cities; historical aerial photos; historical assessments; city and county records; and reviewing environmental databases. Much of this material can be found from a local library or county records office, interviews with neighbors; and internet research, as well as the EPA "Cleanups in my Community" database, which offers a map of hazardous waste cleanup locations and grant areas (see resources section for more information.)
2. **Understand regional soil concerns.**
   (US EPA, 2011, Shayler et al, 2009)
   In the US, soil varies based on geologic soil type, management strategies and land use; and soil types have an influence on how contaminants are retained or move through the soils. Background contaminants also vary significantly, as many metals are natural in soils. Contact your regional department of Environmental Protection to get an understanding of local soils. Also gardeners should seek out their local agriculture extension office to understand issues for urban gardeners in the area and get resources and recommendations for specifics on soils.

3. **Perform Soil Sampling.**
   (Clark, 2006; Shayler et al, 2009, Guide to soil testing; US EPA, 2011)
   Basic and inexpensive soil sampling tests examine soil aspects such as pH, nutrient content, and soil composition. These tests are helpful for understanding how to best enhance soil health. However, it is important that in high risk areas, gardeners and gardeners-to-be use the site history and regional concerns to test for relevant contaminants, based on research from #1 and #2. Because contaminant loads may vary substantially, testing should cover multiple areas of the garden and be measured through composites (multiple areas tested and mixed together).

4. **Use Best Growing practices on-site** (Stehouwer, 2002; Shayler et al, 2009, Contaminants and Best Practices; US EPA, 2011, Kim, Poulson et al, 2014)
    a. **Incorporate clean soil, compost, manure or peat moss**
    This dilutes contamination, and binds to materials such as Arsenic, Chromium, Copper, and Lead. Clean amendments should be added annually, as contaminants can blow/settle on the garden.
    b. **Maintain soil pH to near-neutral (6.5 or more)**
    Most metals are more bioavailable in acidic soils, and higher pH reduces availability to the plants. Adjusting pH can be done through soil amendments.
    c. **Wear gloves when handling soil.**
    Though lead is not typically absorbable though skin, gloves also help reduce hand-to-mouth contact.
    d. **Avoid treated lumber and railroad ties.**
    Though treated lumber has been banned for household use, treated lumber may contain arsenic or other contaminants
    e. **If contamination is believed/known to be particularly high:**
        i. **Build raised beds and add** landscape fabric underneath to prevent roots from entering contaminated soil under bed.
        ii. **Grow plants that are less likely to take up contamination**: vegetable fruits and seeds, tree fruits, and berries; and avoid green leafy vegetables, broccoli, cauliflower, and root crops.

5. **Use other on-site practices to protect the garden** (Shayler et al, 2009, Contaminants and Best Practices; Wortman and Lovell, 2013)
    a. **Install multifunctional buffers around the garden.**
    Planting woody or herbaceous crops that are not intended for consumption will improve infiltration of stormwater, buffer runoff protect crops from winds, filter contaminated aerosols and pollutants, and offer opportunities for value-added products such as cut flowers or craft materials.
    b. **Mulch walkways and areas where food isn't being cultivated.**
    This can trap contaminants and prevent inhalation from dust.
    c. **Grow food away from areas adjacent to buildings.**
    Areas next to buildings are likely to have the highest lead levels.

6. **Use Best Practices outside of the garden and in food preparation.** (Stehouwer, 2002; Shayler et al, 2009//Contaminants and Best Practices; MISA, 2010; US EPA, 2011)
    a. **Wash hands and other exposed skin**.
    If skin comes into contact with soil, wash well, especially before eating or preparing food
    b. **Wash and peel crops well before storing and eating.**
    Additionally, and remove outer leaves of leaf crops, especially on the bottom.
    c. **Reduce tracking by shoes.**

Take off shoes in the home after gardening, use a doormat, clean floors with a damp mop, and wash boots

7. **Use special care with vulnerable populations and communities with multiple burdens of risk** (Shayler et al, 2009//Contaminants and Best Practices; Gochfield and Burger, 2011; Clark et al, 2006)
    a. **Watch young children carefully**. Teach older children to avoid hand-to-mouth soil consumption.
    b. **Test levels of contaminants in and around areas where children play.**
    c. **Wash pacifiers and toys frequently.**
    d. **Wash pets and limit exposure to contaminated areas.**

