Risks and benefits of gardening in urban soil; heavy metals and nutrient content in Los Angeles Community Gardens (1021)

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Overview:

- Community gardens in Los Angeles provide food, medicinal and aesthetic ecosystem services to participants
- Soil properties are an important aspect of urban agriculture within local control, impacting both biodiversity and plant abundance
- Urban soils can build up toxic heavy metals through pollution and legacy effects, affecting garden participant health
- Study focus: Interaction of gardener soil management and the presence and mobility of soil heavy metals

Key Results:

- Garden soils show long term evidence of overfertilization with high P and K fertilizers
- Arsenic, Cadmium, Copper and Lead show elevated levels in neighborhoods near community gardens
- Organic matter content mobilizes As, while immobilizing Cd and Cu.

Long Term Project Goals

1. Survey and compare community garden biodiversity and species uses across multiple years
2. Investigate how management activities and cultural practices impact ecosystem service production
3. **Assess garden and neighborhood soil nutrients, organic matter, and metal content**

Objectives and Methods

1. **Assess garden soil nutrients and organic matter**

Methods:

- Summer 2011: 6 gardens (3 immigrant gardens and 3 non-immigrant gardens) were selected out of our 13 surveyed gardens.
- Soil cores (15 cm deep) obtained from 6-10 garden plots
- Uncultivated public soils outside the garden collected for comparison
- Samples tested for pH and organic matter content and N, P, and K content.
- Summer 2012: soils from plots and outside in 7 other gardens tested for pH and organic matter

2. **Test soils for heavy metal content and metal accessibility**

Methods:

- Soils collected in 2011-12 were analyzed for total heavy metal content of 48 different elements using ICP/AES.
- Sub-sample of 42 plots and 26 outside locations subjected to sequential metal extraction at University of Pittsburgh
- 0.25 g sample of soil was treated with 0.11 mol acetic acid; extract was then analyzed with ICP/AES.
- This extracted fraction represents the fraction of exchangeable metal readily available to crop species through cation exchange mechanisms.

Hypotheses:

1. **Nutrient and OM content in plots will depend on individual gardener management decisions**
2. **Legacies of past urban development and on-going air pollution depostion will cause elevated levels of metals**
3. **Exchangeable metal fraction will decrease with higher OM in soils due to organic sequestration**

Funding Sources:

Table 1: Characteristics and biodiversity from 13 sample gardens

	Total	Immigrant Garden	Non-immigrant Garden
No. of gardens	13	7	6
Avg. Values		**Garden Info**	
Household Income	$46,800	$36,900	$58,400
Garden age	24	19	30
Garden size (M^2)	3121	2830	3460
Plot size (M^2)	31	25	38
# of plots	531	333	198
Total values		**Species Survey**	
No. of species	648	366	412
No. of plot species	544	346	407
Edibles	211	170	161
Medicinals	40	25	31
Ornamentals	405	157	230

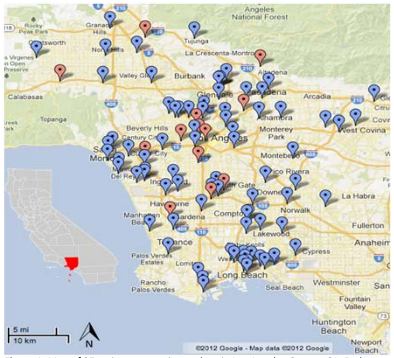
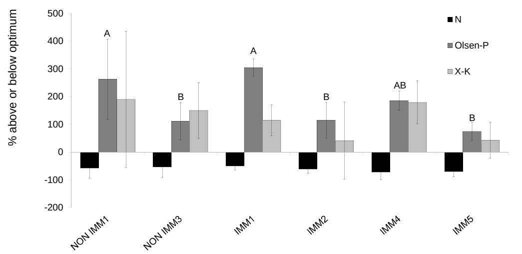


Figure 1: Map of 95 active community gardens in Los Angeles County, CA. Red dots denote 14 surveyed gardens. Inset CA map shows the location of Los Angeles County in the state.

Section 1: Nutrients and organic matter



	Nitrogen (NO_3^- and NH_4^+)	Phosphorous	Potassium
Optimum levels	15-25 ppm	40-60 ppm	150-200 ppm

Figure 2: Percent N, P, K above or below optimum levels for agriculture in 6 selected gardens. Error bars represent standard deviation. Bioavailable forms of N (NO_3^- and NH_4^+) and P (Olsen-P) and exchangeable K (X-K) were measured. While N is low in all locations (and does not vary), P and K levels range into 2-3 times the recommended levels. N and K levels are consistent across all gardens, though K is variable within gardens. P is significantly higher in two gardens (significance is indicated by different letters) which provide free fertilizer for all gardeners.

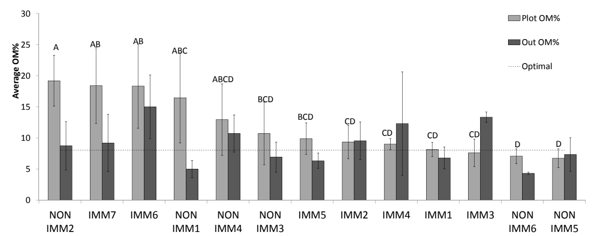


Figure 3: Percent organic matter (OM) content in plots and outside soils in 13 sampled gardens. Error bars denote standard deviation within a garden. The dotted line denotes the lowest desirable level of OM for agricultural soils (optimal levels range between 8-15%). Significant differences between garden plots are denoted with different letters. Outside locations were variable and no neighborhood had significantly higher levels. Generally, garden plots contain higher levels of OM than nearby uncultivated locations, with the exception of a few gardens with below optimal OM levels. Gardens with the highest plot OM also have the highest variability. This indicates management practices and gardener decisions impact plot OM more than garden location. In addition, there was no correlation between P/K and organic matter availability, indicating independent decision making about these soil conditions.

