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Lead Levels in Urban Gardens

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Abstract

In the early 1890's during the depression, land was donated for gardening by the unemployed. By the early 1920's, civic beautification campaigns in many parts of the country included gardens on vacant lots and at school sites. War gardens became popular first as the US School Garden Army during WWI (1917-1919) and as Victory Gardens during WWII (1941–1945). The popularity of urban gardens have subsided and reoccurred many times since the 50's and are popular once more.

Presently, school and community gardens are used as resources to inform students and the general population about nutritious food choices and for providing fresh produce for home use and food banks. Students in the UC Davis chapters of a national organization are involved in development of community gardens for the homeless in Sacramento, CA. Understanding that lead content may be a major concern in potential gardens sites that once had homes built during an earlier era, the first concern for members of the organization was to analyze the soil for specific metal contaminants, especially lead.

Introduction

According to Lawson [1], Mayor Pingree (Detroit, IL) proposed and promoted production of Pingree Potato Patches on donated vacant lots during the depression of 1893. Following the success of these gardens, others were created in Boston, Chicago, New York and Philadelphia. As noted in Figure 1, the popularity of urban gardens subsided and rose again during various times in US history. By the 1970's the American Community Gardening Association was formed by activists across the country.

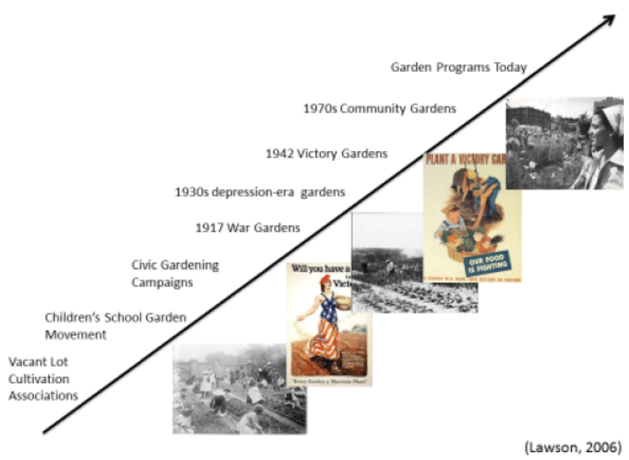

Figure 1: Community Garden Development in the US.

Today, nonprofit organizations like the Center for Land-Based Learning (Winters, CA) promote urban farming in West Sacramento, CA and other locales through its California Farm Academy (Figures 2a,2b,3a and 3b) [2]. Also, urban farming was promoted in an exhibit at the 2014 California State Fair (Figure 3c).

Figure 2a: Amending the soil for urban farming in West Sacramento, CA.

Figure 2b: Early stages of garden. Center for Land-Based Learning West Sacramento Urban Farm Program, 2014. Center for Land-Based Learning West Sacramento Urban Farm Program, 2014.

Figure 3a: Ready for harvest, urban farming in West Sacramento, CA.

As in many urban centers, Sacramento, CA also supports development of community gardens. Presently, two gardens for the homeless are under development in the Alkali Flats area of Sacramento, characterized by beautiful old homes and revitalized small to medium size businesses. A typical vacant lot donated for garden development is shown in Figure 4. The project is affiliated with a UC Davis student organization (Multiculturlism in Agriculture, Natural Resources and Related Sciences, MANRRS). Under the supervision of their advisor, members of the organization decided to assess content of specific metals in surface and subsurface levels of soil at the 3 initial sites (Figure 5). This paper reports results of the research.

Figure 3b: Innovative planter boxes. Center for Land-Based Learning West Sacramento Urban Gardening Program, 2014.

Figure 3c: 2014 State Fair urban farming exhibit. Center for Land-Based Learning West Sacramento Urban Gardening Program, 2014.

Figure 4: Early 1900's home site adjacent to an industrial area slated for development of a community garden. MANRRS, 2013.

Figure 5: MANRRS members -from right, 1st (Gaby Pedroza) and 3rd (Matthew Warren) - at a potential garden site.