8. **Use best practices with animals, including egg-laying chickens.**
(Recommendations outlined above in "Chickens and Egg production")

Policy Gaps and Areas for Future Consideration:

1. **Definitive safety standards are inconsistent.**
(US EPA, 2011; Gochfield and Burger, 2011; Kim, Poulson et al, 2014),
There are no definitive standards for soil contaminants for safe food production that reflect soil site conditions and management practices and standards vary between experts, including the EPA and University researchers, as well as between Canada, Europe and the United States. Further, tolerance levels must include the most vulnerable as a central part of a risk analysis, such as environmental justice communities.

2. **Standards for soils quality don't exist**.
(US EPA, 2011; USDA 2016)
Standards have not been established to regulate quality in soil. Standards currently exist for sewage sludge, soil imports, and contaminants in the final product, but not in the soil-growing medium. Without such regulations, gardeners can buy soil without knowing the true quality; don't have a guarantee that there are not contaminants are in it; and must test it rigorously to ensure safety.

3. **Resources and technical assistance for the public**
(US EPA, 2011; Kim, Poulson et al, 2014; USDA 2016)
Soil testing offered by County Extension services typically assesses soil health, in particular the presence and balance of beneficial elements for cultivation such as nitrogen, phosphorus, potassium, pH, and organic matter. Through the County Extension soil testing for lead can be obtained, it is often an "add-on" option at additional cost. While vitally important for food cultivation, these tests don't go far enough to understand the nature and extent of other toxic contaminants, where testing may require more extensive sampling and analysis.

Such services—which fall under the domain of "brownfield" conditions, are significantly more expensive and more time consuming, requiring strict protocols prescribed by US EPA. As such, brownfield assessments require either private funding or grant-funded resources that local and regional governments are eligible to receive through the EPA Brownfields program. Easier access among gardener/citizens to resources that support brownfield testing, better outreach and education campaigns at all levels of communication from direct outreach to database repositories is recommended; and alignment of recommendations between different authoritative bodies is suggested to reduce confusion.

Resources for Urban farmers and Gardeners:

Soil Testing and Technical support

Cornell University Department of Crop and Soil Sciences. Guide to Soil Testing and Interpreting Results. http://cwmi.css.cornell.edu/guidetosoil.pdf

Cornell Waste Management Institute. Soil Quality, Resources and Testing. http://cwmi.css.cornell.edu/soilquality.htm.

Groundwork USA's Brownfields Technical Assistance Program: Groundwork USA operates a technical assistance program and supports a community of practice for nonprofit and local government practitioners working to achieve equitable development and environmental justice in brownfield-affected communities. For those in need of "brownfield for community benefit" strategies, including development of a campaign to build will and gather resources for urban ag/greening projects on former brownfields: http://groundworkusa.org/ta-services/equidev-brownfields-planning

Johns Hopkins Center for a Livable Future: Soil Safety Resource Guide for urban farmers. http://www.jhsph.edu/research/centers-and-institutes/johns-hopkins-center-for-a-livable-future/_pdf/projects/urban-soil-safety/CLF%20Soil%20Safety%20Guide.pdf

University of Massachusetts Soil and Plant Testing Laboratory. According to USDA Urban Agriculture toolkit (2016) the UMass lab is one of the most affordable soil testing labs in the country and it does complete panel testing for metals. http://soiltest.umass.edu/services

United States Department of Agriculture's Urban Agriculture Toolkit. Provides comprehensive resources on business planning, testing, and contaminants of concern. http://www.usda.gov/documents/urban-agriculture-toolkit.pdf

Understanding Contamination

Agency for Toxic Substances and Disease Registry: http://www.atsdr.cdc.gov/

California Office of Environmental Health Hazard Assessment. A database with toxicity information on many chemicals. http://www.oehha.ca.gov/risk/ChemicalDB/index.asp

National Pesticide Information Center. Provides information about pesticides and related topics. http://npic.orst.edu/

Penn State University. Information about lead in residential soils, garden use of treated lumber, and other issues. http://cropsoil.psu.edu/extension/esi.cfm

