Chapter 4

COMMUNITY GARDENS IN BERKELEY: APPROPRIATE LAND-USE IN A DENSELY POPULATED CITY?

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Introduction

The City of Berkeley, with a 1985 population of approximately 106,600, has presently reached a population peak. The 1980 census count was 103,328 (U.S. Department of Commerce, 1982), and population is expected to fall back down to this level by the year 2000 (ABAG, 1985). Berkeley's relative population stability, in spite of the high growth rate for the Bay Area as a whole, is related to Berkeley's housing shortage and its near exhaustion of further development potential. Yet, perhaps surprisingly, a large amount of open space still exists in Berkeley. In residential districts alone, 320 parcels, or one to two percent of the residential land area, are presently vacant (Copperman et al., 1985).

In this study, I will assess the advisability of using some of Berkeley's open space, both public and private, for the development of community gardens. Through the recreational value of gardening and the food-distribution policies of many gardeners, community gardens benefit several significant segments of Berkeley's population, including apartment-dwellers, senior citizens, and the homeless. This study will focus on land owned by either the City of Berkeley or the University of California. Although these particular sites are government-owned, in other communities gardens often are located on privately-owned lots which are rented or leased by neighborhood groups (Jobb, 1979). Given the large number of privately-owned vacant lots in Berkeley, this type deserves consideration as a potential land-use.

Aside from the economic, social, and political questions about open space, urban community gardens should also be studied for an additional factor, heavy metals contamination. Background levels of heavy metals are closely tied to traffic density (Shibko, 1978), which is increasing due to overall growth in the Bay Area. This study analyzes contamination by the metals lead and cadmium in soils and in certain indicator vegetables at three study sites to determine if people are being exposed to potentially harmful levels from the produce they eat. Such an analysis may be helpful in guiding future planning decisions for Berkeley's parks and vacant lots.

Past Studies

Little comparative research has analyzed the value of urban gardens versus other uses of open space (Francis, 1986, pers. comm.). However, many community gardens throughout the U.S. have clearly improved neighborhood esthetics, fostered a sense of community, and produced psychological benefits for participants (Menninger, 1977). One recent comparative study of a park and a community garden in Sacramento (Francis, 1986) found that the park was twenty times more expensive to develop and twenty-seven times more expensive to maintain than the garden. The garden and the park were generally used by different members of the community, and residents rated the garden higher on visual quality and safety.

Studies of heavy metals in New York and Boston community gardens (Kneip, 1978; Spittler and Feder, 1978) showed a mean lead content in urban-grown leafy green vegetables of two to four times that of rural-grown samples. It is known that average background concentrations of lead in air are ten to twenty times greater in urban areas than in rural (WHO, 1972). Man-made sources of lead and cadmium include vehicular sources from oil and tires (cadmium), gas exhaust, industrial sources, and pesticides (Shibko, 1978). High levels of localized lead contamination in urban soils and gardens have also been linked to lead leached from house paints and to lead dusts washed from rooftops and sides of houses with precipitation (Boggess, 1977; Spittler and Feder, 1978).

Metals in Vegetable Gardens

Of the different heavy metals which may accumulate in urban gardens, lead and cadmium should be of particular concern because neither has any known biological benefit, and both act as cumulative toxins (API, 1985; Curran, 1978).

Lead accumulates in the soil over time, but its availability to uptake by plants varies. Low pH, low cation exchange capacity, low organic matter content, and low phosphate levels all favor root uptake. However, lead-phosphate deposits formed around root cells tend to limit lead translocation to above-ground parts (Boggess, 1977). Root vegetables (e.g., radishes, carrots, turnips, beets) are the best indicators of available soil lead. Leafy greens (e.g., lettuce, collard, swiss chard) tend to accumulate airborne lead on their surfaces; some of this becomes embedded in the cuticle and cannot be removed by washing (Boggess, 1977).