Figure 6: A malleable piece of lead found in a garden site. MANRRS, 2014.

Metals and Other Elemental Contaminants

Several elements - occurring where unwanted or in forms/ concentrations that are detrimental to humans and the environment - can be considered contaminants [3,4]. Some contaminating elements are metals such as mercury, lead, cadmium, thallium and beryllium; some are non-metals (fluorine) while others fall into an intermediate class called semi-metals (for instance, arsenic and selenium). Hawkes [5] noted that several of the toxic metals are dense and are sometimes called 'heavy metals' that are >0.18 ounce, oz/0.39 inches^3, in^3 (>5 grams/centimeter^3, >5 g/cm^3) while Duffus [6] disagreed with use of the terminology because toxicity is not always associated with density or heaviness. Indeed, many dense elements have little toxicity (rare earths elements such as cerium, lanthanum and yttrium) or are so uncommon that they are 'precious' metals–gold and platinum [7]. More complicated are the transition metals (for instance, iron, chromium, manganese and nickel) that are indeed relatively dense and required by humans and other organisms in appropriate concentration ranges for proper health [4,8].

There are 5 elements that have no known beneficial role in human, other animal health or in plants [4]. Cadmium, produced from melting copper ores, iron or zinc, is used to make batteries, plastics and as a possibly restricted pigment in paints [4,9]. The use of thallium in rat poison has been banned in the US; it is mainly used in chemical and medicinal (nuclear imaging) research [10]. Presently, beryllium is primarily used in highly specialized industrial operations, for instance, as metal alloys for aerospace operations, in nuclear reactors or as an alloy and an oxide in microwave ovens and electrical equipment [11]. Uranium is extensively used in military munitions and nuclear reactors [12]. Lead is the most widespread insoluble heavy metal due to long-term use in paint and gasoline [4,13] (Figure 6). Small amounts occur naturally; therefore, it can be detected anywhere. Some plants are highly tolerant and may accumulate large concentrations while others absorb iron very slowly [14].

For the purpose of urban gardening, there are two major questions relative to elemental contaminants. Which toxic elements might occur in the soil? What are their plausible pathways for human exposure? Some elements can be found in water soluble forms, and can be taken up by plant roots, leading to ill effects in the plants or in those who consume them. Elements which are not water soluble may still be taken up on fine particles swept along in the water or may cause exposure as dust that is inhaled, licked off children's fingers or consumed from the surface of produce [4].

Figure 7: Lead based paint. CLEARCorps/Detroit|A Brief history of lead, clearcorpsdetroit.org.

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Lead Poisoning

As the most widespread heavy metal, lead has been used by societies in ancient and modern history. It was found in the 6,400 B. C. Neolithic settlement of Çatalhöyük in central modern day Turkey [15]. Ancient Roman society was the first group in recorded history that incorporated lead into daily products such as face powders, mascaras and rouges as well as a pigment in many paints [15]. Also, lead was used as an additive to heighten the sweet taste of wine and in lead pipes for water transport systems [15].

As a dense, soft and malleable metal, lead has useful physical and chemical properties; as such, before it was considered a health hazard, lead was added to many US products to enhance performance. In the early 1900's, lead was found in US gasoline, paints and pipes (Figure 7).

Since the 1990's, numerous studies have confirmed the dangerous side-effects of lead for adults and its neurotoxicity in growing children [16]. It is well known that lead poisoning has greater effects on fetuses and young children than on adults due to the rapidly developing nervous systems of the young. The adverse effects for children include permanent damage to the brain and nervous system, lower IQ, behavioral problems and slow growth [16].

Magyar et al. [17] elucidated the etiology of neurotoxicity by revealing the effect of lead binding in proteins needed for human metabolic function. Due to its cationic property, lead has the ability to compete with zinc (Figure 8). Zn (II) binds in a 4-coordinate mode with sulfur in proteins while lead (II) binds in a 3-coordinate lead (II)–sulfur mode. Altered geometry due to the binding of lead causes improper function/dysfunction of proteins, leading to developmental toxicity related to childhood lead poisoning.