US EPA's Cleanups in My Community Tool: Enables mapping of hazardous waste cleanup locations and grant areas and drill down to details about cleanups and grants, as well as other related information. https://www.epa.gov/cleanups/cleanups-my-community

US Environmental Protection Agency's Integrated Risk Information System (IRIS). Searchable database with information on the toxicity of numerous chemicals. http://cfpub.epa.gov/ncea/iris/index.cfm

Best Gardening and Farming Practices

Master Gardener Program. Led by the American Horticultural Society. http://www.ahs.org/gardening-resources/master-gardeners

Washington State University Cooperative Extension. Gardening on Lead- and Arsenic-Contaminated Soils. Additional information about arsenic and lead in garden soils.

Accessible at: http://cru.cahe.wsu.edu/ CEPublications/eb1884/eb1884.pdf

USDA National Institute of Food and Agriculture's Cooperative Extension System. This is a nationwide educational network, staffed by experts in agriculture working to identify and address current issues and problems in the local and national sphere. Find your local extension office here: https://nifa.usda.gov/partners-and-extension-map

Bibliography

Aelion, C., Davis, H., Lawson, A., Cai, B., McDermott, S. (2013.) Associations between soil lead concentrations and populations by race/ethnicity and income-to-poverty ratio in urban and rural areas. *Environ Geochem Health.* 35 (1), 1-12.

Betts, K. (2012.) CDC Updates Guidelines for Children's Lead Exposure*. Environmental Health Perspectives.* Vol 120, No 7.

Brown, S., Chaney, R., Hettiarachchi, G. (2015.) Lead in Urban Soils: A Real or Perceived Concern for Urban Agriculture? *Journal of Environmental Quality.*

Brulle, R., Pellow, D. (2006.) Environmental Justice: Human Health and Environmental Inequalities. Annu. Rev. Public Health. 27:103-24

Centers for Disease Control and Prevention. (n.d.) Blood Levels in Children: A CDC Factsheet. Retrieved online: http://www.cdc.gov/nceh/lead/acclpp/lead_levels_in_children_fact_sheet.pdf

Centers for Disease Control and Prevention. (2014.) What do Parents Need to Know to Protect their Children? Retrieved online: http://www.cdc.gov/nceh/lead/acclpp/blood_lead_levels.htm

Clark, H., Brabander, D., Erdil, R. (2006.) Sources, sinks, and exposure pathways of lead in urban garden soil. *Journal of Environental Quality.* 35(6).

Datko-Williams, L., Wilkie, A., Richmond-Bryant, J. (2014). Analysis of U.S. soil lead (Pb) studies from 1970 to 2012. *Science of the Total Environment.* 468–469, 854–863.

Gochfeld, M., Burger, J. (2011.) Disproportionate Exposures in Environmental Justice and Other Populations: The Importance of Outliers. *American Journal of Public Health.* 101 (S1).

Horak, K., Chipman, R., Murphy, L., Johnston, J. (2014.) Environmental Contaminant Concentrations in Canada Goose Muscle: Probabilistic Risk Assessment for Human Consumers. *Journal of Food Protection.* 77 (9).

Hwan-Cheol, Kim, et al. (2015). "Evaluation and management of lead exposure." *Annals of Occupational and Environmental Medicine.* 27(30).

Kaiser, M., Williams, M., Basta, N., Hand, M., Huber, S. (2015.) When vacant lots become urban gardens: Characterizing the perceived and actual food safety concerns of urban agriculture in Ohio. Journal of Food protection. Vol 78, No 11, pp 2070-2080.

Kim B., Poulsen M., Margulies J., Dix K., Palmer A.. (2014.) Urban Community Gardeners' Knowledge and Perceptions of Soil Contaminant Risks. PLoS ONE 9(2).

McBride, M., Shayler, H., Spliethoff, H., Mitchell, R., Marquez-Bravo, L., S. Ferenz, G., Russell-Anelli, J. Casey, L., Bachman, S. (2014) Concentrations of lead, cadmium and barium in urban garden-grown vegetables: The impact of soil variables. *Environmental Pollution*. 194: 254-261.