Section 2: Heavy Metal Availability

Table 2: Source, exposure routes, and mobility of 4 important urban metals with human health risks. As and Cd are actively deposited and replenished through dry/wet pollution deposition. Cu and Pb are legacy heavy metals, often present in older locations with treated wood lead paint. Leaded gasoline legacies means that transportation corridors are often Pb contaminated.

Metal	Source	Human health risk	Contamination route	Mobility
Arsenic (As)	Mineral; Air pollution	**Acute:** poisoning, seizures, nausea **Long term:** Cancer, cardiovascular disease, diabetes	Edible plant uptake; local dust	Medium
Cadmium (Cd)	Mineral; Air pollution	**Long term:** Kidney failure, cancer, respiratory disease	Edible plant uptake	High
Copper (Cu)	Mineral; Building materials	**Long term:** Liver/Kidney damage	Edible plant uptake; exposure to building materials	Immobile
Lead (Pb)	Legacy pollution	**Acute:** Neurotoxin; developmental stunting in children/fetuses **Long term:** Kidney failure, neural damage	Ingestion of local dust; Edible plant uptake	Immobile

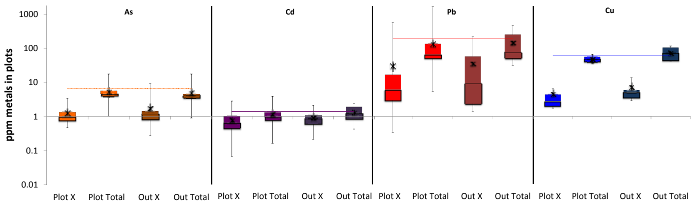


Figure 4: Box and whisker plot of 4 metals of concern (As, Cd, Pb, Cu) and their exchangeable (labeled X) and total fractions in the soil in plots (left) and outside areas (right). Axis is logged for comparison of multiple levels. Lines in each box indicate background As levels (6.5 ppm), agricultural limits in Canada for Cd (3.5 ppm) and Cu(63 ppm) and the CA limit for Pb in soils where children play (200 ppm). Exchangeable fraction of As is higher in plots than outside, though total As levels do not vary. Both As and Cd are very mobile in soils, existing mainly in the exchangeable fraction. Pb and Cu are less mobile in the soil, and are higher outside the garden in both exchangeable and total fractions, and variability is also higher. For all metals, (except Cu) there are both plot and outside locations ranging past recommended soil levels for X and total values. This indicates possible uptake by planted species and cross contamination from outside dust.

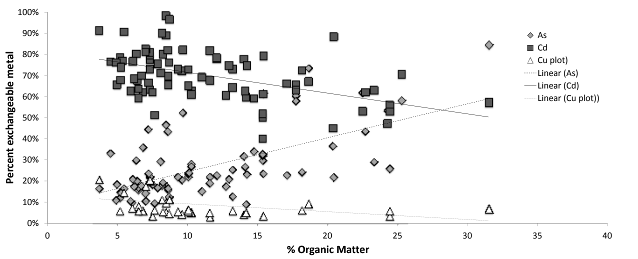


Figure 5: Extractable metals (As, Cd, Cu) as a percent of total metal content compared to percent organic matter (OM) across all locations. Only plot level Cu is shown because of its low availability. Pb was not affected by OM. Cd is very available in soil (over 80% in most cases), but as organic matter is added, that availability decreases ($p<0.0001$; $R^2=0.128$). Though Cu is quite unavailable in soil, its availability also decreases with OM in plots ($p=0.001$; $R^2=0.211$). In contrast, with higher OM, extractable As increases from 20% to over 60% with added OM ($p<0.0001$; $R^2=0.411$).

OM can readily immobilize Cd and Cu into organic complexes, removing them from the exchangeable fraction. High phosphate fertilizers like manure can mobilize Cd, which may explain the high exchangeable fraction overall in plant soils. An alternate pattern is shown with As, with more exchangeable As with increased OM. OM may react with metal oxide in soils, releasing sorbed As compounds and placing them in the exchangeable fraction.

Conclusions

- Consistently high P and K levels in garden plots indicate long-term over-fertilization with phosphate and potassium rich fertilizers like compost and manure. Organic matter (OM) levels are variable, based on gardener management
- Garden soils contain elevated and highly variable levels of As, Cd, Cu, and Pb, likely due to Pb legacies and ongoing air pollution deposition
- Increased OM levels can reduce the availability of Cd and Cu by immobilizing them into organic complexes, while mobilizing As through reaction with metal oxide

Recommendations for LA gardeners:

- Fertilize with targeted N fertilizers to prevent P and K over-fertilization
- Maintain 10-20% OM for reduction of As, Cd, and Cu mobility
- Wash vegetables near Pb contaminated soil to prevent contaminated dust ingestion
- Remediate As and Cd contaminated plots through seasonal planting of metal accumulators