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Lead (Pb) and other metals in New York City community garden soils: Factors influencing contaminant distributions

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ABSTRACT

Urban gardens provide affordable fresh produce to communities with limited access to healthy food but may also increase exposure to lead (Pb) and other soil contaminants. Metals analysis of 564 soil samples from 54 New York City (NYC) community gardens found at least one sample exceeding health-based guidance values in 70% of gardens. However, most samples (78%) did not exceed guidance values, and medians were generally below those reported in NYC soil and other urban gardening studies. Barium (Ba) and Pb most frequently exceeded guidance values and along with cadmium (Cd) were strongly correlated with zinc (Zn), a commonly measured nutrient. Principal component analysis suggested that contaminants varied independently from organic matter and geogenic metals. Contaminants were associated with visible debris and a lack of raised beds; management practices (e.g., importing uncontaminated soil) have likely reduced metals concentrations. Continued exposure reduction efforts would benefit communities already burdened by environmental exposures.

1. Introduction

Urban community gardens are growing in popularity as a source of healthy, affordable, locally grown foods in neighborhoods where such foods may not otherwise be readily available. By our estimate, New York City (NYC) has around 1500 community gardens, including neighborhood, senior, public housing, and school gardens, and some reports suggest even greater numbers ([ACGA] American Community Gardening Association, 1998). These gardens, which are often located in areas with limited access to fresh food (Fig. 1), low rates of fresh vegetable consumption and relatively high rates of poverty (Table 1), provide many benefits to communities. Community gardeners have been reported to eat more fresh fruits and vegetables than non-gardeners (Alaimo et al., 2008), and a diet rich in these foods can reduce risk for stroke, diabetes, heart disease, obesity and some types of cancer (Abdulla and Gruber, 2000). Community gardens also provide many other benefits associated with urban green space, opportunities for recreation and community building (Alaimo et al., 2010; Leake et al., 2009).

However, urban soils often have elevated concentrations of lead (Pb) and other contaminants as a result of historical human activities such as waste incineration, coal and oil combustion, and the use of leaded gasoline and paints containing Pb and other metals. Gardening and related activities can increase the potential for adults and children to be exposed to soil contaminants through incidental soil ingestion, soil resuspension and subsequent exposure (Zahran et al., 2013), produce consumption, chicken egg consumption (Spliethoff et al., 2013), and other pathways. People living in some urban neighborhoods with community gardens may already be subject to greater environmental exposures, and exposures to soil contaminants can add to this burden. For example, community gardens were often located on vacant lots in neighborhoods with historically elevated blood Pb (Witzling et al., 2010) primarily resulting from factors such as deteriorating housing and associated lead paint. In NYC, the percentage of housing built before 1950 is significantly ($p = 0.002$) higher in the 83 ZIP Code Tabulation Areas (ZCTAs) with mapped community gardens ($n = 484$) than the 96 ZCTAs without those gardens (Table 1) (OASIS, 2012; US Census Bureau, 2011). It is important to note that blood Pb levels

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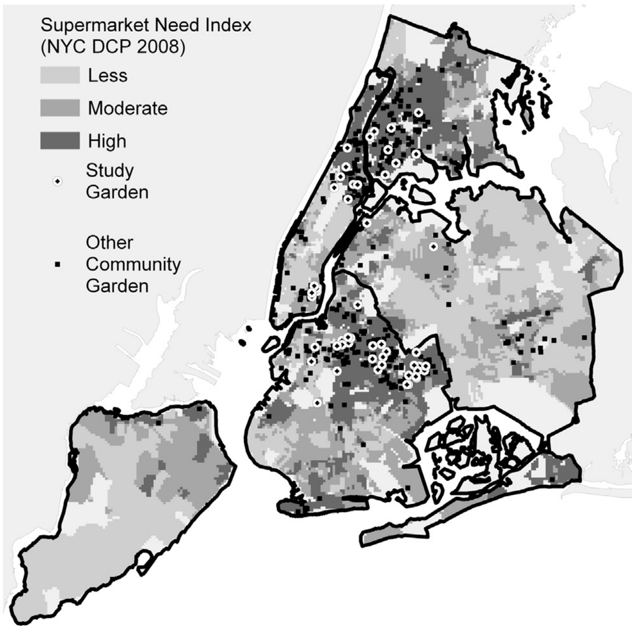

Fig. 1. NYC community garden locations and Supermarket Need Index developed by NYC Department of City Planning to determine the areas with the "highest levels of diet-related diseases and largest populations with limited opportunities to purchase fresh foods" (NYC DCP 2008). For various reasons, many community gardens are located in areas with greater need for access to fresh foods. SNI material used with permission of the New York City Department of City Planning. All rights reserved.

throughout NYC as a whole have declined 85% since 2000 (NYC DOHMH, personal communication). Incidence of elevated (>10 μg/dL) blood-Pb levels by ZIP code in NYC for the year 2000, the most recent year for which ZIP-code-level data are available, was significantly higher (Student's *t*-test, $p < 0.0001$) in the 84 ZIP codes with mapped community gardens (median 26.7 cases per 1000 tests) than in the 106 ZIP codes without (median 14.3 cases per 1000 tests) (NYC DOH, 2002; OASIS, 2012; Spliethoff et al., 2011). (Note that incidence data for children's blood lead levels above the present-day CDC reference level of 5 μg/dL are not yet available.) It is important to recognize environmental sources of lead exposure such as urban garden soil in these vulnerable communities and take steps to minimize exposures for gardeners and their families. However, the nature and extent of community garden soil contamination in many urban areas remain poorly defined. Tests for chemical contaminants can be prohibitively expensive for gardeners with limited resources, often preventing them from learning whether their garden soil contains elevated levels of contaminants.

