K·STATE Research and Extension

Gardening on Lead-Contaminated Soils

Department of Agronomy | MF3166 | Soil Quality

Human health effects of lead

Lead affects everyone. Lead accumulates in humans, and the body releases that lead slowly. Children between the ages of 6 months and 5 years have been found to be the most vulnerable to lead toxicity. The Centers for Disease Control and Prevention (CDC) currently considers 5 μg dL^{-1} as the threshold for "elevated" blood lead, while pointing out that no safe blood lead level in children has been identified (CDC, 2012).

Published studies identify an inverse relationship between blood lead concentrations and arithmetic and reading scores for children with blood lead concentrations lower than 5.0 μg dL^{-1}. It is important for pediatricians to screen for childhood lead exposure levels during well-baby visits. In addition to nutritional concerns, parents should be aware of the hazards of peeling lead-based paints, especially in older houses, as well as the importance of early (6 months) and routine lead screening.

Lead and its historical use

Lead is a soft, gray-colored metal that occurs naturally in the earth's crust. Although it is very dense, it can be molded and shaped easily.

These properties make lead useful in a wide range of industries, including paint and transportation fuels (Table 1). Its high density also makes it a suitable product to use as ammunition. Lead was added to paints to improve its appearance and speed the drying process. Because of its resistance to corrosion, lead was used extensively to paint houses, bridges, and other materials that could be exposed to air and water. It was added as an organic lead compound (tetraethyl lead or TEL) to gasoline as an effective octane-booster and to reduce the "knocking" that occurs in combustion engines of motor vehicles and piston-powered aircraft engines (Table 1). It is also used in the production of acid-batteries. The use of lead arsenate as a pesticide in orchards was widespread in the early 1900s. Lead arsenate can still be found in many orchard soils.

Why do urban soils have high lead levels today?

Mean lead concentrations in uncontaminated surface soils (0 to 15 cm) of the United States are 22 mg kg^{-1} (Smith et al., 2013). Concentrations of the metal are often reported as parts per million (ppm). One ppm of lead is the equivalent of 1 milligram of lead per kilogram of that medium.

Human activities are the main cause of high levels of lead in urban soils. Soil dusts from former mining sites and airborne particles from smelting metals deposited lead on surface soils.

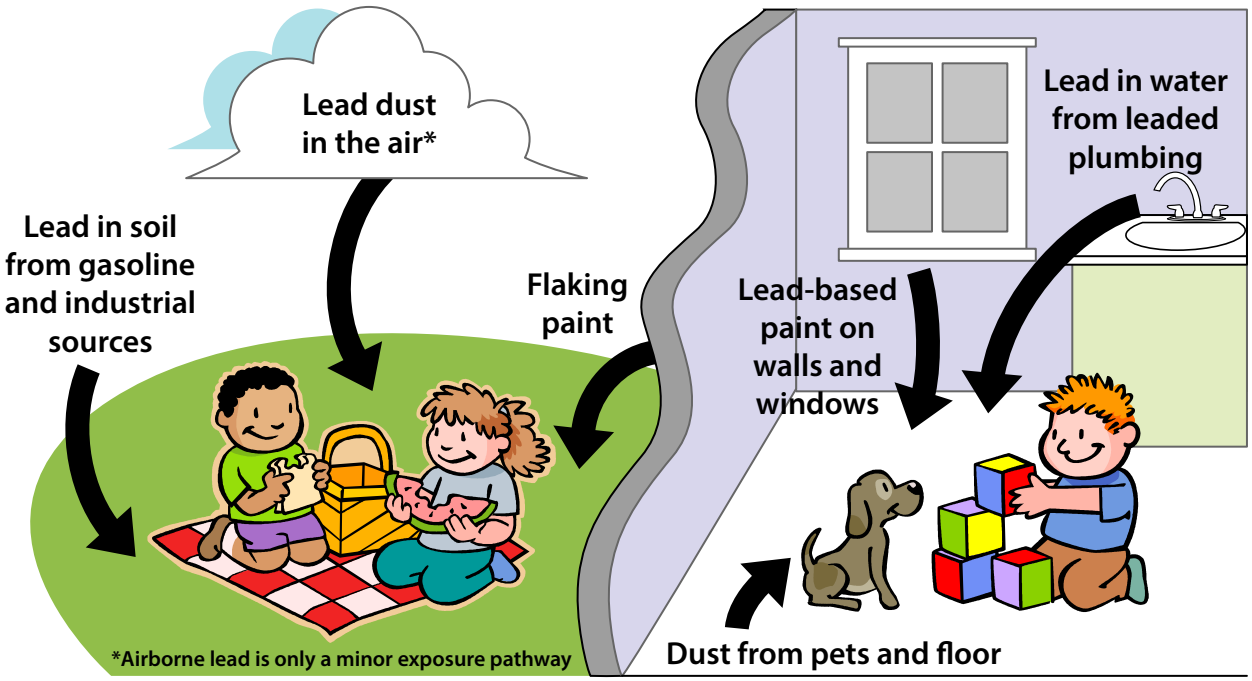
Before being outlawed in the United States in 1986, automobile emissions from gasoline-powered engines led to significant deposition of the organic compound (TEL) on the surrounding soils. Urban soils in city centers exposed to heavy automobile traffic have higher lead concentrations than suburban or rural areas with reduced traffic volumes.