In most locations, the atmospheric input of cadmium exceeds the rate with which it is leached from the topsoil, increasing overall concentrations. The most significant inhibitors of cadmium uptake by plant roots are a high concentration of cations such as calcium in the soil and a soil pH around neutral. Cadmium is readily available to plants from both air and soil sources, but, as with lead, cadmium absorbed by the roots is not easily translocated. Although humans can receive cadmium from water, air and several food sources, the tendency of leafy and root vegetables to accumulate and concentrate cadmium from the air and soil makes them a major route of cadmium supply to people (Kabata-Pendias and Pendias, 1984).

Human Consumption of Heavy Metals

Because both lead and cadmium are toxic and cumulative in the body, as little as possible should be consumed. World Health Organization (WHO) guidelines for maximum daily consumption of these metals, as compared to the amounts normally found in root vegetables and leafy vegetables, are shown in Table 1. Human metabolic studies have estimated that total average lead intake for adults ranges from 90 to 400 ug/day (Lowenberg and Kneip, 1978), which is below WHO limits. A 1974 Federal Department of Agriculture (FDA) study of total daily cadmium intake in the diet showed a 33.5 ug/day average per person (Shibko, 1978), also below WHO limits.

	Cadmium	Lead
Average Concentrations in Urban Soils 0-2.5 cm (µg/g or ppm)[a]	2.3	292
Mean Metal Content in Plant Foodstuffs (µg/g or ppm) dry weight leafy greens[b]	0.39	2.4
Mean Metal Content in Plant Foodstuffs (µg/g or ppm) dry weight root vegetables[b]	0.16	1.5
Heavy Metals - Maximum Daily Consumption Guideline for Humans (in µg/g)[c]	57-71	429

Table 1. Concentrations of cadmium and lead in urban soils and plant foodstuffs.

[a] Adapted from Linzon _et al_. (1976), Table 1.

[b] Adapted from Kabata-Pendias and Pendias (1984), Tables 45 and 98.

[c] WHO, 1972 - Provisional maximum daily guidelines for adults.

Chronic exposure to excessive levels of cadmium affects almost all major organs and systems; the first symptoms are usually renal damage or emphysema (API, 1985). The effects of low-level exposure to lead include disturbances in the synthesis of several enzymes necessary for hemoglobin production and impaired renal function; other symptoms appear at higher exposures (Hammond, 1977). The effects on children are more severe and may include neurological disorders such as reduced learning ability, convulsions, and even death. Children should be considered a special risk group, and their daily intake should probably not exceed 100 to 200 ug/day (Lowenberg and Kneip, 1978). Therefore, the added concentrations of metals which may be found in urban-grown vegetables would be more likely to push children than adults over the maximum daily limit.

Methodology

Vegetable and soil samples were taken from three gardens in different parts of Berkeley (Figure 1), in order to monitor local variations in metals contamination due to such factors as traffic density and soil quality. The types of vegetables chosen for analysis were those which accumulate the greatest amounts of lead and cadmium in their tissues and, therefore, pose the greatest risk for human consumption. The first study site (site A, Figures 1 and 2) is located at the West Berkeley Senior Center, owned by the City of Berkeley. This garden is a 10 x 40 meter plot, enclosed by a stone wall and a wooden picket fence, and located about 70 meters from heavily-travelled University Avenue. Approximately eight members of the Senior Center work their plots and distribute surplus produce, including many root crops and leafy vegetables, to other members of the Center (Bridgewater, 1986, pers. comm.).

The second study garden is Ohlone Park Organic Garden (site B, Figures 1 and 2), which serves 20-30 families, primarily apartment-dwellers, and is owned and partially funded by the Berkeley Parks

Figure 1. Berkeley City map showing locations of gardens.

A. West Berkeley Senior Center, 6th St. north of University Ave.
B. Ohlone Park, Hearst Ave. west of McGee St.
C. People's Park, between Haste and Dwight, east of Telegraph Ave.

Base Map: Rand McNally and Company, 1983.

and Recreation Department (Reynolds, 1986, pers. comm.). It is an irregularly-shaped plot, approximately 15 x 35 meters, surrounded by a steel fence and located about 30 meters from a quiet part of Hearst Avenue. At the time of this study, many families were growing lettuce and carrots, in addition to other crops.

