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Heavy Metals in Topsoil under Selected Vegetable Cultivation Areas in Cameron Highlands, Pahang, Malaysia

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ABSTRACT Heavy metal contents of soil under vegetable cultivation in the Cameron Highlands were determined. Five stations selected for this purpose were Kg. Raja (forest reserve), Kuala Terla (cabbage), Tringkap (cabbage) and two stations at Blue Valley (cabbage and an abandoned tea plantation). Soil samples were collected during the harvesting season for cabbage. Soil in the tea plantation and forest were used for comparison. The mean of all of the heavy metals examined, except arsenic, were high in soil cultivated with cabbage compared to the soil under natural forest and tea plantation. The increase in heavy metal content for the agricultural area was attributed to the common practice of fertilizing, liming and pest control. Heavy metal content in all stations was within the normal range in soils but As and Zn concentrations were already within the potential toxic threshold in soil. Soil parameters such as pH, organic matter, silt and phosphorus content in soil had an influence on the enrichment of Pb, Co, Ni, Zn and Cr in soil.

ABSTRAK Kandungan logam berat di dalam tanah yang digunakan untuk pertanian sayuran di Cameron Highlands telah ditentukan. Lima stesen yang dipilih untuk tujuan ini ialah Kg. Raja (hutan rizab), Kuala Terla (tanaman kobis), Tringkap (tanaman kobis) dan dua stesen di Blue Valley (tanaman kobis dan ladang teh terabai). Sampel tanah telah diambil pada masa musim menuai bagi sayuran kobis. Tanah yang diambil daripada hutan rizab dan ladang teh terabai digunakan sebagai perbandingan. Kandungan logam berat dalam tanah yang ditentukan, melainkan As, adalah lebih tinggi di dalam kawasan pertanian berbanding dengan kandungan di dalam tanah di hutan simpanan dan ladang teh terabai. Peningkatan kandungan logam berat di kawasan pertanian dapat dikaitkan dengan faktor pengurusan kawasan pertanian sayuran yang biasa iaitu pembajaan, pengapuran dan kawalan serangga perosak. Kandungan logam berat di dalam semua stesen berada pada julat biasa yang terdapat di dalam tanah. Walaubagaimanapun, kandungan As dan Zn didapati berada pada aras yang berpotensi toksik dalam tanah. Parameter tanah seperti pH, bahan organic, kandungan kelodak dan fosforus mempengaruhi pengayaan Pb, Co, Ni, Zn dan Cr di dalam tanah.

(Heavy metals, topsoil content, vegetable cultivation, Cameron Highlands)

INTRODUCTION

Cameron Highlands is being progressively developed for agriculture and tourism activities. Agricultural products such as tea, a variety of vegetables and flowers are extensively cultivated in order to meet domestic demand. These activities therefore put great pressure on the land. Human activities around Cameron Highlands that include construction of infrastructures such as road network, resorts and hotels also influence the natural ecosystem of this highland area [11].

Cameron Highlands is located 30 km from Tapah, northwest of Pahang. This area is dominated by sequences of mountains and hills as part of the Titiwangsa Mountain Range between 1280 and 1830 m above sea level. Geologically, this area consists of granitic rock with grain size ranging from medium to coarse [4]. This rock was part of the main range granite which is aged Late Mesozoic. The granitoid mountain range forms the main component of the highland area with the highest point; Gunung Brinchang occurring at 2030 m. Tjia [19] suggested that the granitoid rock was part of batholith intrusion, which formed the main range of Malaysian peninsula. Soils developed from this kind of parent material comprise of coarse textured soil of sandy type. The soils normally contain very low amounts of clay and silt particles. Lower amounts of clay means the soil may have low plastic and elastic limits. In other words, this type of soil may not have the strength to withstand erosion especially with reference to their position in the highlands [4].

The increasing demand for vegetable products for domestic and export purposes requires the land to produce high volume of vegetables. To meet this demand, agricultural lands are being cultivated extensively with high technology and management input right from seeding to harvesting. A variety of techniques have been applied in order to control the quality and quantity of these agricultural products. Pesticides and herbicides are being used extensively, as well as, fertilizer on to the soils. These chemical substances are partially absorbed by plants and the rest are left in the soils or leached away to the watercourse. Fertilizers and pesticides will accumulate in soil if they are applied continuously. Cultivation in open area soils which receive natural rainwater input may dilute the chemical substances effectively, but under the shade where substantial cultivation activities are being carried out the fertilizer and pesticides may accumulate up to a critical level where crop tolerances are pushed to their limits. Among problems related to high fertilizer input in soil is the increase in heavy metals such as As, Co, Cu, Cr, Pb, Ni and Zn concentration in agricultural soils as well as in vegetable components [3].

This paper attempts to account for the heavy metal concentration in soils from selected vegetable farms in Cameron Highlands. Physico-chemical properties normally influencing heavy metal composition in soils were also determined.

EXPERIMENTAL

The study area covers five agricultural areas in Cameron Highlands, Pahang, Malaysia (Figure 1). The stations selected for this purpose were A - Kg. Raja (forest), B - Blue Valley 2 (tea), C - Blue Valley 1 (cabbage), D - Kuala Terla (cabbage) and E - Tringkap (cabbage). These five agricultural areas were taken as representative stations for the kinds of land use they currently employ. Five replicates of topsoil samples were collected within the same cultivation area to represent every one of the stations. These topsoil replicates were collected on the same day for each of the station and the sampling was carried out once only. Heavy metal content of the topsoil samples were analyzed using the X-ray fluorescence (XRF) technique [16] in the form of pressed pellet. In the XRF analyses a Phillips PW 1480 X-ray digital instrument controlled by a Digital Software X-44 Microcomputer was used. Graph calibration method was obtained using the Alpha on Line Program [7, 8].