Another potential source of contamination is paint. Most houses built before 1978 were painted with lead-based paint. The deterioration of these homes over several decades due to poor maintenance or harsh environmental conditions can result in paint chips or deposits near the sides of these homes (Figure 1).

Table 1. *Historical uses of some lead compounds/substances*

Substance	Previous Use	Year banned
Lead-based paint	Used as a pigment in paint for houses, bridges, metal structures, and roads. It improves the paint's appearance, speeds up the drying process, and resists moisture (corrosion increases with increasing moisture).	1978†
Tetra-ethyl lead	Mixed with gasoline as an anti-knocking agent (increases fuel efficiency and vehicle performance).	1986
Lead arsenate	Used in pesticides for control of codling moth in apple orchards and other insect pests on agricultural fields.	1988

Figure 1. *Lead exposure in the home environment*



Studies show lead levels in urban soils may range from 50 to about 3,000 mg kg^{-1}. The demolition of old homes; wastes generated from former paint factories; and shops that either fabricated or recycled metals, often within a small geographic area, account for the heterogeneity of soil lead distribution in urban environments.

Some residential properties now are sited on land previously used for industrial activities that contributed to high levels of lead in the soil (Table 2). Preventing housing growth on contaminated soils could be assisted by soil testing before construction. However, soil tests are often overlooked or even ignored due to the pressure for housing. Moreover, movement of lead through soil is slow; hence, even though the use of these contaminants was banned (lead-based paint – 1978; TEL – 1986; lead arsenate – 1950s) over many decades, they can still pose health problems to residents.

What are the regulations for gardening on urban soils?

Currently, there are no set regulations for gardening on urban soils. The Office of Solid Waste and Emergency Response residential soil screening level for lead, also used as the upper limit for child play areas by the United States Environmental Protection Agency (EPA), is 400 mg kg^{-1}. However, both published (Attanayake et al., 2014; Defoe et al., 2014) and unpublished scientific studies have expressed some concerns about gardening on soils with lower lead concentrations. Figure 2 summarizes suggested actions that should be followed if soil test results report lead concentrations in the specified range provided.

Exposure pathways

Exposure to lead in soils primarily happens in two ways, direct exposure to lead-contaminated soil or exposure to plants that grew in lead-contaminated soil.

Soil-to-human exposure

This mainly involves direct exposure either by ingesting the soil or breathing contaminated dust. Incidences include:

a. Children playing in the garden may ingest the soil.
b. Eating root crops without proper washing to remove soil or dust particles.
c. Children prone to pica activities (abnormal desire to eat substances not normally eaten) may ingest soil present under their fingernails or around their hands.

Soil-to-plant/plant-to-human exposure

Plants grown on contaminated soils may accumulate lead in their root and shoot systems; however, research has shown that most plants do not absorb high amounts of lead into their systems. Some crops