The third garden, People's Park West (site C, Figures 1 and 2), is located on a narrow strip (6 x 80 meters) of a vacant University of California-owned parcel with a long history of controversy over land-use. The gardeners, who number about five per season and distribute much of their produce to neighborhood homeless (Axelrod, 1986, pers. comm.), face a problem which is common to the majority of U.S. community gardeners: location on a legally insecure or impermanent site (Bassett, 1977).

Sample Collection and Processing

At each garden, in late October or early November, one to two samples of a leafy vegetable (several leaves of Swiss chard or lettuce) and one to two samples of a root vegetable (either radish or carrot) were removed and placed in labeled plastic bags. Individual maps of the gardens, marked with the locations from which samples were taken, are shown in Figure 2. The vegetables were washed with distilled water, weighed, dried at 70°C for four hours, reweighed, and frozen in plastic bags according to the procedure in Skogerboe and others (1977). Approximately two kilograms of soil, from the upper five to seven centimeters, were taken from the area surrounding each plant sample. After rocks and organic matter were removed, the samples were air-dried and frozen.

Thawed soil samples were ground and sieved through a 2-millimeter mesh sieve, and 5 gm of each sample were digested at 70°C in 35 ml of 4 N nitric acid (prepared by combining 750 ml water with 250 ml of 16 N nitric acid). The thawed dried plant samples were ground in a Wiley Mill, and 1 gm of each sample was digested overnight in 10 ml of 16 N nitric acid at 70°C. Dr. Harvey Doner of the Plant and Soil Biology Department was very helpful in describing both of these procedures. Next, each sample was diluted and tested for lead and cadmium with an Atomic Absorption Spectrophotometer (AA). Tom Morrison of the Chemistry Department gave extensive help with the atomic absorption analysis.

Calculations for the concentrations of heavy metals in the original plant and soil samples were made using the following formula:

$$\frac{\text{dilution of sample (ml)}}{\text{weight of sample (gm)}} \times \frac{\text{ugm metal (ppm AA)}}{\text{ml solution}} = \frac{\text{ugm metal (ppm)}}{\text{gm orig. sample}}$$

Metal Concentrations

The concentrations of metals in the soil and plant samples are shown in Table 2. Sample numbers on this table correspond to the site numbers on Figure 2, the map of individual gardens. Concentrations of lead range from 67.3 ppm to 692 ppm in the soil, from 17.12 to 116.7 ppm in the leafy vegetables, and from 20.00 to 81.47 ppm in the root vegetables. People's Park has the highest lead