Organic matter content was determined by loss on ignition [6], particle size distribution was determined by pipette method for the finer particle size (< 20μm) and dry sieving method for the coarser particles (20μm-2mm) [2]. Particle fractions were expressed as percentages of the summed fractions of peroxide-treated soil [2]. Soil texture was acquired by plotting the sand, silt and clay content into the soil texture triangle chart. The soil pH was determined using soil: water ratio of 1:2.5 [13].

Exchangeable Al and H were extracted with 1M KCl and then determined by titration. Exchangeable Na, K, Ca and Mg were extracted with 1M Ammonium acetate after which, their concentrations were determined with an Atomic Absorption Spectrophotometer. Cation exchange capacity was obtained by summation of acidic and basic cations [15]. Electrical conductivity was determined in saturated $CaSO_4.2H_2O$ extract [12]. Available phosphorus was extracted with 1M ammonium acetate-acetate acid extractant, then phosphorous in the solution extract was determined spectrophotometrically using the method of Murphy and Riley [14].

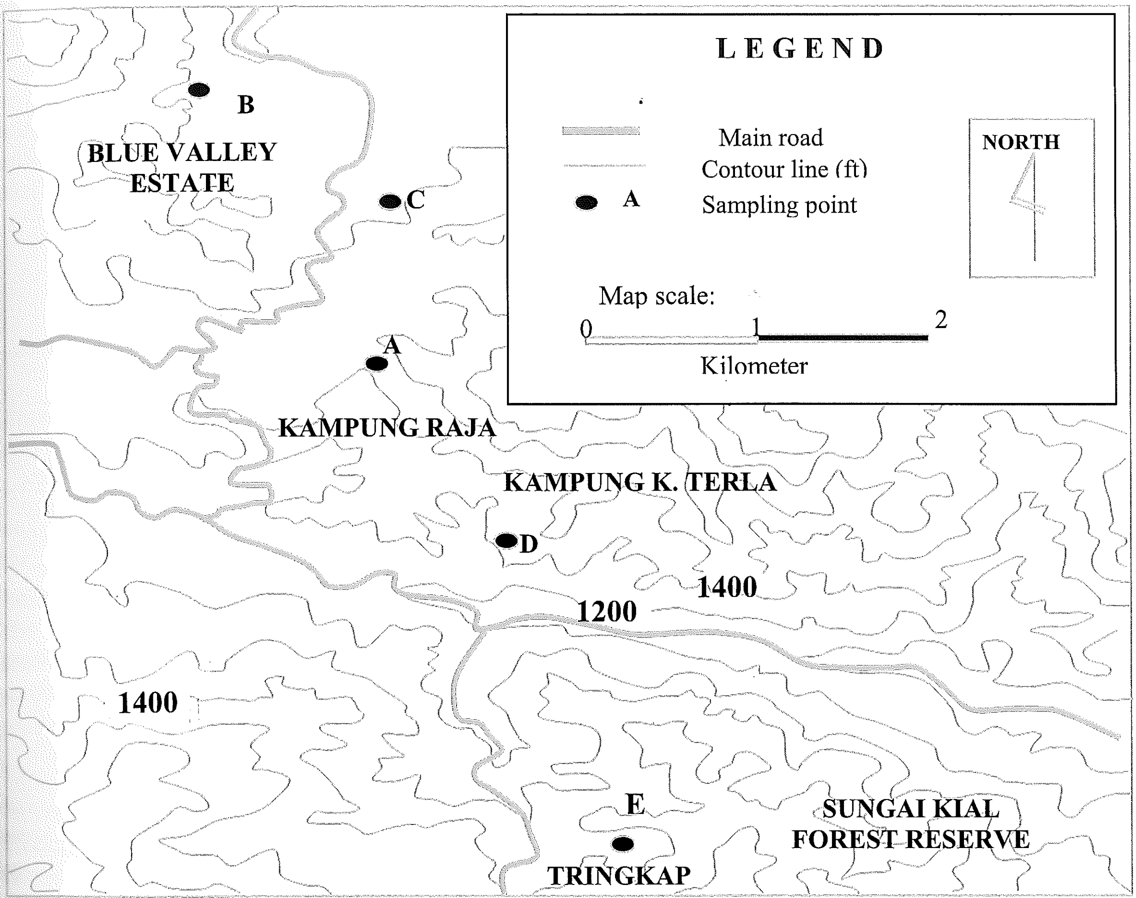

Figure 1. Map of the study area and sampling location.

RESULTS AND DISCUSSION

Physical properties of soil

Particle size in the topsoil of all samples was dominated by silt and sand particle. Forest soil had sand content between 44 to 64% with an average of 53%. It is slightly higher in the tea plantation with a range from 39 to 73% and averaged at 61%.

The average sand content in the cabbage cultivation areas are within values of 44, 45 and 53% for Blue Valley, Kuala Terla and Tringkap, respectively. The average amount of silt under the forest is 26% and 22% under tea plantation. In the cabbage cultivation areas, the average silt content is 32, 33 and 36% in Blue Valley, Kuala Terla and Tringkap, respectively. Silt content in an agriculturally active area is higher than under the forest and tea plantation, indicating that the frequent process of ploughing and disturbing the land disintegrates the coarser sand properties into the smaller silt size. The average clay content under the forest is 24% while 17% under tea plantation.

In cabbage cultivation areas the average clay content is 18, 15 and 19% in Blue Valley, Kuala Terla and Tringkap, respectively. The clay content under the forest, tea and cabbage cultivation area do not differ very much because their presence was controlled and subjected to the same intensity of natural weathering action. Soil texture is dominated by sandy loam, with some loam, sandy clay loam, clay loam and loamy sand.