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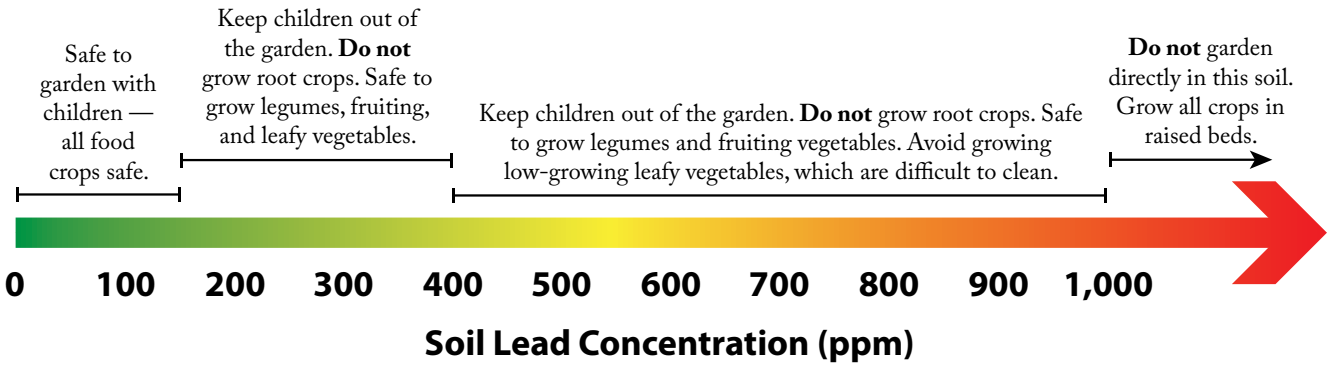
Table 2. *Common urban soil contaminants and their sources (modified Angima and Sullivan, 2008).*

General source	Examples of previous site uses	Specific contaminants
Paint (before 1978)	Residential buildings; mining; leather tanning; landfill operations; aircraft component manufacturing	Lead
High-traffic areas or near roadways	Next to roadways or highways; near roadways built before leaded fuel was phased out	Lead, zinc, polycyclic aromatic hydrocarbons (PAHs)
Treated lumber	Lumber treatment facilities; structures built with treated lumber	Arsenic, chromium, copper, creosote
Burning wastes	Landfill operations	PAHs, dioxins
Contaminated manure	Copper, zinc salts added to animal feed	Copper, zinc
Coal ash	Coal-fired power plants; landfills; homes with coal furnaces	Arsenic, selenium, cadmium, sulfur
Biosolids	Wastewater treatment plants; agriculture	Cadmium, copper, zinc, lead, persistent bioaccumulative toxins (PBTs)
Petroleum spills	Gas stations; residential/commercial/ industrial uses (anywhere an aboveground or underground storage tank is or has been located)	PAHs, benzene, toluene, xylene, ethyl benzene
Pesticides	Widespread pesticide use in orchards; pesticide formulation, packaging, and shipping	Lead, arsenic, mercury, chlordane, dichlorodiphenyltrichloroethane (DDT), and other chlorinated pesticides
Commercial or industrial site use		PAHs, petroleum products, solvents, lead, and other heavy metals (e.g. cadmium, arsenic, chromium, lead, mercury, and zinc)
Dry cleaners		Stoddard solvent and tetrachloroethene (TCE)
Metal finishing operations		Metals and cyanides

Figure 2. *Soil lead level limits for growing food in gardens*



[†]*Assume soil testing for lead with EPA Method 3051A*

absorb more lead than others. Root crops such as carrots and beets are more prone to lead absorption than leafy vegetables. If grown in highly contaminated soils (lead concentrations greater than 1,000 mg kg^{-1}) and poor soil conditions (low pH and organic matter), eating the edible portions of leafy vegetables may become a concern. If in doubt, take a soil sample to your local extension office or college/university.

Factors to consider when growing on urban soils

Nutrient level and soil pH

Urban soils often have low levels of soil nutrients. They suffer from heavy compaction and erosion losses. The alteration of the natural soil profile has been chiefly responsible for the degradation in soil structure and texture (major factors affecting the movement of water in soils). Hence, fertilizer and/or organic manure additions are required to improve soil fertility levels and improve the soil structure. Recent studies have shown that organic matter inputs on moderately (100 – 400 mg kg^{-1}) contaminated lead soils reduce lead uptake in vegetables.

