# Heavy metal contamination in a school vegetable garden in Johannesburg

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*Background*. Feeding schemes based on school garden produce have been proposed as an effective solution to food insecurity and hunger among learners in South Africa. However, few studies have looked at the potential contamination of school food gardens when situated near mine tailing dams.

*Objectives*. The aim of the study was to evaluate the potential heavy metal contamination in a school vegetable garden in Johannesburg.

*Methods*. Twenty soil samples were collected from the study school and a comparison school. Surface and deep (~10 cm beneath the surface) soil samples were analysed using X-ray fluorescence for levels of arsenic, chromium, copper, lead and zinc. Thirteen vegetables samples were collected from the school garden, and compared with six samples from a national retailer and four obtained from a private organic garden. The heavy metal concentrations of the vegetable samples were analysed in the laboratories of the South African Agricultural Research Council.

*Results*. High levels of arsenic were found in the school soil samples, and elevated concentrations of lead and mercury in the school vegetables. Calculation of the estimated daily intake for a child of 30 kg, however, indicated that levels of lead, mercury and arsenic in vegetables were within acceptable limits. However, the levels of lead in the vegetable samples were high across all three sites.

*Conclusion*. Further investigation and research should be undertaken to assess the source/s and extent of public exposure to heavy metals in vegetables in South Africa.

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**To the Editor:** School fruit and vegetable gardens promote healthy eating habits. Feeding schemes based on school-garden produce have been proposed as an effective solution to food insecurity and hunger among learners in South Africa, with the additional potential for income-generation.[1] In a long-term urban health study (Health, Environment and Development (HEAD) study)[2] being undertaken in Johannesburg, increasing levels of food insecurity and hunger were observed at the poorest of five study sites. Earlier a school from a study site had initiated a food garden and feeding scheme in response to teachers' perceptions of growing hunger among learners. The research team raised concern regarding the proximity of the school garden to gold-mine tailing dams (approximately 500 m), and a decision was taken to conduct a preliminary, small-scale investigation of soil and vegetable concentrations of heavy metals.

## Methods

A total of 20 soil samples were collected from the study school and a comparison school situated approximately 1.4 km from the study school and 1.7 km from the gold-mine tailing dams. Surface and deep (±10 cm beneath the surface) soil samples were collected by the research team at each sampling point. To reduce the moisture content, soil samples were dried overnight at 90°C in a laboratory oven at the National Institute for Occupational Health. The samples were then crushed and sieved to a particle size of less than 250 µm. Each sample was analysed by the research team for 60 seconds using a handheld X-ray fluorescence spectrometer (Thermoscientific Niton XRF Analyzer – XLT 800 series) for levels of arsenic, chromium, copper, lead and zinc.

Thirteen samples of vegetables were collected from the school garden, including a selection of rooting vegetables (carrots, onions and potatoes), leafy vegetables (basil, cabbage and spinach) and fruiting vegetables (butternut, cherry tomatoes, peppers, pumpkin and tomatoes). Six vegetable samples (broccoli, butternut, carrots, potatoes, tomatoes and spinach) were purchased from a national retailer (control A). Four vegetable samples (carrots, eggplants, potatoes and tomatoes) were obtained from a private organic garden (control B). All vegetable samples were washed thoroughly with tap water, and leafy vegetables were oven dried at 70°C to reduce moisture content, and milled prior to analysis. The moisture content in rooting and fruiting vegetables was determined and the heavy metal concentrations were calculated on a dry basis using inductively coupled plasma-optical emission spectroscopy (ICP-OES) in the laboratories of the South African Agricultural Research Council. Non-normally distributed continuous variables are presented using median and interquartile range (IQR) and compared using Wilcoxon rank-sum (Mann-Whitney) test. The estimated daily intake (EDI) of heavy metals was calculated on an average intake of 100 g of school-garden vegetables consumed daily by a 30 kg child.

## Results

Table 1 lists median concentrations and IQRs of metals in soil (ppm) and in vegetables (mg/kg dry weight). The reference levels based on the Canadian Council of Ministers of the Environment[3] for arsenic were exceeded by the study school and 37.5% (3/8) of the soil samples from the control school, and levels were exceeded for chrome in all of the soil samples from both schools. The median levels of arsenic in the soil were statistically significantly elevated at the study school (30.5 ppm) relative to the comparison school (0 ppm, $p$=0.006).