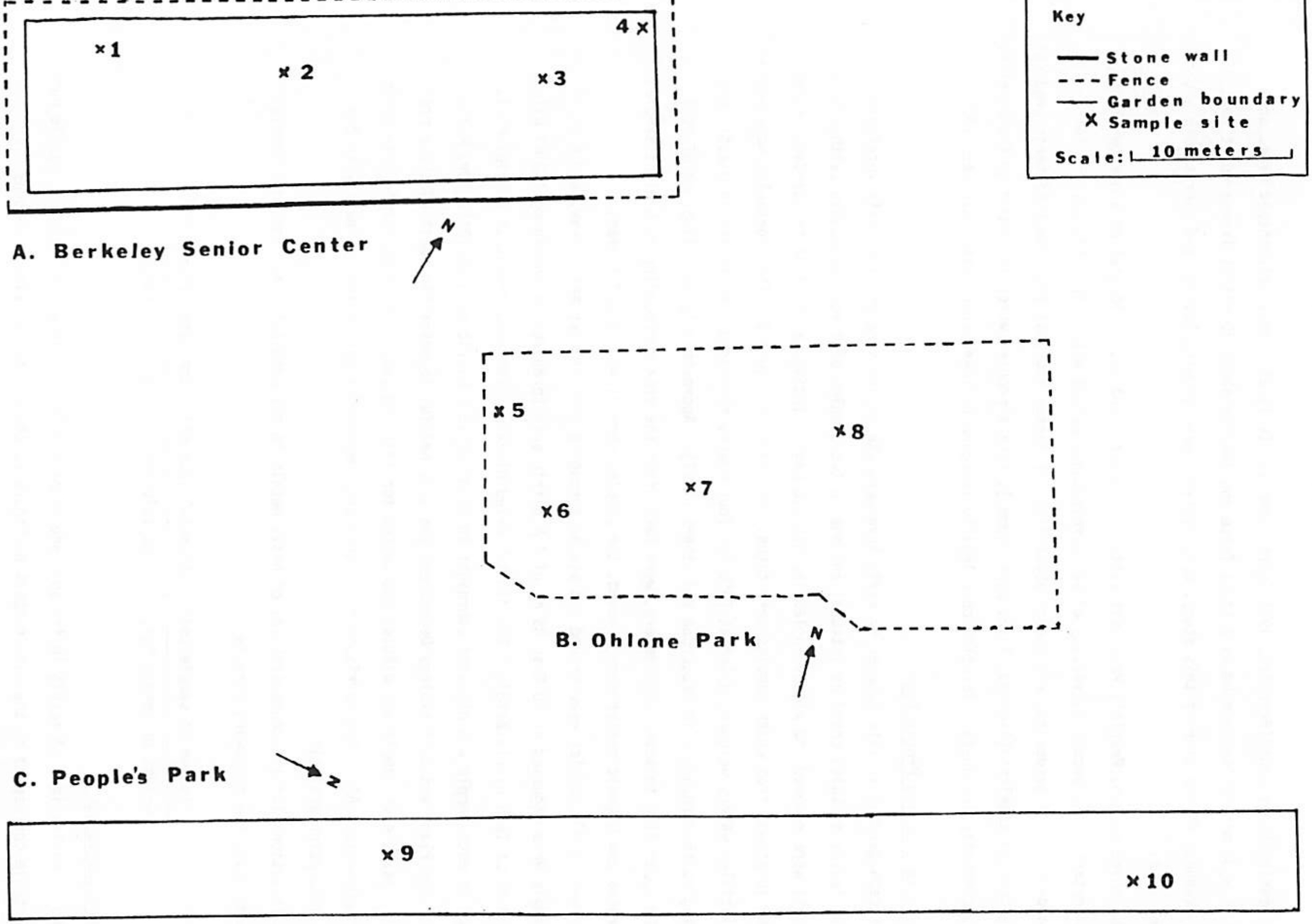

Figure 2. Sites of soil and vegetable samples at Berkeley community gardens.

			Concentration (ppm dry wt)	
	Sample	Garden	Cadmium	Lead
I. Soil				
	1a	Sr. Ctr.	2.49	92.2
	2a	Sr. Ctr.	2.33	113.2
	3a	Sr. Ctr.	1.10	81.0
	4a	Sr. Ctr.	1.54	70.5
	5a	Ohlone	1.21	67.3
	6a	Ohlone	2.03	71.7
	7a	Ohlone	2.37	143.0
	8a	Ohlone	1.94	116.9
	9a	People's	2.23	692.0
	10a	People's	2.03	294.4
Average			1.93	174.2
II. Leafy Vegetables				
Swiss chard	1b	Sr. Ctr.	1.08	72.16
Swiss chard	4b	Sr. Ctr.	5.18	95.22
Lettuce	6b	Ohlone	2.21	17.12
Lettuce	8b	Ohlone	5.07	116.70
Swiss chard	9b	People's	1.37	40.90
Average			2.98	68.42
III. Root Vegetables				
Carrot	2b	Sr. Ctr.	5.70	73.56
Carrot	3b	Sr. Ctr.	5.54	72.88
Carrot	5b	Ohlone	6.20	81.47
Carrot	7b	Ohlone	1.18	20.00
Radish	10b	People's	3.54	42.40
Average			4.43	58.06

Table 2. Concentrations of heavy metals in samples.
I. Soil. II. Leaf vegetables.
III. Root vegetables.

concentration for soil (692 ppm), and Ohlone Park has the highest levels for both leafy vegetables (116.70 ppm) and roots (81.47 ppm).

