Heavy metal concentration in crops and soils collected from intensively cultivated areas of Sri Lanka

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Abstract
Intensification of agriculture could have resulted in accumulation of heavy metals due to excess use of agrochemicals and amendments. Surface horizons of 40 agricultural soils from low country and up country wet zone of Sri Lanka under vegetable crops were sampled to determine concentrations of Cd, Cu, Ni, Pb and Zn. Some selected soil chemical properties were determined to understand the relationships between the metal concentrations in soils and other soil properties. Crops which were grown in the same fields where the soils were collected also analyzed for the heavy metals. Elevated levels of Cd, Cu, Ni, Pb and Zn than the uncultivated soils were observed in both up country and low country wet zone of Sri Lanka. Measured mean values of Cd in few soils exceeded the maximum allowable limits imposed by the European standard; however, Cd concentrations in the vegetable crops were still below the standard levels. The Cd to Zn ratio in studied soils indicated safer limits for Cd in more than 95% of the soils studied. Metals in soils correlated significantly with number of years cultivated. These results provided the initial evidence of elevated heavy metal concentrations in Sri Lankan leafy vegetables and soils emphasizing the importance of extensive investigations.

Key Words
Heavy metals, vegetable crops, intensive cultivation, agrochemicals.

Introduction
Heavy metals are important environmental pollutants threatening the health of human population and natural ecosystems. Heavy metals can affect for the quality of agricultural soils, including phytotoxicity and transfer of heavy metals to the human diet from crop uptake (Nicholson *et al.* 2003). Fertilizers and organic amendments contain many impurities leading to contaminate soils subsequently transferring to the humans through food chains. In Sri Lanka use of fertilizers and organic manures in more than recommended doses is a common practice in intensively cultivated vegetable growing soils. Though the agricultural soils can be a long-term sink for heavy metals, data on heavy metal concentrations in soils and crops are not available for Sri Lankan soils. Analysis of heavy metals concentrations in soils and identifying the sources are essential to implement control measures to reduce heavy metal inputs to soils though agrochemicals. The objectives of the study were to determine concentrations of Cd, Cu, Ni, Pb and Zn in soils and vegetable crops in locations where the intensive agriculture has been performing more than 10 years, and to establish relationships between heavy metal concentrations and soil properties.

Materials and methods
Sample collection
Soil (0-20 cm) samples were collected from wet zone low country (22 samples) and wet zone up country (18 samples) of Sri Lanka where annual rainfall was common (1700-3300 mm) for both places and annual average temperature was 32 – 35 ^{0}C and 13 – 18 ^{0}C respectively for up country and low country. In these selected places leafy vegetables and vegetable crops were grown intensively for long period of time.

Soil digestion
Soil pH, available N, exchangeable potassium, available phosphorous, cation exchange capacity and soil organic matter were determined as the basic soil properties. The total concentration of cadmium (Cd), copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn) in soils were determined after digesting soil with 4M HNO_3 acid (1:10 ratio) at 80 ^{0}C water bath for four hours. Exchangeable Cd, Cu, Ni, Pb and Zn were determined using DTPA extraction at 1:2 soil to solution ratio.

Plant and fertilizer digestion
Plant samples of leafy vegetables at the harvesting stage were collected along with the soil samples from the same field. Metals in the oven dried (55 ^{0}C) plant tissues were determined after digestion with conc. HNO_3 acid. Total heavy metals in fertilizer samples were determined by digestion with conc. HCl acid of the powdered fertilizer sample. After ash the ground manure sample it was dissolved in conc. HCl and measured the heavy metals(Hettiarachchi and Pierzynski 2004).

Sample analysis
Metals of Cu, Ni, Pb and Zn extracted from soils, plants, fertilizers and manures were determined using an atomic absorption spectrophotometer (GBC Avanta Ver 1.33) and Cd was determined by atomic absorption spectrophotometer coupled with graphite furnace (GBC Avanta Ver 1.33). Correlation matrix was used to identify the relationship between heavy metal concentrations and soil properties.

Results and discussion
The mean values of the heavy metal concentrations (mg/kg) in soils were in the following order; Cd (1.16±0.69) < Ni (21±25) < Cu (51±34) < Pb (60±58) < Zn (227±106). Among the soil properties tested, pH, CEC and available P showed positive significant correlations with some metals. The mean values of the heavy metals in the plants were recorded as Cd 0.59±0.44; Cu 11±6; Ni 13±9; Pb 8±3 and Zn 40±20. The differences of soil and plant heavy metal contents in the studied two regions were not significantly different. Some elevated levels of Cd, Cu, Ni, Pb and Zn were observed in soils under long-term intensive vegetable cultivation as compared to uncultivated soils collected from the same areas. Only two fields out of the 40 exceeded the maximum acceptable upper limit (3 mg/kg) imposed by the European community set standards in 1986 (McGrath *et al.* 1994). Among the soils studied only three soils indicated Cd:Zn ratio exceeding 0.015 in this study. The soils contain usual geochemical ratio of Cd:Zn (0.005 to 0.015) indicates that the human or wildlife species are not at risk of chronic Cd consumption (Chaney *et al.* 1999).