The *Healthy Soils, Healthy Communities* project is a community-research-Extension partnership formed to address concerns expressed by gardeners and others about the potential for exposure to contaminants in urban community gardens. As a first step, project partners conducted a study to assess the distribution of Pb and other metals in soil at a subset of NYC community gardens and to evaluate the extent to which concentrations of metals pose a health risk for gardeners. The study also examined potential associations between contaminant concentrations and garden characteristics that were easily observed (e.g., whether a garden has raised beds or is growing directly in the ground) or measured (e.g., soil pH). Such associations could be useful in helping gardeners make efficient use of resources for soil testing and/or mitigative measures to help reduce exposure to soil contamination. Finally, the study used principal component analysis (PCA) to identify common groupings of chemical elements in garden soil samples.

2. Materials and methods

Forty-four community gardens on New York City Department of Parks and Recreation (NYC Parks) property in four NYC boroughs (8 in the Bronx, 24 in Brooklyn, 10 in Manhattan, and 2 in Queens) were selected for the initial phase of the study between October 2009 and June 2010. These gardens were selected for sampling for the initial phase of the study from a pool of gardens with a history of actively producing food, size of a minimum of 0.25 acres, and NYC Parks records indicating that they had likely received at least one delivery of "clean" (uncontaminated) soil and/or compost within the previous eight years. An additional 10 gardens (1 in the Bronx, 7 in Brooklyn, 2 in Manhattan), all of which met the same criteria met by the first 44 gardens, except that they had been cited recently by NYC Parks for maintenance-related violations, were selected for a second phase of the study in August and September 2010. Records of soil and compost delivery were obtained from NYC Parks, and publicly available information about garden neighborhoods was compiled (NYC DOH, 2002; NYC DOHMH, 2012; OASIS, 2012).

The layout of each of the 54 gardens was mapped, and food-growing beds (typically approximately 1.2 m by 2.4 m in size) were identified and assigned numbers. A smartphone random-number generator application was used to select 10 beds from each garden for soil sampling (fewer if the garden had fewer than 10 beds). From each bed, one composite soil sample was created from 5 subsamples of soil, each from a depth of 0–12 cm. In addition, one discrete 0–12 cm soil sample was collected from a non-growing area ("non-bed") at each garden. An additional non-bed sample was collected at two gardens, for a total of 508 bed samples and 56 non-bed samples across all 54 gardens. At each sample location, detailed field observations were recorded on a sampling survey and one or more photographs were taken.

Soil samples were air dried and passed through a 2-mm plastic sieve. A portion of the <2 mm fraction was then digested using US EPA Method 3051A (US EPA, 2012) and analyzed for total Al, B, Ca, Co, Fe, K, Li, Mg, Mo, Na, P, S, Ti, V, As, Ba, Be, Cd, Cr, Cu, Pb, Mn, Ni, Zn by inductively coupled plasma-optical emission spectrometry (ICP-OES) (US EPA Method 6010C)(US EPA, 2012). Quality control for the ICP-OES analysis

Table 1
NYC Community Health Survey and housing age data for areas in NYC with study gardens and other community gardens.

Areas in NYC	# of community gardens	# of ZIP code tabulation areas (ZCTAs)[a]	# of neighborhoods (UHF 34)[b]	Percentage of housing built before 1950, median of ZCTA values, 2007 - 2011[a]	NYC community health Survey[c] — Median percentage in UHF 34 neighborhoods, 2009	
					Below poverty level	Ate no fruits or vegetables Yesterday[d]
With Study Gardens	54	30	16	57%[e]	24%[f]	17%
Without Study Gardens	429	149	18	49%[e]	13%[f]	11%
With Community Gardens	483	83	29	56%[g]	19%[d]	12%
Without Community Gardens	0	96	5	45%[g]	12%[d]	8%

[a] U.S. Census Bureau, 2011. "Zip Code Tabulation Areas" are geographic areas defined by the U.S. Census Bureau to align census data with U.S. Postal Service ZIP Code service areas.
[b] NYC is divided into 34 United Hospital Fund Neighborhoods ("UHF34").
[c] NYC DOHMH, 2012.
[d] Differences are not statistically significant; $p > 0.05$ (Student's *t* test).
[e] Difference is not statistically significant; $p > 0.05$ (Mann–Whitney *U* test).
[f] Statistically significant difference; $p = 0.03$ (Student's *t* test).
[g] Statistically significant difference; $p = 0.002$ (Mann–Whitney *U* test).