The bulk density of top soil (Figure 2) under the forest and tea plantation seems to be significantly lower than under cabbage cultivation and this has been directly influenced by the organic matter content in the top soil. This is confirmed by the highly significant negative correlation ($r=-0.952$, $p<0.001$, $n=25$) between bulk density and organic matter content. Low bulk density indicates a non-compacted, well-structured high porosity soil that enables free percolation of water. Organic matter content under the forest and tea plantation is significantly higher compared to the organic matter content in cabbage cultivation area (Figure 3). It is well known that under continuous agricultural practice the organic matter content in the topsoil will decrease due to lack of organic matter returned to the soil. In the natural condition all the organic matter produced by the vegetation is returned to the soil [20]. Low bulk density indicates that the soil is not compacted and has more porosity. This criterion gives benefit to root activity, water infiltration into the soil and overall growth of crops. Soils under the cabbage cultivation are clearly lacking these criteria.

Table 1. Particle size distribution and soil texture

LOCATION	REPLICATES	SAND (%)	SILT (%)	CLAY (%)	TEXTURE
Kampong Raja (Forest)	1	64	23	13	Sandy Loam
	2	56	26	19	Sandy Loam
A	3	51	32	17	Loam
	4	50	19	31	Sandy Clay Loam
	5	44	32	24	Loam
Blue Valley 1 (Tea)	1	63	25	12	Sandy loam
	2	61	18	21	Sandy Clay Loam
B	3	39	44	17	Loam
	4	69	12	19	Sandy Loam
	5	73	12	15	Loamy Sand
Blue Valley 2 (Cabbage)	1	45	33	22	Loam
	2	46	30	25	Loam
C	3	34	39	28	Clay Loam
	4	48	33	19	Loam
	5	47	23	18	Sandy Loam
Kuala Terla (Cabbage)	1	54	31	15	Sandy Loam
	2	58	26	16	Sandy Loam
D	3	51	35	14	Sandy Loam
	4	53	33	14	Sandy Loam
	5	47	39	15	Loam
Tringkap (Cabbage)	1	41	43	16	Loam
	2	47	28	25	Sandy Clay Loam
E	3	43	38	19	Loam
	4	47	36	17	Loam
	5	46	35	19	Loam

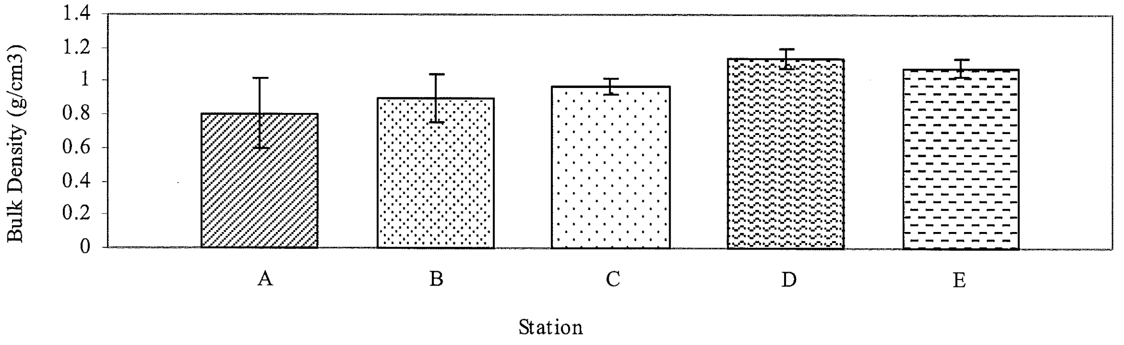

Figure 2. Soil bulk density

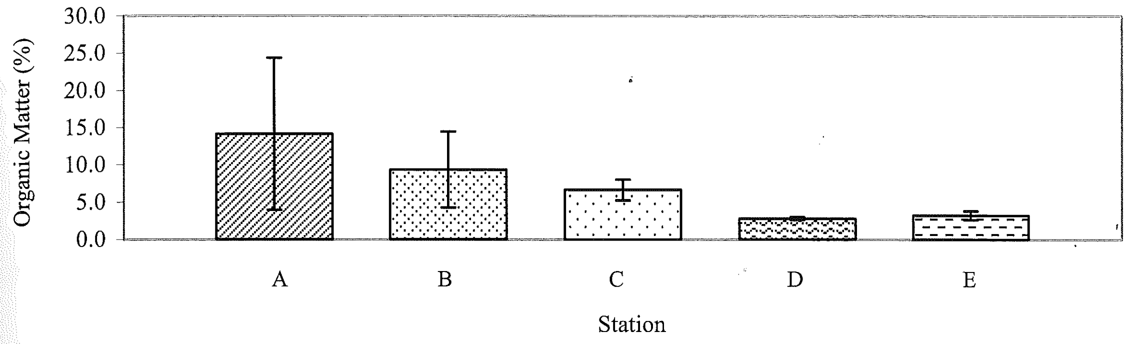

Figure 3. Soil organic matter content

Exchangeable cations and cation exchange capacity

Cation exchange capacity (CEC) is the measure of net negative charge present in soil exchange base. This is measured indirectly by measuring the amount of cations taking place as exchangeable cations in the soils. The cation exchange capacity in soils under forest (4.89±0.96 meq/100g) and tea plantation (5.02±2.32 meq/100g) is significantly lower than cation exchange capacity in soil under cabbage cultivation (28.5±1.84 to 30.8±1.10 meq/100g). Under the forest, the cation exchange capacity is dominated by Al and H ions, which account for about 60% of the total exchangeable cation, whilst in tea plantation the Al and H ions account for only 40% of the total cation. In the cabbage cultivation area the acidic cation accounts for less than 7% of the total cation. The amount of base saturation under the forest and tea plantation is 40% and 60%, respectively, whereas, under cabbage cultivation, the base saturation ranged from 93 to 97% of the total exchange capacity of soil. Under the forest and tea plantations, the base saturation is significantly lower than under the cabbage cultivation. The dominant cation that is present in the exchange base of cabbage-cultivated soil is Ca with concentration ranging from 19 to 21.7 meq/100g. This is then followed in decreasing order by cations K^+, Na^+ and Mg^{2+}. The actual cation exchange capacity of sandy soil in the Cameron Highlands area is very low due to its low ability to produce negative charge on its surface compared with clay soil. This is demonstrated by CEC under the forest and tea plantation, which is only about 5meq/100g soil. The high amount of CEC shown in the cabbage cultivation area might not represent the actual CEC in soil because the cationic bases measured (K and Mg) could originate from slow release fertilizer pellets applied to the soil or from chicken manure applied as organic fertiliser. The high amount of Ca could be attributed to liming practice in vegetable farming.

