LAND-USE EFFECT ON DISTRIBUTIONS OF As, Cr AND Cu IN SOILS ADJACENT TO CCA-TREATED UTILITY POLES IN ARTVIN AND RIZE, TURKEY

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ABSTRACT

Chromated copper arsenate (CCA)-treated wood has been widely used in Turkey to protect it from decay. In this study, influences of land-use types on distributions of As, Cr and Cu in soils adjacent to CCA-treated utility poles were studied in tea and hazelnut plantations as well as crop fields. Ten poles from each land-use type (a total of 30 poles) were chosen for the study purposes in Arhavi and Fındıklı towns of Artvin and Rize, Turkey, respectively. Soil samples were collected from surface layers of soil (0-10 cm depth), adjacent to the utility poles and at distances of 0.5 m and 10 m (control). Concentrations as high as 80, 520 and 94 mg kg^{-1} were observed in soils adjacent to utility poles for As, Cr and Cu, respectively. Soil As, Cr and Cu levels decreased significantly with the distance from the CCA-treated poles. Cr concentrations in soil were significantly higher in the tea plantations than in the crop fields ($P < 0.05$). Soil pH, sand, clay and organic matter content varied significantly with land-use type. Our results indicate that the use of CCA-treated utility poles in the tea plantations poses more environmental contamination risks compared to that in hazelnut plantations and crop fields. These risks could be eliminated by using alternative arsenic-free wood preservatives.

KEYWORDS: Chromated coppper arsenate (CCA), heavy metal pollution, soil contamination.

INTRODUCTION

CCA is a major wood preservative and has been used for more than 50 years for many applications, such as utility poles, railroad sleepers, residential fencing, decks and children play-grounds. CCA is water-soluble and introduced under high pressure into the pores of wood in order to prevent decay arising from the activities of bacteria, fungi, or insects [1]. In Turkey, CCA is currently the most used wood preservative. However, there is an increasing public concern about environmental contamination from CCA-treated wood [2, 3]. On February 12, 2002, the US Environmental Protection Agency (EPA) announced a voluntary decision by the pressure-treated wood industry to phase out use of common arsenic-based wood preservative CCA in products with destination to consumer markets. Since January 2004, the EPA no longer allowed pressure-treated wood containing CCA to be used for residential applications, such as children's play structures, decks, picnic tables, landscaping timbers, residential fencing or walkways [4-6]. However, there is no regulation on the use of CCA-treated wood in Turkey, partly due to the lack of enough scientific data associated with the potential environmental impacts.

Numerous studies have been done dealing with environmental risks that CCA elements represent for both aquatic environments and soils (e.g. [1, 2, 7-10]). However, there are only two studies that have done in Turkey by Erdin et al. [11] and Gezer et al. [6]. Gezer et al. [6] studied CCA element concentrations in soils near the utility poles and observed higher concentrations adjacent to them, compared to control soils. Erdin et al. [11] studied the content and mobility of copper (Cu), chromium (Cr) and arsenic (As) in the soil of a wood-preserving plant using CCA. They found concentrations as high as 513, 1945 and 2400 mg kg^{-1} for arsenic, copper and chromium, respectively.

Toxicity and mobility of As, Cu and Cr in soil depend on different soil characteristics, such as contents of clay, sand and silt (texture), organic matter, soil pH, Al, Mn, Fe oxides, soil redox potential, etc.[7, 6]. Soil constitutes chemically react with As, Cu and Cr by reactions of specific and non-specific adsorption, precipitation, cation exchange, organic complexation, etc. Balasoiu et al. [7] reported that retentions of Cr and Cu in soils increased with increasing organic matter content, while As retention did not change with organic matter. Chromium exhibits a typical anionic sorption behavior, its adsorption decreasing with increasing pH and when competing dissolved anions are present

[12]. These elements are transformed in the soil medium and the type of reaction can increase or depress element toxicity [13].

Land-use type is an important factor influencing soil physical, chemical and biological properties. Soil parameters, such as organic matter, clay and pH, are directly influenced by the land-use type [14], and they are important determinants of the CCA retention in soils [7]. However, to our knowledge, no data are available on influence of land-use type on distributions of CCA elements in soils adjacent to utility poles.

In this study, the main objective was to assess the distributions of Cu, Cr and As in soils with varying distances from CCA-treated utility poles installed in cropfield, tea and hazelnut plantations in Arhavi and Fındıklı towns of Artvin and Rize, Turkey, respectively. Our second objective was to determine the influence of land-use type on the distributions of these elements. In addition, As, Cr and Cu accumulations in young leaves and twigs of tea plants near the CCA-treated utility poles were investigated.