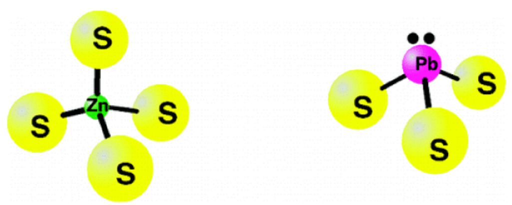

Figure 8: Lead (Pb) binds with three sulfur groups of proteins to replace zinc (Zn) that binds with four sulfur groups. The geometry of the proteins is altered due to Pb binding, thereby changing their functionality and ultimately leading to symptoms of lead poisoning, especially in children [17].

Figure 9 shows a painter with the characteristic wrist drop (peripheral neuropathy) caused by licking the tip of his brushes to produce fine points, thereby constantly exposing himself to lead [18]. In adults, consuming a dangerous amount of lead increases infertility in women, promotes cardiovascular disease, decreases mental activity and reduces red blood cells causing anemia [19].

As noted above, before lead was confirmed as a neurotoxin, it was widely used in gasoline and paints. In the US, the Lead-Based Paint Poisoning Prevention Act was signed into law in 1971; it was followed by the 1990 Clean Air Act, prohibiting use of lead in many products [20,21]. Use of lead in gasoline and paint in the past explains the reason why urban soil, especially in industrial areas, tends to contain higher levels of lead than that in rural areas. For homes built before 1940, building age in the strongest statistical predictors of lead in soil [22].

Figure 9: American painter with characteristic wrist drop caused by neurological damage from high lead exposure in paint [18].

Paint from older homes is deposited in soil due to exterior deterioration, remodeling, renovation (blasting, sanding and/or scraping) and/or weather [22]. Thus, it is particularly important to assess lead content in older home sites slated for development as urban gardens.

Specific Metals and Lead in 3 Sites

Collecting soil samples

Initially, 3 project sites (Lots 1, 2 and 3) were sampled for content of specific metals and subsequently, lead, during the winter of 2013. Lots were divided into 3 regions of approximately equal size and further subdivided into right and left areas creating 6 sub sections per lot. Triplicate samples of surface soil at 0 to 4 in (0 to 10.16 cm) and subsurface soil at 12 to 16 in (30.48 to 40.64 cm) were collected from each sub region. Precautions were taken to avoid inclusion of organic matter in samples. Depending on the size of the lot, samples were taken at 10 to 20 feet (3.05 to 6.10 meters) apart. Samples from the right and left side of each lot were pooled and analyzed in duplicate for metal content. Triplicate samples of each subsections were collected and combined for analysis in duplicate for lead content.

Analysis for metals and Lead

Soil samples (0.035 oz, 1 g) were mixed with concentrated nitric acid in a 1:1 ratiofor 12 to 16 hours to dissolve organic material and present metals in their elemental forms. Mixtures were placed in a sonicator (for vibration) with heating in a fume hood for 1 hour, then diluted in deionized distilled water at 1:10. Samples of the solutions were analyzed in an Inductively Coupled Plasma Mass Spectrometer (Department of Civil and Environmental Engineering, University of California, Davis, CA).

Specific metals and Lead in soil of 3 lots

Except for lead, analysis showed no abnormally high concentrations of specific metals in the soil of each lot. The screening level for lead is set at <400 parts per million (ppm, milligram/kilogram) and is meant to note a safe level for children playing in residential soil [23,24]. Soil was analyzed to determine levels that exceeded this standard (<400 ppm) and new recommendations proposed by the Technical Review Workgroup of the Environmental Protection Agency [24].

The initial analyses for determination of overall lead content for each lot. This information along with established and proposed recommendations was used to decide if further analyses were warranted for any particular lot. Except for quantity of lead (641.5 ppm) in the left side subsurface of Lot 3, all levels for lots were <400 ppm. This value for lead (641.5 ppm) indicated that more analyses should be conducted in Lot 3 (dubbed the Long Lot because of it shape).