Soil chemical properties

Selected soil chemical properties such as phosphorus, pH and electrical conductivity values are shown in Figures 4, 5 and 6, respectively.

The amount of available P in soil under the forest and tea plantation is very low and can be graded into Index 0 in the ADAS [5] recommendation. In the vegetable cultivated area, the P content range is not high either. The value is from 0.18±0.01 to 2.76±0.51 ppm, which falls in the Index 0 to 1 category. At this value there is a probability of failure of arable crops if there is no further application of P fertilizer [5]. The content of P in cultivated areas is significantly higher than the content under the forest. The difference of P content in cultivated area and forest/tea plantation could be attributed to the P fertilizer application in vegetables cultivated area.

pH value in soil under the forest and tea plantation is lower than soil pH under cabbage cultivation (Figure 5). The pH of soil under cultivated area is however lower than the pH requirement of mineral soil for arable use recommended by ADAS [5] at pH 6.5. This means that liming for the soil under cabbage cultivation should be carried out. The soil pH under the forest in particular is quite low. All of the soil pH is considered acidic. The low soil pH give rises to the amount of exchangeable Al and H in soil (Table 2).

Electrical conductivity (Figure 6) in all of the sampling area ranges from 1.02 to 1.44 mS/cm and can be put into Index 0 in the ADAS [5] recommendation. This means that their values are within the normal range normally found in outdoor soil.

This will pose no restriction for vegetable cultivation.

Table 2. Mean and standard deviation for cation, base saturation and cation exchange capacity (CEC)

STATION	AL^{3+}	H^+	NA^+	K^+	CA^{2+}	MG^{2+}	CEC	BS
				meq/100g soil				%
A	1.66±0.69	1.37±0.18	0.28±0.03	0.27±0.09	0.34±0.13	0.93±0.25	4.89±0.96	39
B	0.83±0.35	1.17±0.13	1.25±0.41	0.4±0.21	0.48±0.20	0.72±2.67	5.02±2.32	60
C	0.64±0.46	0.56±0.56	3.16±0.21	3.16±1.09	19.72±1.26	2.04±2.07	28.5±1.84	96
D	0.59±0.19	0.55±0.14	2.04±0.42	3.31±1.21	21.5±0.67	1.37±0.45	29.39±2.19	97
E	0.83±0.47	1.25±0.56	2.11±0.19	2.83±0.95	21.77±0.78	1.98±0.23	30.8±1.10	93

A, Kg. Raja (Forest); B, Blue Valley (Tea); C, Blue Valley (Cabbage 1); D, Kuala Terla (Cabbage 2); E, Tringkap (Cabbage 3); CEC, Cation exchange capacity; BS, Base saturation.