Cadmium concentrations in soils range from 1.10 ppm to 2.49 ppm, leafy vegetables range from 1.08 ppm to 5.18 ppm, and root vegetables range from 1.18 ppm to 6.20 ppm. The West Berkeley Senior Center has the highest cadmium level for soil (2.49 ppm) and for leafy vegetables (5.18 ppm). Ohlone Park has the highest cadmium level for a root vegetable (6.20 ppm).

Lead levels in the soils at Ohlone Garden and the West Berkeley Senior Center fall well below average concentrations for urban soils (Table 1). The lead concentrations in the soil samples at People's Park are much higher than at the other gardens. Sample 9a, with a lead concentration of 692 ppm, is well above average. The average cadmium concentration (1.93 ppm) for all ten soil samples is below the average for urban soils, although few other trends are evident from the data. The values for lead and cadmium in all of the vegetable samples greatly exceed the mean concentrations for urban plants (Table 1).

No trends for relative concentrations of heavy metals in the plant samples emerge, whether the samples are compared with the same type of vegetable from different gardens, with the other species analyzed in the same garden, or relative to the surrounding soil.

In the case of root vegetables, percentage of metal concentrations in the plants relative to that in surrounding soils is especially useful in determining metal uptake efficiency. For cadmium, efficiencies ranged from 50% in sample 7 at Ohlone, to 512% for sample 5, also at Ohlone. For lead, these percentages ranged from 14%, for samples 7 and 9 at Ohlone and People's Park, to 121% for sample 5 at Ohlone.

Past studies have shown that vegetables generally accumulate these metals to levels which rarely exceed 10% of the soil concentrations, even when they are grown in highly contaminated soils (Friberg et al., 1974; Ter Haar, 1972). The data of this study show bio-uptake efficiencies several times higher than normal.

Discussion

The concentrations of cadmium and lead in the soil samples are consistent with the findings from past studies and with our knowledge of the three garden sites in this study. However, the concentrations in vegetable samples represent levels several times higher than could be explained by normal bio-uptake of metals from these soils. This discrepancy most likely results from one or more problems intrinsic in the method of plant analysis. Levels of lead in soils samples 1a through 8a were near the lower range of values reported in two recent Berkeley studies (Bisio, 1986; MacDonnell, 1986). Both of their sample sites were along Highway I-80, and the somewhat higher average concentrations of lead found in their studies could be explained by the emissions from nearby heavy traffic.

The concentrations of lead found in the two samples from People's Park garden indicate that lead pollution may be a problem at this site. Sample 10a is near the average for urban soils and 9a, at 692 ppm, is well above the 500 ppm threshold, which indicates a source of contamination in the vicinity (Spittler and Feder, 1978). Several factors specific to the People's Park site could account for its high degree of lead contamination relative to the other two gardens. People's Park is the only site which is not partially protected from traffic contamination by a fence. This site, which is located approximately 25 meters from Haste Street, near a parking lot and off Telegraph Avenue, is probably surrounded by more traffic than any of the other sites. Finally, the Senior Center and Ohlone Park gardens may be protected from lead contamination through frequent applications of compost. This organic matter would serve to dilute the lead which accumulates in the soil from such sources as auto emissions. The addition of compost is of further benefit to gardeners because organic matter in soils is known to inhibit the efficiency of lead uptake in plants (Bassuk, 1986).

The cadmium levels in soils were also comparable to those found near the Berkeley waterfront by Bisio (1986) and MacDonell (1986). Concentrations in samples 1a and 2a at West Berkeley Senior Center and Sample 7a at Ohlone Garden slightly exceeded the average for urban gardens. However, it is impossible to predict the precise effects that these levels will have on the vegetables because the calcium ion concentration, the soil pH, and organic matter content (important factors which affect the bio-uptake of cadmium) are all unknown.