Mielke, H. W., E. T. Powell, A. Shah, C. R. Gonzales, and P. W. Mielke. (2001.) Multiple metal contamination from house paints: consequences of power sanding and paint scraping in New Orleans. Environ. Health Perspect. 109:973–978.

Minnesota Institute for Sustainable Agriculture (MISA). (2010.) Urban Gardens and Soil Contaminants: A Gardener's Guide to Healthy Soil. Retrieved online: http://www.misa.umn.edu/prod/groups/cfans/@pub/@cfans/@misa/documents/asset/cfans_asset_287228.pdf

Mitchell, R., Spliethoff, H., Ribaudo, L., Lopp, D., Shayler, H., Marquez-Bravo, L., Lambert, V., Gretchen S. Ferenz, G., Russell-Anelli, J., Stone, E., McBride, M. (2014.) Lead (Pb) and other metals in New York City community garden soils: Factors influencing contaminant distributions. *Environmental Pollution.* 187:162-169.

Schwarz, K., Pickett, S., Lathrop, R., Weathers, K., Pouyat, R., Cadenasso, M. (2012). The effects of the urban built environment on the spatial distribution of lead in residential soils. *Environmental Pollution*. 163:32-39.

Shayler, H., McBride, M., Harrison, E. (2009.) Guide to Soil testing and interpreting results. *Cornell Waste Management Institute.* Retrieved online: http://cwmi.css.cornell.edu/guidetosoil.pdf

Shayler, H., McBride, M., Harrison, E. (2009.) Sources and Impacts of Contaminants in Soils. *Cornell Waste Management Institute.* Retrieved online: http://cwmi.css.cornell.edu/sourcesandimpacts.pdf

Spliethoff, H., Mitchell, R., Ribaudo, L., Taylor, O., Shayler, H., Greene, V. Oglesby, D. (2014) Lead in New York City community Garden Chicken Eggs: Influential factors and health implications. *Environ Geochem Health.* 36:633-649.

Stehouwer, R. (2002.) Environmental Soil Issues: Garden Use of Treated Lumber. *Penn State College Extension*. Retrieved online: http://extension.psu.edu/plants/crops/esi/treated-lumber/extension_publication_file

United States Department of Agriculture. (2016.) Urban Agriculture Toolkit. Retrieved online: http://www.usda.gov/documents/urban-agriculture-toolkit.pdf. 27pp.

United States Environmental Protection Agency (2005.) Successful Rail Property Cleanup and Redevelopment. Lessons learned and guidance to get your railfields projects on track.

Retrieved online: https://www.epa.gov/sites/production/files/2015-09/documents/05_railfields.pdf. 24pp

United States Environmental Protection Agency. (2007.) Framework for Metals Risk Assessment. Office of the Science Advisor, Risk assessment forum. Retrieved online: https://www.epa.gov/sites/production/files/2013-09/documents/metals-risk-assessment-final.pdf. 172pp.

United States Environmental Protection Agency. (2011.) Brownfields and Urban Agriculture: Interim guidelines for safe gardening practices. Retrieved online: https://www.epa.gov/sites/production/files/2015-09/documents/bf_urban_ag.pdf

United States Environmental Protection Agency. (2014.) Fight Lead Poisoning with a Healthy Diet. Retrieved online: https://www.epa.gov/sites/production/files/2014-02/documents/fight_lead_poisoning_with_a_healthy_diet.pdf

United States Environmental Protection Agency. (2015.) Brownfield Overview and Definition. Retrieved online: https://www.epa.gov/brownfields/brownfield-overview-and-definition

United States Environmental Protection Agency. (2015.) Land Revitalization Fact Sheet: Urban Agriculture. Retrieved online: https://www.epa.gov/sites/production/files/2015-08/documents/fs_urban_agriculture.pdf

United States Environmental Protection Agency. (Updated 2016.) Cleanups in my Community Tool. Retrieved online: https://www.epa.gov/cleanups/cleanups-my-community

World Health Organization International Agency for Research on Cancer. (2006.) , Inorganic and Organic Lead Compounds. *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans.* 87

Wortman, S., Lovell, S. (2013.) Environmental Challenges Threatening the Growth of Urban Agriculture in the United States. J. Environ. Qual. 42:1283–1294