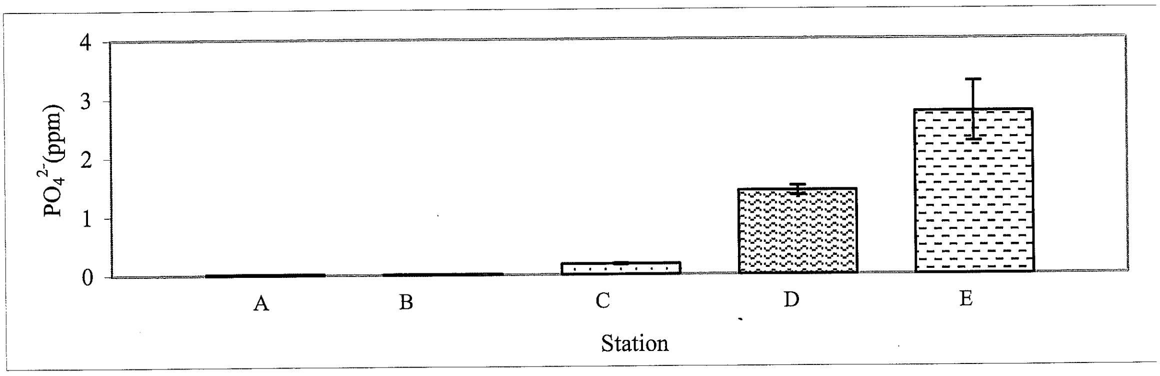

Figure 4. Available phosphorus content of soil

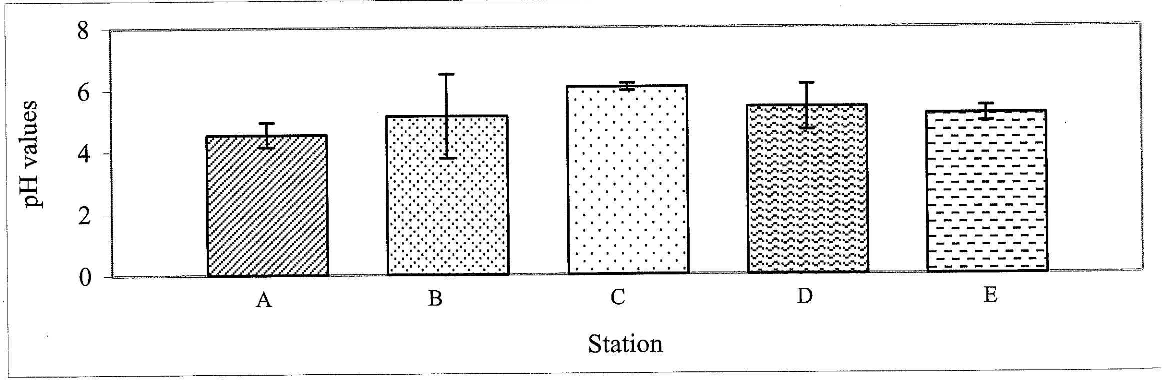

Figure 5. pH value of soil

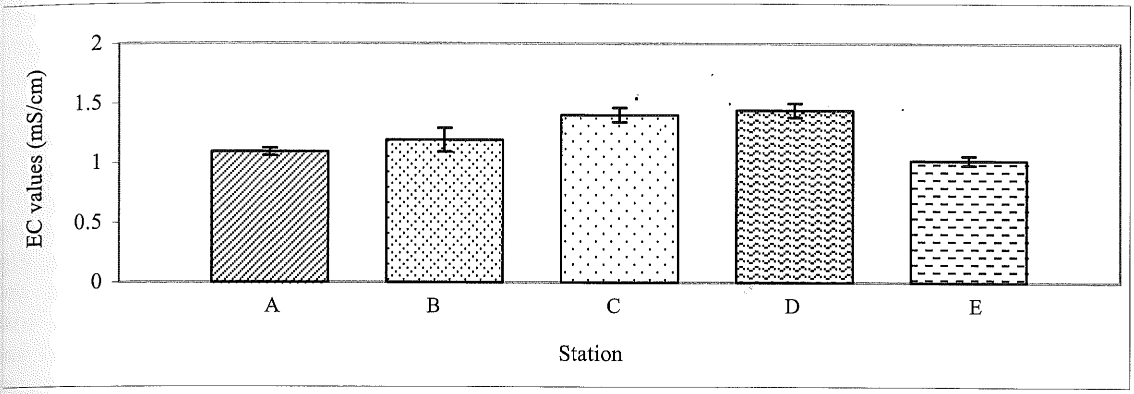

Figure 6. Electrical conductivity value of soil

Heavy Metal Content of Soil

Heavy metal content of soils is shown in Figures 7, 8 and 9. Mean As content in soil under cabbage cultivation ranged from 20.6±5.59 to 30.2±6.5 µg/g. Under the natural forest soil and abandoned tea plantation the mean value was 29.8±6.8 and 43.2±7.72 µg/g, respectively. There is no significant difference between means of As content in all of the stations. As contents in soils are within the normal concentration range in soils at 0.1 to 40 mg/kg, except for soil under the abandoned tea plantation. As concentration in all of the soils are within the critical soil total concentration range at 25-50 mg/kg suggested by Kabata-Pendias and Pendias [10].

The mean concentration of Co under vegetable cultivation ranged from 18±6.52 to 19.8±3.27 µg/g (Fig. 7). The mean content in the forest reserve and abandoned tea plantation are 12.2±10.04 and 15.4±16.6 µg/g, respectively. Co content under vegetable cultivation is slightly higher than Co in the forest reserve and abandoned tea plantation, however there is no significant difference between means of Co content in all of the stations. Co contents in soils are within the normal concentration range in soils at 0.5 to 65 mg/kg and below the critical soil total concentration range at 25-50 mg/kg suggested by Kabata-Pendias and Pendias [10].

Mean Cr content in land cultivated with cabbage ranged from 44.6±1.14 to 61.6±6.58 µg/g (Figure 7). The mean content under abandoned tea plantation and forest reserve was 49.6±26.03 and 33±4.74 µg/g, respectively. Cr content in Station A (Forest Reserve) is significantly lower than the Cr content in cultivated area. Cr contents in soils are within the normal concentration range in soils at 5 to 1500 mg/kg and well below the critical soil total concentration range at 75-100 mg/kg suggested by Kabata-Pendias and Pendias [10].

The mean content of Cu is higher under cabbage cultivation, ranging from 13.8±13.7 to 59.2±39.8 µg/g (Figure 7). Highest value occurs at Blue Valley 2, followed by Kuala Terla, then Tringkap. Under the abandoned tea plantation, the mean of Cu content is 34±13.5 µg/g, whereas the mean of Cu concentration at Kg. Raja Forest Reserve is 13.8±5.36 µg/g. Cu content in cabbage plantations at Stations C and D are significantly higher than the Cu content in the natural forest soil. This means that agricultural practices have contributed to the increment in Cu content in cultivated area. Co contents in natural forest soil and cabbage cultivation are within the normal concentration range in soils at 2 to 250 mg/kg and below the critical soil total concentration range at 60-125 mg/kg suggested by Kabata-Pendias and Pendias [10].

Mean Ni concentration under cabbage cultivation ranged from 19±0.71 to 20.2±4.32 µg/g (Figure 8). Under the forest and tea plantation the mean of Ni was 11.6±2.51 and 9.4±2.61 µg/g, respectively. Ni contents under vegetables cultivation are significantly higher than the content in forest reserve and abandoned tea plantation. The significance increase in Ni content under cabbage cultivation could be due to normal agricultural practices. Ni contents in soils are within the normal concentration range in soils at 2-750 mg/kg and well below the critical soil total concentration range at 100 mg/kg suggested by Kabata-Pendias and Pendias [10].

The mean Pb content in vegetable cultivation area ranged from 35.4±8.56 to 78±6.32 µg/g (Figure 8). The content of lead in all cabbage farms are highest in Kuala Terla (78 µg/g) followed by Tringkap (69 µg/g) and Blue Valley 2 (35 µg/g). The lead content in forest reserve area was 57.8±13.3µg/g, whereas in tea plantation area lead content was the lowest with a value of 34.8±32.5µg/g. Lead content is significantly higher in cabbage cultivation area (station D) compared to natural forest soil. This could be contributed to mechanization used for field preparation. Pb contents in soils are within the normal concentration range in soils at 2-300 mg/kg and well below the critical soil total concentration range at 100-400 mg/kg suggested by Kabata-Pendias and Pendias [10].