MATERIALS AND METHODS

The study sites are located at Arhavi and Fındıklı towns of Artvin and Rize, respectively, in Turkey. Thirty utility poles, established in crop fields as well as tea and hazelnut plantations (10 poles per land-use type) were randomly selected in these towns. The poles were in service for more than fifteen years. The sites with different aspects and gentle slopes (10-20%) range in elevation from 50 m to 150 m. Soils at the sites are well-drained red-yellow podsolic ones. The mean annual temperature is 14 °C, mean annual relative humidity is 75%, and total annual percipitation is 1660 mm in the study sites.

Soil samples were collected adjacent to utility poles (0-5 cm), 0.5 m away from the utility poles, and 10 m away from them (control) from surface layers (10 cm depth) of soil in the crop fields, tea plantation and hazelnut plantation areas. A soil auger was used to take soil samples. A total of 90 soil samples were collected. The soil samples were air-dried in the laboratory and sieved to remove coarse fragments larger than 2 mm. Soil organic matter content, pH and texture of soil samples were analyzed. Organic matter contents of soils were determined according to the wet digestion method described by Kalra and Maynard [15] (modified Walkley-Black method). Soil texture was determined by Bouyoucos` Hydrometer Method described by Gulcur [16]. Soil pH was determined by a combination glass-electrode in H_2O (soil-solution ratio 1:2.5) [15]. Soil Cu, Cr and As contents were determined using X-ray fluorescence spectrometry (XRF) according to American Wood Preservers' Association (AWPA) A9-99 test method [17].

The accumulations of Cu, Cr and As in the leaves and young twigs of tea plants (adjacent to, 0.5 m away, and control sites) were also determined for the poles established in the tea plantation areas. For this purpose, 1-2 years old twigs and leaves from tea plants were collected, combined, dried at 65 °C for 24 h, ground and sieved to remove coarse fragments larger than 2 mm. Pellets containing prepared tea samples were scanned to determine copper, chromium and arsenic using XRF according to AWPA A9-99 test method [17].

Statistical comparisons were made using SPSS program. We used ANOVA to compare soil As, Cr and Cu concentrations among distances (adjacent to, 0.5 m away and control) and land-use types (crop field, tea and hazelnut plantations). Differences between specific land-use types and between specific distances were determined with Duncan test at $\alpha = 0.05$.

RESULTS AND DISCUSSIONS

Cu, Cr, and As levels in soil varied significantly with distance from CCA-treated utility poles (Table 1 and Figures 1-3). Soils adjacent to poles had significantly higher Cu, Cr and As concentrations than soils in 0.5 m distance and control sites. But, Cu, Cr, and As did not differ significantly between control and 0.5-m samples. Similar findings have been reported by Erdin et al. [11], and other researchers [1, 6, 9, 10, 13, 18-21]. They found higher Cu, Cr and

TABLE 1 - Mean Cr, Cu and As concentrations in soil samples of the study area.

	Distance from utility pole	Cr ($mg\ kg^{-1}$)		Cu ($mg\ kg^{-1}$)		As ($mg\ kg^{-1}$)	
		Mean	Std*	Mean	Std	Mean	Std
Tea plantation	Adjacent to	437.80	41.31	71.44	8.81	69.35	1.60
	0.5 m away	358.59	41.21	60.97	2.48	65.04	1.69
	Control	349.16	38.02	59.90	1.99	64.59	1.62
Hazelnut	Adjacent to	414.07	34.72	68.66	4.45	70.52	3.73
	0.5 m away	350.91	25.78	60.00	1.74	65.30	1.52
	Control	349.70	27.80	59.83	1.35	63.89	1.66
Crop field	Adjacent to	400.88	16.37	66.48	3.05	68.72	1.43
	0.5 m away	326.57	15.45	58.88	2.22	63.40	1.14
	Control	316.48	15.03	58.06	2.50	62.83	1.14