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**Table 1. Concentration of heavy metals in soil and vegetables from the study sites**

| Samples | Reference levels[3,4,6] | School (median (IQR)) | Control A (median (IQR)) | Control B (median (IQR)) |
|---|---|---|---|---|
| **Soil** (ppm)[3] | | | | |
| *N* | | 12 | 8 | 0 |
| Arsenic (As) | 10 | 30.5 (23.20 - 44.60) | 0 (0 - 21.50) | - |
| Chrome (Cr) | 64 | 190.7 (130.70 - 206.20) | 219.7 (197.05 - 282.90) | - |
| Copper (Cu) | 50 | 0 (0 - 80.30) | 0 (0 - 5.40) | - |
| Lead (Pb) | 200 | 46.8 (27 - 100.20) | 53.85 (16.55 - 174.35) | - |
| Zinc (Zn) | 300 | 235.6 (91.4 - 427.20) | 154.05 (96.40 - 229.85) | - |
| **Vegetables** (mg/kg dry weight) | | | | |
| *N* | | 13 | 6 | 4 |
| Arsenic (As)[4] | 1.0 | 0.34 (0.30 - 0.47) | 0.30 (0.30 - 0.48) | 0.50 (0.40 - 0.57) |
| Chrome (Cr)[6] | 2.3 | 1.11 (0.92 - 1.71) | 0.75 (0.46 - 1.35) | 0.69 (0.48 - 1.13) |
| Copper (Cu)[4] | 30 | 14.85 (12.35 - 19.92) | 11.03 (8.77 - 16.34) | 14.55 (10.45 - 20.85) |
| Lead (Pb)[4] | 0.3 | 1.09 (0.66 - 1.46) | 0.71 (0.58 - 0.84) | 1.49 (1.12 - 2.15) |
| Mercury (Hg)[4] | 0.03 | 0.09 (0.06 - 0.20) | < 0.05 (0.04 - 0.09) | < 0.05 (0.05 - 0.05) |
| Zinc (Zn)[4] | 40 | 69.98 (53.73 - 97.60) | 60.56 (29.54 - 80.99) | 59.85 (45.75 - 101.55) |

Source: CCME (1997) updated in 2001,[3] Joint Codex Alimentarius Commission, (2001),[4] DOH (2003).[6]
IQR = interquartile range.

Though higher median levels of chrome were found in soil in the comparison school relative to the study school, it was not significant (219.7 ppm v. 190.7 ppm, $p$=0.123).

The percentage of vegetable samples that exceeded the recommended limits for lead, zinc and mercury, based on the Joint Codex Alimentarius Commission[4] were 91% (21/23), 83% (19/23) and 75% (16/23) respectively. The median concentration of lead was highest in fruiting vegetables across all three sites and decreased in the order: tomatoes (1.91 mg/kg) > peppers (1.85 mg/kg) > butternut (1.09 mg/kg) > pumpkin (0.47 mg/kg). The median concentration of zinc was particularly high in rooting and leafy vegetables, with the highest concentration found in carrots (143 mg/kg) from the private organic garden. The median concentration of mercury was highest in fruiting vegetables found mainly in the school garden, and decreased in the order: peppers (0.99 mg/kg) > tomatoes (0.76 mg/kg) > butternut (0.21 mg/kg) > pumpkin (0.12 mg/kg).

The EDI levels of arsenic, lead, mercury and zinc were within normal limits. The EDI levels of chrome ranged from 0.003 mg/kg/day to 0.005 mg/kg/day across the study sites and exceeded the acceptable daily intake limit of 0.001 mg/kg/day.[5] The EDI levels of copper ranged from 0.05 mg/kg/day to 0.06 mg/kg/day across all sites and were shown to be above the acceptable daily intake limit of 0.01 mg/kg/day.[5]

## Conclusion and recommendations

This study points to metal contamination of soil and vegetables at the study school garden and at the control sites. Of particular concern in the school garden were the high levels of arsenic found in the soil and the elevated concentrations of lead and mercury in the school vegetables. Calculation of the EDI of heavy metals for a child of 30 kg, however, indicated that levels of lead, mercury and arsenic in vegetables were within acceptable limits. However, chrome and copper levels exceeded the acceptable intake limits in the study and control school samples.

Children attending many South African schools require food supplementation, failing which malnutrition is likely to impact negatively on learning ability. However, at the same time there is a need to ensure their protection against exposure to harmful substances in the environment. Children are particularly vulnerable to environmental exposures and in line with the precautionary principle in children's environmental health, schools and education departments should adopt a differentiated approach to the promotion of school vegetable gardens. Risk assessments should pay particular attention to schools located in close proximity to potential sources of pollution, including mining, industrial and traffic pollution.

Of additional concern in this study are the elevated metal concentrations determined in vegetables sourced from further afield: organic vegetables from a major national retail store and a home-based, organic garden. Further investigation and research should be undertaken to assess the source/s and extent of public exposure to metals in vegetables in South Africa.

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