The mean of Zn content under cabbage cultivation ranged from 82.8±8.76 to 251.8±93.7 µg/g. The highest Zn content is shown in Station C. The Zn content in cabbage cultivated areas are significantly higher than Zn content in natural forest soil (57.8±9.04 µg/g) and abandoned tea plantation (28.2±15.5µg/g). Higher Zn content under cabbage cultivation could be contributed by normal management practices in agriculture. Zn contents in soils are within the normal concentration range in soils at 1 to 900 mg/kg, however Zn content in cabbage cultivation areas are already within the range of critical soil total concentration range at 70-400 mg/kg suggested by Kabata-Pendias and Pendias [10]. Generally the concentration of heavy metals under cabbage cultivation is higher than their content in forest reserve and tea plantation except for As. Forest reserve represents a non-disturbed environment whilst tea plantation is a less disturbed environment compared to the cabbage cultivation areas, which required active management of land. This means that soil under vegetable cultivation has undergone some changes in term of their heavy metal content compared to natural undisturbed land under the forest. The difference in heavy metal concentration could be due to the normal practice of fertilizer and pesticides application in order to induce good yield. According to Alloway [3] agricultural practices constitute very important non-point sources of metals which make significant contributions to their total concentration in soils in region of intensive farming in many part of the world. Pesticides are common sources of Cu, As, Hg, Pb, Mn and Zn [3]. Most agricultural and horticultural soils are regularly amended with fertilizer, organic fertilizer (livestock base) and lime. The typical heavy metal concentrations found in these materials are given in Table 3. It can be seen that phosphatic fertilizers, organic fertilizers and lime are important sources of heavy metals in agricultural soils. Heavy metal components in fertilizers have also been characterized in detail in Otero *et al.* [17] for further references.

Based on the threshold toxicity level given by Kabata-Pendias and Pendias [10], the As and Zn mean content in all of the soils are already within the range of critical soil total concentration range at 25-50 µg/g and 70-400 mg/kg, respectively. Arsenic content in soil is inherited from the soil parent material because the content is high in the soil under the forest reserve which has not undergone any chemical modification.

High Zn content can be attributed to fertilizer, lime and pesticides application as indicated by Alloway [3] and Otero *et al.* [17]. Abdel-Haleem, *et al.* [1] indicated that with every kg of rock phosphate and limestone application to agricultural soil in Egypt about 13.32 and 37.9 mg/kg of Zn are added to the soil. Heavy metal content analysis on some fertilizers and pesticides carried out by Gimeno-Garcia *et al.* [9] showed a considerable amount of Zn at 13.3 to 50 mg/kg in fertilizers and high amount of Zn at 32.5 to 274000 mg/kg in pesticides.