*: Standard deviation

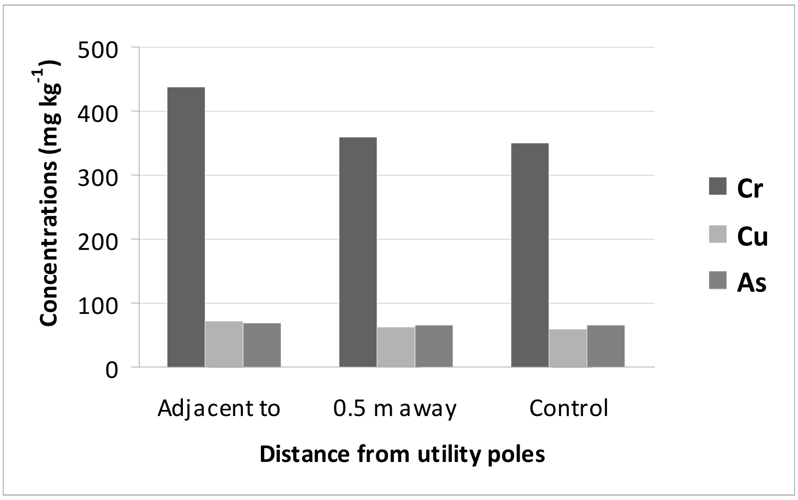

FIGURE 1 - Mean Cu, Cr and As concentrations in soil samples collected at 3 different distances from the utility poles in the tea plantation areas.

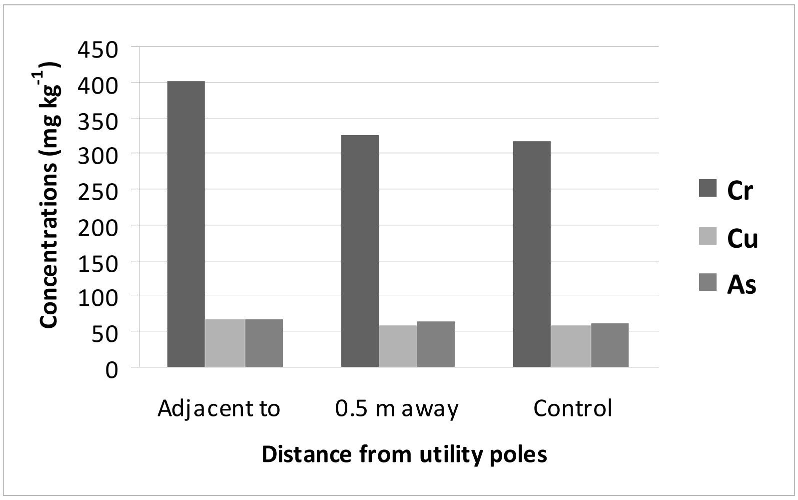

FIGURE 2 - Mean Cu, Cr and As concentrations in soil samples collected at 3 different distances from the utility poles in the hazelnut plantation areas.

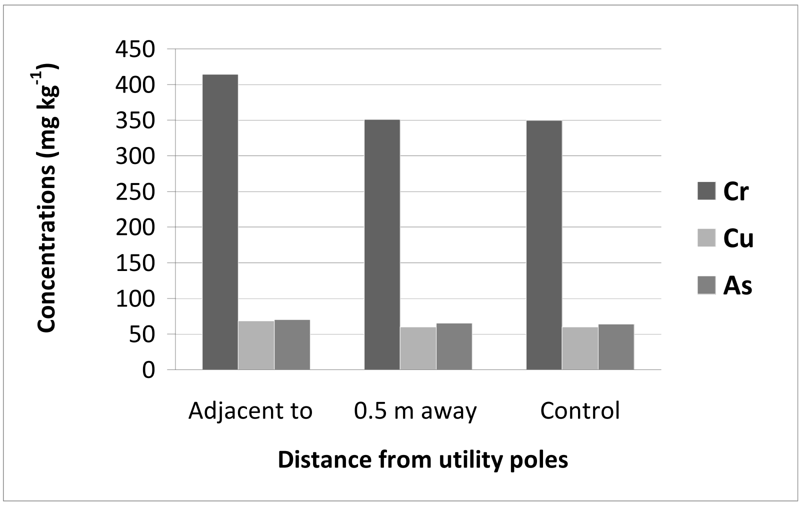

FIGURE 3 - Mean Cu, Cr and As concentrations in soil samples collected at 3 different distances from the utility poles in the crop fields.

As concentrations in soil samples taken adjacent to poles, with regard to those taken from 0.5 m away.

