

Heavy metal distribution in soils of some urban and peri-urban horticultural farms in Botswana

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Abstract

Despite the fact that there is high usage of agrochemicals and use of urban waste water for irrigation, the concentration of potentially toxic metals in urban and peri-urban agriculture (UPA) farms has not been widely investigated in Botswana. The study focused on quantitative assessment of potentially toxic metals in horticultural production under UPA. Crops which are cultivated at the selected study sites include spinach (*Spinacia oleracea* L.), rape (*Brassica rapa* var. *rapa.*), cabbage (*Brassica oleracea* var. *capitata*), green pepper (*Capsicum annum*) and tomato (*Solanum lycopersicum*). Two farms from areas surrounding Gaborone namely Glenn Valley and Mmankgodi, were sampled for the determination of total heavy metals concentration in soils. In Glenn Valley secondary treated waste water is used for irrigation while in Mmankgodi underground water is used. Four soil profile pits were dug at each farm and soil samples of 20 cm increment were collected from the surface to a depth of 100 cm. Results showed concentration ranges of 0.12 - 1.22 mg/L for Cr, 0.09 - 0.47 mg/L for Cu and from 0.01 - 0.24 mg/L for Pb. Copper and Chromium were above threshold levels for crop production (Cu 0.2 mg/L, Cr 0.1 mg/L) as per Food and Agriculture (FAO) standards and Botswana Bureau of Standards (BOBs), while Pb concentration was significantly higher at Glenn Valley than Mmankgodi, but below recommended threshold levels of 2.0 mg/L. These results are a wake-up call that policies on the use of sewage effluent and agrochemicals should be enforced.

Key words: Soil profile, threshold level, toxic metals, wastewater

Résumé

Malgré le fait qu'il y ait une forte utilisation de produits agrochimiques et l'utilisation des eaux usées urbaines pour l'irrigation, la concentration de métaux potentiellement toxiques dans les fermes agricoles urbaines et périurbaines (AUP) n'a pas été largement étudiée au Botswana. L'étude a porté sur l'évaluation quantitative des métaux potentiellement toxiques dans la production horticole sous UPA. Les cultures qui sont cultivées sur les sites d'étude sélectionnés comprennent les épinards (*Spinacia oleracea* L.), le colza (*Brassica rapa* var. *rapa.*), le chou (*Brassica oleracea* var. *Capitata*), le poivron vert (*Capsicum annum*) et la tomate (*Solanumlycopersicum*). Deux fermes des régions environnantes de Gaborone,

à savoir le Vallée de Glenn et le Mmankodi, ont été échantillonnés pour la détermination de la concentration totale en métaux lourds dans les sols. Dans la vallée de Glenn, le traitement secondaire des eaux usées est utilisé pour l'irrigation alors que dans Mmankodi les eaux souterraines sont utilisées. Le profil des sols de quatre fosses ont été creusés à chaque ferme et les échantillons de sol de l'augmentation de 20 cm ont été recueillis à partir de la surface jusqu'à une profondeur de 100 cm. Les résultats ont montré des gammes de concentration de 0,12 – 1,22 mg / L pour le Cr, 0,09- - mg/L pour le Cu et de 0,01 – 0,24 mg/ L pour le pb. Le cuivre et le chrome étaient au-dessus des seuils pour la production végétale (Cu 0,2mg/L, Cr 0,1 mg/L) selon les normes de l'Organisation pour l'alimentation et l'agriculture (FAO) et le Bureau de Standards de Botswana (BOBs), alors que la concentration de Pb était significativement plus élevée à la vallée de Glenn qu'à Mmankodi, mais au-dessous des seuils recommandés de 2,0 mg / L. Ces résultats sont un appel de réveil que les politiques sur l'utilisation des effluents d'eaux usées et les produits agrochimiques devraient être appliquées.

Mots clés: profil du sol, le niveau de seuil, les métaux toxiques, les eaux usées

Background

Agriculture is usually thought of as only a rural activity, yet urban and peri-urban agriculture (UPA) is fairly widespread in the developing world. In Botswana, farmers around Gaborone city are engaged in UPA, which is an important source of food for the entire city and for vulnerable households. These farmers use secondary treated waste and underground water for irrigation of vegetables for public consumption. Despite the fact that there is also high usage of agrochemicals in UPA farms, the concentration of potentially toxic metals in soils irrigated using urban waste water has not been widely investigated in Botswana. This study is designed to gain understanding of the dynamics of potentially toxic metals movement and the associated health risks for vegetable consumers.