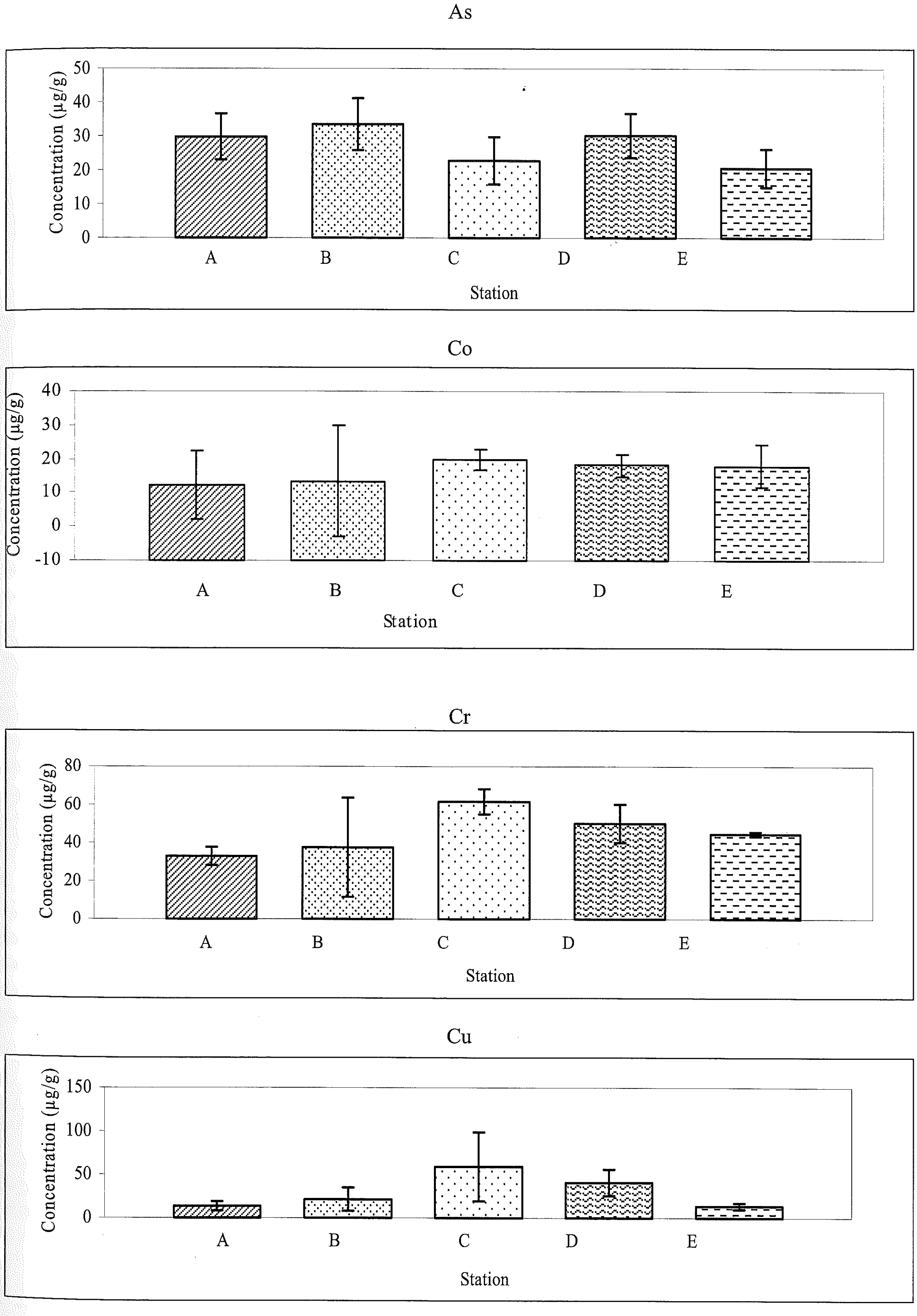

Figure 7. Heavy metal (As, Co, Cr, Cu) concentration in the study area A, Kg. Raja (Forest Reserve); B, Blue Valley (Tea); C, Blue Valley (Cabbage); D, Kuala Terla (Cabbage); E, Tringkap (Cabbage)

Table 3. Typical range of heavy metal concentrations in fertilizer, farmyard manure and lime (mg/kg) [3]

	PHOSPHATE FERTILIZERS	**NITRATE FERTILIZERS**	**FARMYARD MANURE**	**LIME**
As	2-1200	2.2-120	3-25	0.1-25
Cd	0.1-170	0.05-8.5	0.1-0.8	0.04-0.1
Co	1-12	5.4-12	0.3-24	0.4-3
Cr	66-245	3.2-19	1.1-55	10-15
Cu	1-300	-	2-172	2-125
Mo	0.1-60	1-7	0.05-3	0.1-15
Ni	7-38	7-34	2.1-30	10-20
Pb	7-225	2-27	1.1-27	20-1250
Zn	50-1450	1-42	15-556	10-450