Mean As concentrations in 0, 0.5 and 10 m (control) samples were 69.7, 64.8 and 63.8 mg kg^{-1}, respectively, being higher than those reported by Townsend et al. [19] (28 mg kg^{-1} in adjacent to, 1.5 mg kg^{-1} in control), Chirenje et al. [9] (6.9 mg kg^{-1} in adjacent to, 2.2 mg kg^{-1} in control), Ursitti et al. [21] (20.3 in adjacent to, 2.4 mg kg^{-1} in control) and Kim et al. [1] (48.8 in adjacent to, 5 mg kg^{-1} in control); and lower than the values reported by Gezer et al. [6] (around 200 mg kg^{-1} in adjacent to, 50 mg kg^{-1} in control), Stilwell and Gorny [18] (76 mg kg^{-1} in adjacent to, 3.7 mg kg^{-1} in control), and Zagury et al. [10] (around 153-410 mg kg^{-1} in adjacent to, 6.3-61 mg kg^{-1} in 0.1 m away) for adjacent to-samples. Relatively higher As values in our control soils might be the results of pesticide application, air combustion or parent material effect.

Mean Cr concentrations in adjacent to, 0.5-m away and control samples were 418.7, 347.2 and 342.2 mg kg^{-1}, respectively. These values were higher than those reported by Gezer et al. [6] (around 100 mg kg^{-1} in adjacent to and 20 mg kg^{-1} in control), Townsend et al. [19] (34 mg kg^{-1} in adjacent to and 10 mg kg^{-1} in control), Chirenje et al. [9] (26.5 mg kg^{-1} in adjacent to and 12.2 mg kg^{-1} in control) and Kim et al. [1] (48.5 in adjacent to and 45.9 mg kg^{-1} in control).

Mean Cu concentrations in adjacent to, 0.5-m away and control samples were 69.1, 60.1 and 59.4 mg kg^{-1}, respectively. Our mean Cu levels were higher than the values reported by Townsend et al. [19] (2000) (40 mg kg^{-1} in adjacent to and 10 mg kg^{-1} in control), Chirenje et al. [9] (36.8 mg kg^{-1} in adjacent to and 16.2 mg kg^{-1} in control) and Kim et al. [1] (42.5 in adjacent to and 24.2 mg kg^{-1} in control), but lower than those reported by Gezer et al. [6] (around 700 mg kg^{-1} in adjacent to and 50 mg kg^{-1} in control).

Mean Cr concentrations in tea and hazelnut plantations and crop fields were 383.4, 372.7 and 349.5 mg kg^{-1}, respectively. Crop fields had significantly lower Cr levels than the tea plantations ($P<0.05$). Lower Cr concentrations in crop fields compared to the other sites could be due to tilling practices. Lund and Fobian [22] reported that Cr concentrations decreased with soil depth. With the tillage, subsurface soil relatively low in Cr content, compared to surface soil, was brought into soil surface. In addition, leaching of Cr might be enhanced by tillage due to the increases in infiltration and percolation of water in soil profile after tillage [23]. There were no soil tilling practices in hazelnut and tea plantation areas, at least for the last 20 years. Soil Cu and As concentrations did not vary with land- use type.

Chromium and copper concentrations of combined tea samples (leaves and young twigs) differed significantly with distance from the utility poles. Mean Cu concentrations in combined tea samples were 25.0, 21.9 and 21.2 mg kg^{-1} for adjacent to, 0.5 m away and control samples, respectively. Cu levels in adjacent to samples were significantly higher than in 0.5-m away and control samples. Mean Cr levels were 107.2, 76.2 and 32.0 mg kg^{-1} for adjacent to, 0.5 m away and control samples, respectively, being significantly different among all distances. Arsenic levels in combined samples were found to be below detectible limit (<1 mg kg^{-1}). This is consistent with the general view that As accumulation into the edible parts of most plants is low [24, 25]. Levels of Cr and As in stem, leaf, and fruit tissue of grapes growing adjacent to CCA-treated posts were below the detection limits of 0.2 and 0.05 mg kg^{-1}, respectively [26]. In the same study, Cu levels were between 4.7-11.6 mg kg^{-1}, well within the normal range found in plant tissues [26].

Soil pH differed significantly with land-use type (Tables 2 and 3, Figs. 4-6). It was found that pH of soil samples taken from tea plantations was significantly lower than that of crop fields or hazelnut plantations ($P<0.05$). Low pH in tea plantations is related to the soil acidifying effect of tea [27]. Also, hazelnut plantations had significantly lower soil pH than the crop fields. Overall, soil pH was low in the study area compared to the other regions of Turkey, due to high precipitation rates in the region [28].

TABLE 2 - Some soil properties in the study area.