Determination of Lead in the Long Lot

Collecting soil samples

During spring of 2013 and winter of 2014, the Long Lot was divided into approximately 3 equal regions from left to right and regions were further subdivided into 3 sections from front to rear to produce 9 sub sections (Figure 10,11a and 11b). Triplicate samples were collected from each sub section.

Figure 10: Sub sections of Lot 3, the long lot in alkali flats (Sacramento, CA). MANRRS, 2013.

Figure 11a: MANNRS members, Lupe Pena, removes organic matter to sample soil and b. Wendy Chen, samples the subsurface. MANRRS, 2014.

Figure 11b: MANRRS, 2014.

Analysis for Lead

Samples from subsections were combined and analyzed in duplicate as delineated above for subsurface soil.

Subsurface Lead in Long Lot Soil

Results from analysis of subsurface lead content in the Long Lot during spring of 2013 and winter of 2014. The first observation is that in 2013, there were some extremely high levels of lead in the soil of the Long Lot. These high values (>2,000 ppm) may have been caused by rusted lead pipes, pieces of lead (Figure 6), old paint cans and other industrial waste illegally dumped on the lot. These items, when exposed, were removed along with debris in 2014. The second observation is that lead content for 2014 was lower than that for 2013. By winter of 2014, various groups were prematurely removing small trees and roots and tilling the soil for planting. As well, some small garden plots within the Long Lot had been planted and partially harvested (Figure 12).

Figure 12: Premature tilling and planting of vegetables causing mixing of soil in the Long Lot during winter of 2014. MANRRS, 2014.

Undoubtedly, mixing the soils at varying levels affected the results for 2014. However, results for both years indicated that for most sub regions (9), lead levels exceeded 400 ppm, because lead content in the Long Lot exceeded limits for planting in the soil, planter boxes with permanent barriers (Figure 13a and 13b) are being used and precautions will be taken to cover paths and picnic areas.

Figure 13a: Planter boxes with barriers in the long lot.

New Recommendations for Lead in Gardens

In December, 2013, the TRW, composed of representatives from all regions of the US (the U.S. EPA Office of Solid Waste and Emergency Response/Office of Superfund Remediation and Technology Innovation) met to discuss new recommendations for lead content in gardens. As stated above, the present CADPH (2014) recommended screening level for lead in bare soil is <400 ppm. The TRW recommended new levels and practices as delineated [24]. A much lower safe level for lead content (<100 ppm) in gardens was proposed because not all gardening exposure pathways for lead are included in the development of the soil screening levels (<400 ppm) set for the safety of children playing in soil. The TRW recommendations account for (a) consumption of home-grown produce, (b) lengthy duration of soil contact, (c) possible ingestion of soil during gardening activities and (d) exposure to soil tracked into homes [24].

Figure 13b: Planter box with soil in the long lot.

Using these new recommendations from TRW for safe levels of lead in gardens, only Lot 1 would be safe for gardening while gardeners in Lot 2 with 100–400 ppm of lead should follow precautions provided [24]. Additionally, gardeners should use plants that absorb lead slowly (Figure 14). These plants include apples, melons, okra, oranges, peppers, beans, corn and peas (Craigmill and Harivandi 2010). Gardeners using the Long Lot would continue to use planter boxes with barriers and/or all other precautions set forth.

Figure 14: Corn, grown in Lot 2 (containing 100 to 400 ppm lead) due to its lower lead uptake. MANRRS, 2014.

We concluded that development of fast, accurate kits that analyze lead in various ranges from 0 to 2000 ppm would be of value to several community groups or individuals with plans to use urban sites for gardens (Figure 15). This is particularly applicable for sites where houses were built prior to 1970.

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Figure 15: (a) Director of community garden project, Janet Little, reveals plans (b) for use of planter boxes in the Long Lot due to analysis of high lead content.

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