Measured mean values of Cd in leafy vegetables, vegetables and root/tuber crop samples changed from 0.17 to 2.05 mg/kgdry weight, where 87.5% of the values were < 1.00 mg/kg. Positive significant correlation between the total and exchangeable Cd (r^2=0.68; p=0.001), Cu (r^2=0.91; p <0.05), Ni (r^2=0.05; p<0.001), Pb (r^2=0.30; p<0.1) and Zn (r^2=0.51; p<0.05) were observed for the studied soils. (Figure 1)

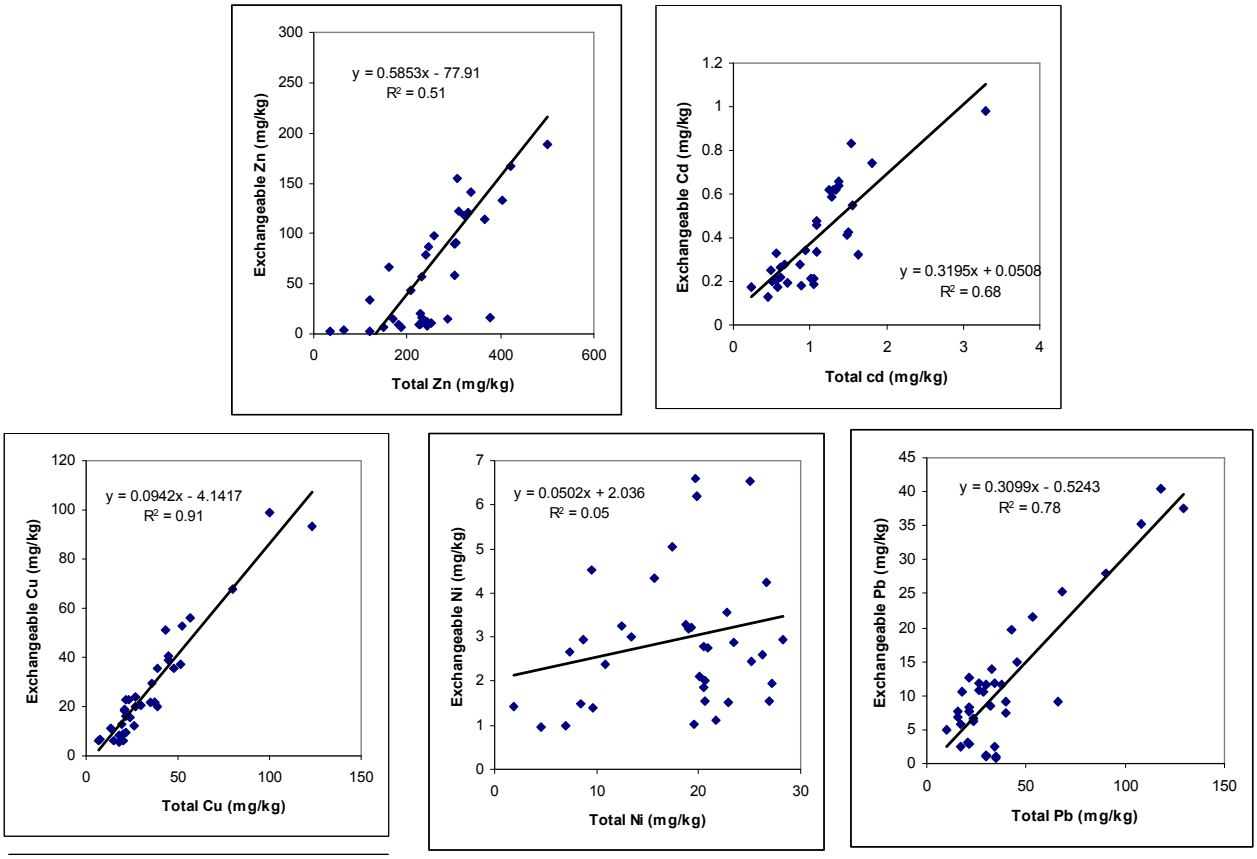

Figure 1. Regression relation of soil total and exchangeable Zn, Cd, Cu and Ni, concentrations in tested soils.

Among organic and inorganic manures/fertilizers analyzed, triple super phosphate (TSP) had the highest Cd concentration (23.5mg/kg). Even though the concentrations of heavy metal in those manure and fertilizers (except for Cd concentration in TSP) did not exceed the maximum permissible levels of heavy metals recommended by the Sri Lankan Standard Institute, they can be accumulated in agricultural soils with time. In Sri Lanka application of phosphate fertilizers, pesticides, fungicides and organic manures 2-3 times higher than the agrochemical doses recommended by the Department of Agriculture, has been a common practice among the farmers for many years. Therefore, long-term over application of agrochemicals may be responsible for elevated Cd in observed in some fields.

Conclusion

These results provide initial evidence that, Sri Lankan leafy vegetables and soils have elevated heavy metal concentrations, and emphasize the importance of extensive investigations on the extent of heavy metal contamination in Sri Lankan soils and vegetables, and their sources as well as possible control measures to reduce the associated risk due to food chain transfer of toxic heavy metals. Regulations should be introduced on agrochemical applications to protect soil resources from further contamination.

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