Literature summary

Urban and peri-urban agriculture is usually characterized by high input intensity. Research has shown that where there is intensive use of chemical fertilisers, pesticides, wastewater, sludges and industrial effluents to increase soil productivity, hazardous metals and pathogens are often found (Binns *et al.*, 2003; Amoah *et al.*, 2005) in UPA soils. This intensive use of agrochemicals and waste water effluents in UPA poses a real danger with regard to produce safety and has a potential to pollute the environment. Their continuous use, particularly waste water, may lead to the accumulation of potentially toxic metals such that the geological background levels are increased and the capacity to immobilize them is greatly exceeded (Wei and Yang, 2010). The elevated concentrations in soil have been shown to have adverse effects on crops as well as human and animal health when they are taken up by crops and transferred up the food-chain or are leached to the ground water (Fuentes *et al.*, 2008).

Study description and methods

The study was conducted at two locations, Glen Valley located between latitudes 24.59°S and 24.62°S and between longitudes 25.97°E and 25.98°E and Mmankgodi situated between 24.40°S and 25.34°E in Botswana. Four soil profile pits were dug at each location (three pits under cultivation and the fourth one at adjacent uncultivated area to serve as control). Soil samples were collected at an increment of 20 cm from soil surface up to a depth of 100 cm at each of the dug soil pits. The soil samples were analyzed for total concentration of Pb, Cu and Cr using Inductively Coupled Plasma (ICP) following digestion of the samples with aqua regia (Huong *et al.*, 2010). Data were subjected to a 2-Way analysis of variance (ANOVA) with location as the main plot and soil profile as subplot using STATISTICA.

Research application

Soil lead concentration at Glenn Valley was significantly higher than that of Mmankgodi (Fig. 1) even though it was below the threshold levels for crop production as given by FAO (1985) and BOBs (2011). Concentrations of Pb ranged from 0.01 - 0.24 mg/L (Fig. 2). At Mmankgodi, crops were irrigated with groundwater whereas in Glenn Valley the only source of water was secondary treated and untreated sewage water. Therefore, the higher Pb concentrations at Glenn Valley could be attributed to the buildup from use of secondary treated waste water which has been reported to contain low levels of heavy metals (Emongor,

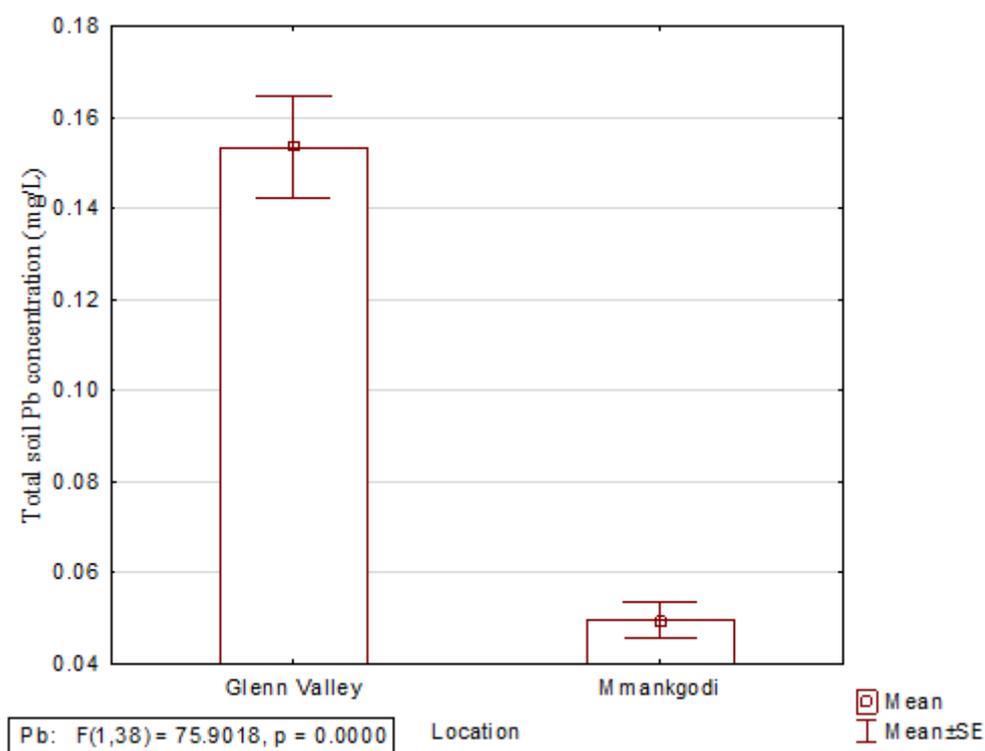


Figure 1. Comparison of the mean soil lead (Pb) concentration at Glenn Valley and Mmankgodi.