Several factors point to the possibility that the high metal concentrations shown in the plant data reflect a problem with the preparation procedures, rather than actual contamination of the plants. An analysis of pickleweed plants in a Berkeley marsh revealed cadmium concentrations close to normal (Kaplan, 1983). Significantly, a similar study done this year, using the same methods as in this study (Chase-Dunn, this report), showed cadmium levels in pickleweed comparable to those found in the vegetables in this study and far above those reported by Kaplan. Because both of the 1987 plant studies produced uniformly high metal concentrations from an identical methodology, it is likely that the concentrations resulted from methodological problems, rather than from suddenly-abnormal metal contamination throughout the City of Berkeley. This hypothesis is further supported by the past studies which show that the bio-uptake efficiency of vegetables is generally many times lower than the results of this study would indicate (Friberg et al., 1974; Ter Haar, 1972).

The steps in the preparation procedure which may have resulted in the unusually high readings may relate to a fundamental difficulty with the plant digestion process: the need to use a sufficient quantity of nitric acid to digest the organic material, while not diluting the sample to the point that metals are undetectable by AA. Another possible problem is the metal concentrations in the lead standards used for the plant samples. The lead standard was calibrated at 2 ppm, and lead was detected to a sensitivity of 0.002 ppm; the cadmium standard was 1 ppm with a sensitivity of 0.001 ppm. However, the expected concentrations in all samples ranged around the lowest limits detectable by these standards. At the lowest levels, the normal AA error of 10% often increases unpredictably (Doner, 1986, pers. comm.).

Another possible reason for error relates to the acidity of the plant solutions (Morrison, 1986, pers. comm.). Experiment during this analysis indicated that for highly acidic solutions, a difference in acidity between samples and standards resulted in incorrect AA readings. Although the standards were prepared with a nitric acid concentration near that of the samples, differences were unavoidable.

If another method had been selected for the plant digestion, some of these difficulties might have been eliminated. The wet ashing method in acidic solution is often preferred, but the acid is usually allowed to evaporate to dryness (Van Loon, 1985), rather than being kept at reflux as in the method used for this study. The evaporation step almost eliminates the acid in solution, allowing for more concentrated solutions after dilution. The dry ashing procedure, done in special ovens at high temperatures, also has this advantage. A nitric acid-hydrogen peroxide procedure may also be used, although Kaplan (1983) was unable to detect the presence of lead in plant samples which had been processed using this procedure.

Recommendations

This study analyzed the levels of lead and cadmium in urban gardens in Berkeley in order to discover potential problems of contamination at these sites. It may also be helpful in alerting any groups considering converting vacant lots in Berkeley into gardens to the possibility of metals contamination.

People's Park was the only garden which showed apparent lead contamination of soils, and if the University wants to find out if this poses a danger to those eating the garden produce, I would suggest further analysis of the lead concentrations in plants grown there. The garden is a productive use of a plot which would otherwise be unused; I suggest that the University adopt a policy to encourage a more productive and safer community garden by helping the gardeners to procure protective fencing and more compost. The low concentrations of soil lead in the two gardens which had fencing and highly organic soils is encouraging to groups which wish to develop similar gardens in Berkeley, although testing at the individual sites may be advisable in areas near heavy traffic. Cadmium concentrations in soils is fairly uniform at all three gardens, and further testing of the plants at these sites would be helpful in assessing any risks to humans.

Observations of the three sites in this study indicate that community gardens should be considered as a viable use of land in Berkeley. Although it is true that many other factors, such as Berkeley's high land values and intense need for housing, must be considered in future decisions on use of privately-owned lots, the development of community gardens on public lands may be an easier choice.

The gardens at West Berkeley Senior Center and Ohlone Park, in particular, benefit people from many segments of the community. Two gardeners at the Senior Center indicated that gardening is an enjoyable activity which helps them stay productive and physically active. The Ohlone Park Garden is used heavily by families as a center for outdoor activity and as a supplemental food source.

As the U.C. Davis study of Sacramento gardens indicated (Francis, 1986), community gardens should cost the City much less than parks in maintenance, and they would likely be utilized by some different groups of people than presently use City parks. Given all of these considerations, I recommend that the City of Berkeley continue to encourage and support the planting of gardens on open space.

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