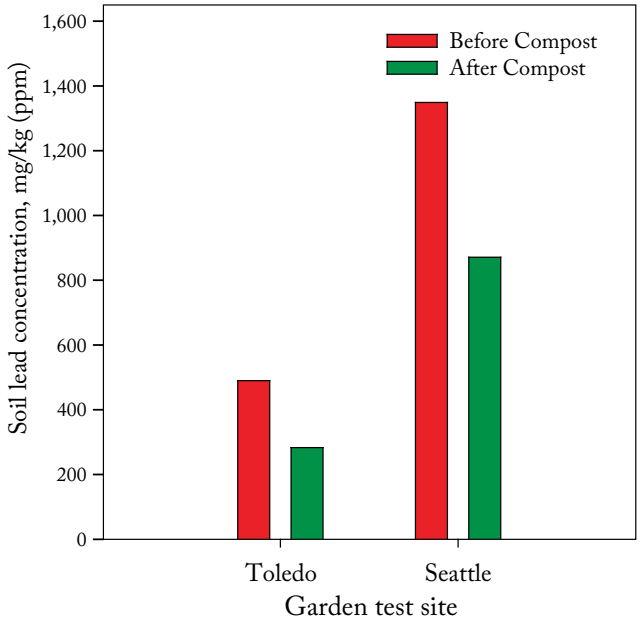
Sources of this organic matter include kitchen/local composts, animal manure, and treated biosolids. Suitable recommended mix ratios of the manures can vary between 30 to 50 percent. Compost addition helps dilute the total lead concentration in soils (Figure 3), making it less bioavailable (the extent to which it can be used by the body). If soil pH tests are low (less than 6.5), consult your local K-State Research and Extension agent about ways to improve your soil pH. Lime (calcium carbonate) additions are usually done to the soil to achieve a desired soil pH in the range of 6.8 to 7.5.

Choosing your crop

If you have tested your soil and found the lead levels to be greater than 400 mg kg^{-1}, then you should mainly grow leafy and fruiting vegetables. Fruiting vegetables such as eggplant, tomatoes, and peppers are recommended on mildly elevated soils. The outer leaves of the vegetables should be discarded and the vegetable should be thoroughly washed in prepared solutions (1 tablespoon of vinegar or liquid detergent dissolved in about a gallon of water).

With root crops (e.g., carrots, beets, radishes, or potatoes) grown on soils where lead concentrations are below 400 mg kg^{-1}, it is advisable that the washing procedure be conducted before peeling. Soil particles

Figure 3. *Soil lead concentration at two urban gardens before and after compost addition*



bound tightly to the root surfaces may be accidentally ingested when eating raw carrots. Research has shown that more than 80 percent of lead in the soil is bound to fine clay particles. Additionally, it is well established that surface contamination can cause much more damage than what is absorbed by plants.

Where do I find help?

Most universities have extension outreach services where basic soil tests and interpretation can be done. Gardeners can contact their local K-State Research

Photo 1. *Raised beds at Tacoma, Washington garden. Contamination of this site has been attributed to dust deposits from a copper smelter that operated in Ruston, Washington (5 miles away) for more than 100 years. (photo Phillip Defoe)*

and Extension office for information on safe gardening and soil testing. University soil testing labs may provide basic tests to give an idea of lead risk in soils at a reasonable price. Extension educators can offer technical advice on soil contaminant and nutrient levels and recommend the suitability of gardening on your soil. Community garden volunteers and organizers also should consider having soils tested and clearly communicate the results to gardeners at the work site. Extension offices also coordinate a program called Master Gardeners, which offers training to home gardeners, and is an excellent opportunity to learn from other local gardeners.

Other practices to follow when gardening in lead-contaminated soil

- Keep a watchful eye on children when they are in the garden to monitor their activities.
- Always wear gloves when gardening. Immediately after gardening, wash your hands thoroughly with soap and shower.
- Keep garden attire separate and wash it in a different load than your other clothes. Clean garden tools and shoes thoroughly and keep tools and garden attire away from toddlers.
- In a moderately contaminated soil, raised beds are encouraged, but they should be tested annually for soil lead. Composted manure should be added to the top 3 to 4 inches, and mixed thoroughly.
- Avoid heavy tilling of the soil, particularly if the soil is sandy, because this could stir up dust particulates, increasing aerial deposition on nearby crops/vegetables. The use of a dust mask is strongly encouraged when weeding or during tillage.
- Ground covering should be used and garden pathways should not be left bare. The use of cover crops is recommended after fall harvesting. It helps provide nutrients to the soil when incorporated the following year and serves as a protection from wind.
- Avoid smoking when gardening because of the contact between your hands and mouth.
- Fencing may help prevent stray animals from burrowing through the garden.

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For more information

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Phillip P. Defoe, Ph.D.
Former Graduate Student
Department of Agronomy

DeAnn Presley, Ph.D.
Associate Professor
Soil Management Specialist

Ganga M. Hettiarachchi, Ph.D.
Associate Professor
Soil and Environmental Chemistry

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