2005). There was a significant difference in the concentration of copper between Mmankgodi and Glenn Valley with Mmankgodi being 24 times higher than Glen Valley (Fig. 3). Results of a questionnaire administered before the commencement of this study indicated that in Mmankgodi, there was high usage of Cu based fungicides to control crop diseases. Heavy

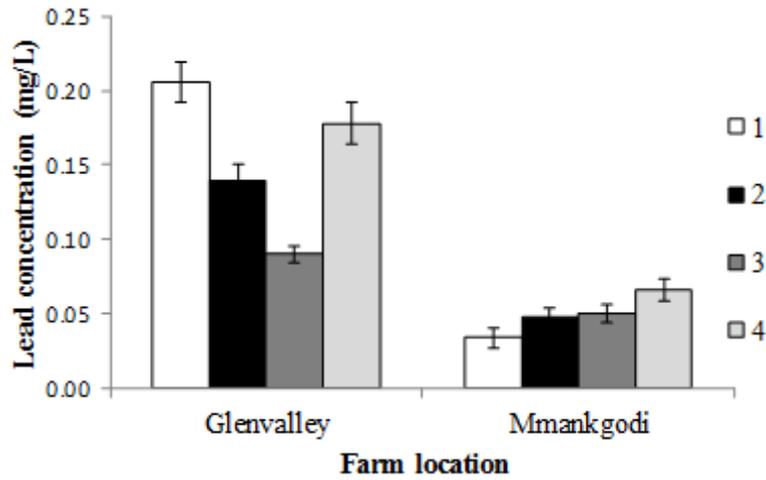


Figure 2. Distribution of lead (Pb) in soil profiles at Glenn Valley and Mmankgodi.

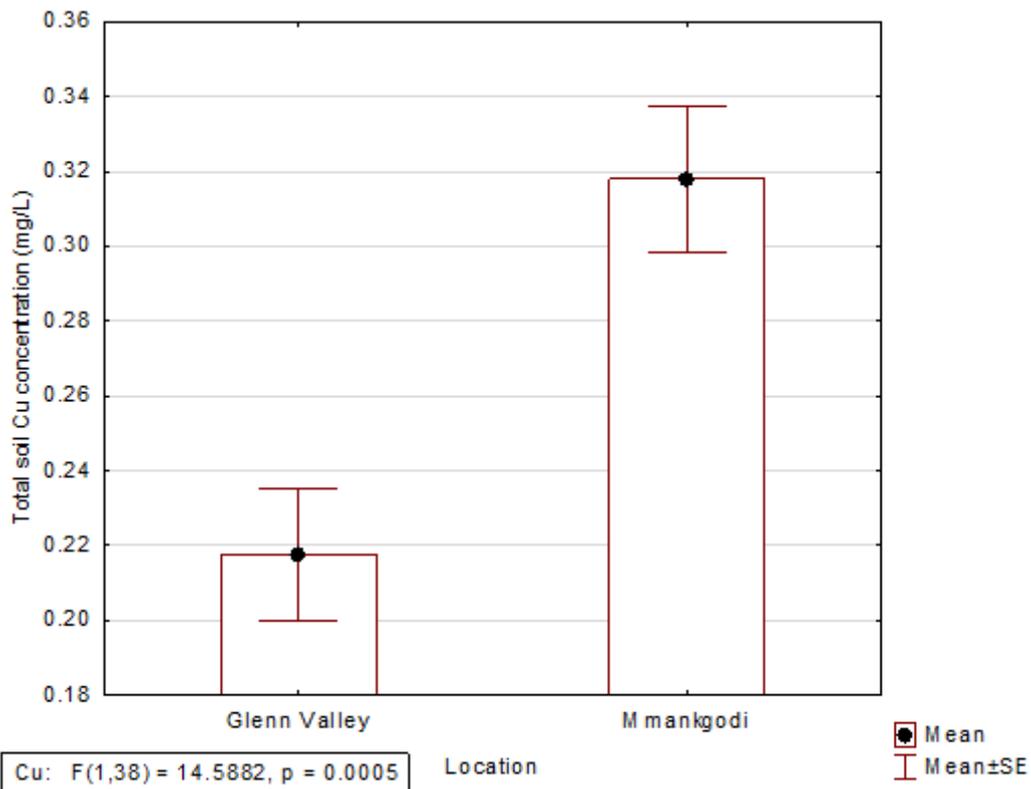


Figure 3. Comparison of the mean soil copper (Cu) concentration at Glenn Valley and Mmankgodi.

metal concentration for Cu and Cr ranged from 0.12 - 1.22 mg/L, 0.09 - 0.47 mg/L respectively and these concentrations were above threshold levels for crop production (FAO, 1985; BOBs, 2011). Chromium concentration between the two locations was not significantly different.

Since this study shows the accumulation of Cu, Cr and Pb in soils of UPA horticultural farms, there is likelihood that these heavy metals loads may lead to elevated concentrations in marketed vegetables and leach to the ground water with negative consequences for human health. Legislation is needed to restrict heavy metal loads in waste water used for irrigating vegetables.

Acknowledgement

We thank the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) for giving us an opportunity to share our findings.

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