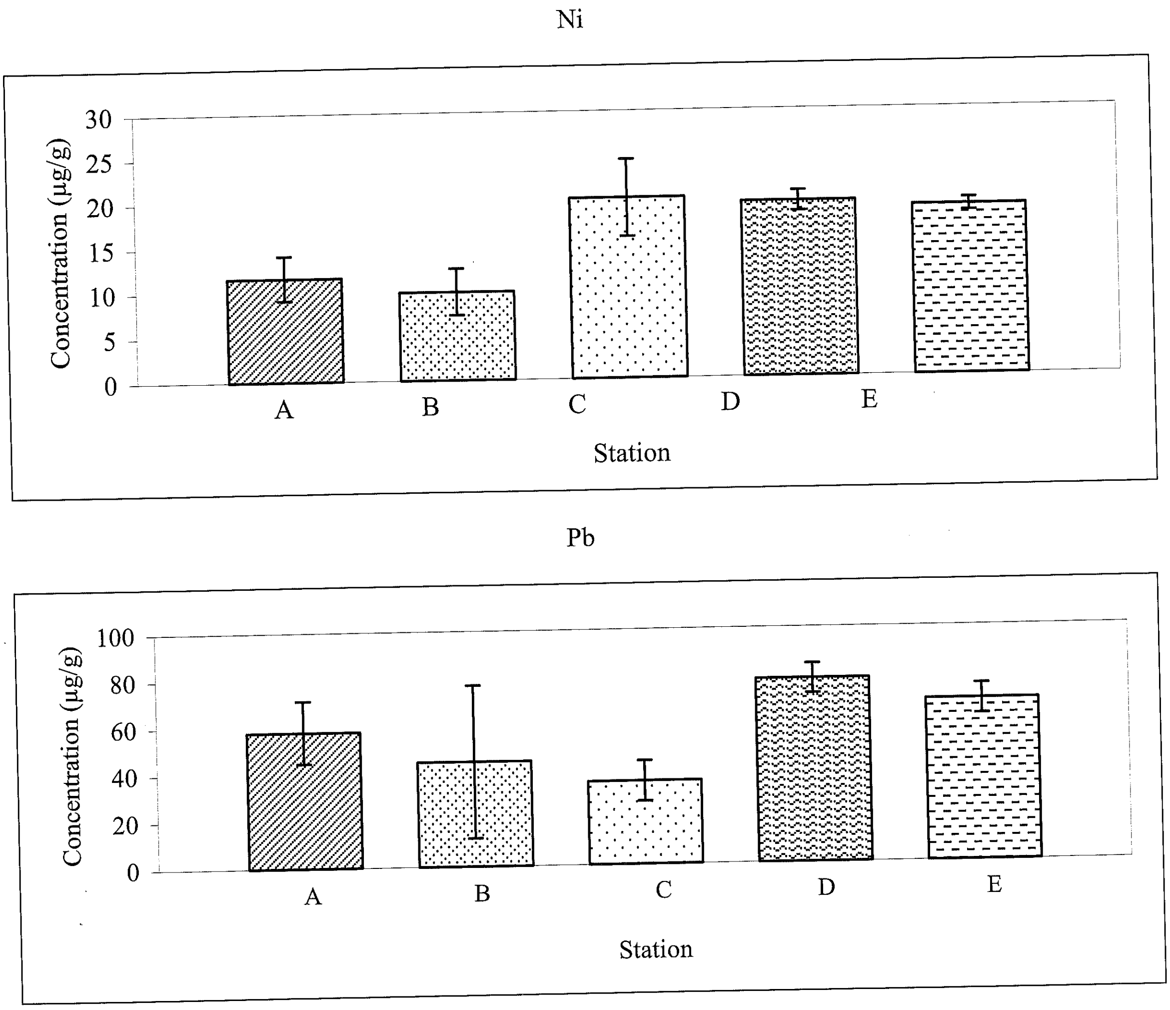

Figure 8. Heavy metal (Ni, Pb) concentrations in the study area

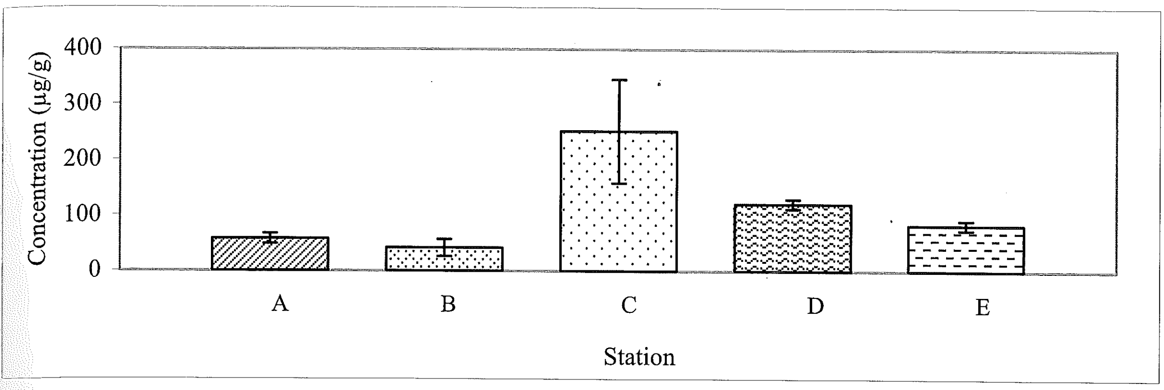

Figure 9. Zinc content in soil of the study area

Correlation between heavy metals and soil parameters

Correlation test (Table 4) was carried out between heavy metals, and then between heavy metals and some soil parameters. This test may answer some of the questions on how the heavy metals interact among themselves and what is the influence of soil parameters to their existence or enrichment in soils. Star markings following the r-value indicate the strength of correlation.

Co and Ni are positively correlated at 5% significance level with Pb. Cu, Ni and Cr have a positive correlation with Zn at more than 5% significance level. Cr is positively correlated with Co at 0.1 % significant level. As has a negative correlation at 5% level of significance with Ni. Positive correlation in the case of heavy metals normally indicates their mutual existence and enrichment in soil, whereas negative correlation indicates their competition to occupy the same site in soil exchange base or lattice. Cobalt, Ni and Pb are commonly co-precipitated in secondary minerals of Mn oxides, whereas Ni, Cr, Zn and Co are commonly co-precipitated in secondary minerals of illites [18]. Ni and As may replace each other in the exchange site of a soil surface.

Clay content in the soil does not show any significant correlation with heavy metals. Sand content negatively correlates with Pb, Ni and Cr, significantly, which means that these heavy metals do not occur in sand particle. They are commonly co-precipitated in illites. Most of the As content in soil is associated with sand particles. Silt content was positively correlated with Pb, Co, Ni and Cr, significantly. This indicates that these heavy metals are more associated with the silt fraction compared to sand and clay. Organic matter (OM) seems to correlate negatively with Ni at 5% level of significance. High organic matter content normally induced low acidity, thus at low pH Ni entered into a chelate reaction with organic matter and fixed into it. This fixation reduced the amount of Ni content in the soil. This explains the inverse proportionate relationship between Ni and organic matter. The pH of soil has a significant positive relationship with Zn, Ni and Cr. Increase in soil pH also gave an increase in Zn, Ni and Cr content in soil. This can be associated with their solubility in soil as the pH increases. As the pH increased Zn, Ni and Cr became insoluble and precipitated on the soil particle surface. The phosphorus content also has a significant positive correlation with Pb and Ni. This could be contributed by phosphorus fertiliser application into the soil that contained some amount of Pb and Ni. The electric conductivity (EC) also has a significant positive correlation with Zn and Cu. This indicates the increase in Zn and Cu content as the ionic cation concentration increases in soil.

Table 4. Correlation between heavy metals and soil parameters

	Pb	Zn	Cu	Co	Ni	Cr	As
Cu		0.721***					
Co	0.447*					0.681***	
Ni	0.426*	0.681***				0.432*	
Cr		0.435*					-0.506*
pH		0.581**			0.427*	0.502*	
PO_4^{2-}	0.486*				0.471*	-0.057	
EC		0.513*	0.679***			0.109	
%OM					-0.531*	-0.064	
%Sand	-0.429*				-0.597**	-0.527*	0.500*
%Silt	0.739***			0.548**	0.566**	0.527*	-0.447*

N=25, $r \geq 0.423$* (significant at 5% level); $r \geq 0.537$** (significant at 1% level); $r \geq 0.652$*** (significant at 0.1% level)

CONCLUSION

Soil in the vegetable cultivation areas contained more finely sized material compared to soil under the forest. Organic matter content in soil under natural forest was higher, thus its bulk density was lower compared to soil under vegetable cultivation.

Soil pH under forest and tea plantation is slightly lower than pH under vegetable cultivation area. The base saturation and cation exchange capacity of soil under vegetable cultivation was significantly higher than under the forest and tea plantation. Soil phosphorus content and electric conductivity are both low.

Heavy metal contents for Co, Cu, Cr, Ni and Zn in vegetable cultivation area were higher than the contents under forest and tea plantation, indicating the impact of fertilization and pesticide application to soils in the vegetable cultivation area. Pb and As content are quite similar in the two areas.

Heavy metal contents for As and Zn were higher than the threshold of potential toxicity level in soils.

Soil pH, organic matter content and electric conductivity have some influence on heavy metal enrichment and decline in soils.

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