	Distance from utility pole	pH		Sand (%)		Clay (%)		Silt (%)		OM** (%)	
		Mean	Std*	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Tea plantation	Adjacent to	4.35	0.55	63.89	9.27	18.04	8.37	18.07	5.34	6.93	1.90
	0.5 m away	4.44	0.58	68.25	9.17	14.54	7.12	17.22	5.98	8.93	2.77
	Control	4.17	0.41	66.41	7.98	14.84	5.43	18.75	5.48	7.99	2.47
Hazelnut	Adjacent to	4.91	0.53	71.87	12.30	12.20	8.18	15.94	5.71	5.56	2.20
	0.5 m away	5.23	0.51	67.56	13.25	14.13	7.95	18.32	6.88	4.38	1.56
	Control	5.12	0.34	68.62	10.08	15.57	4.95	15.80	6.36	4.80	1.55
Crop field	Adjacent to	5.06	0.65	54.62	9.88	24.98	7.16	20.40	5.05	7.11	2.33
	0.5 m away	5.44	0.90	56.07	6.44	24.90	4.91	19.04	3.03	7.16	2.84
	Control	5.47	0.87	54.31	7.80	26.20	5.85	19.50	2.79	7.34	3.25

*: Standard deviation **: Organic matter

TABLE 3 - The effects of distance and land-use type on some soil properties and Duncan test results.

		pH			Sand (%)			Clay (%)			Silt (%)			OM (%)		
		Mean	Std*	HG**	Mean	Std	HG	Mean	Std	HG	Mean	Std	HG	Mean	Std	HG
Distance from utility poles	Adjacent	4.77	0.58	A***	63.46	10.48	A	18.41	7.90	A	18.14	5.37	A	6.53	2.14	A
	0.5 m	5.04	0.66	A	63.96	9.62	A	17.86	6.66	A	18.19	5.30	A	6.82	2.39	A
	1 m (control)	4.92	0.54	A	63.11	8.62	A	18.87	5.41	A	18.02	4.88	A	6.71	2.42	A
Land-use type	Tea plantation	4.32	0.51	a	66.18	8.81	a b	15.81	6.97	a	18.01	5.60	a	7.95	2.38	a
	Hazelnut plantation	5.09	0.46	a b	69.35	11.88	b	13.97	7.03	a	16.69	6.32	a	4.91	1.77	b
	Crop field	5.32	0.81	b	55.00	8.04	a	25.36	5.97	b	19.65	3.62	a	7.20	2.81	a

* Standard deviation; ** Homogeneity Group; *** Different letters in the same column indicate significant difference at $P < 0.05$

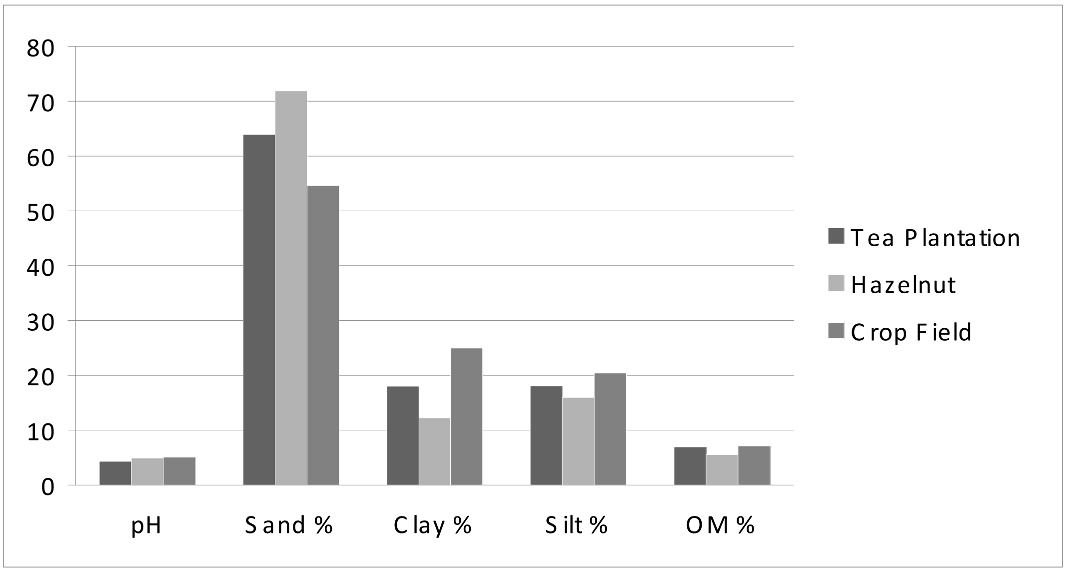

FIGURE 4 - Some properties of soil samples taken adjacent to utility poles.

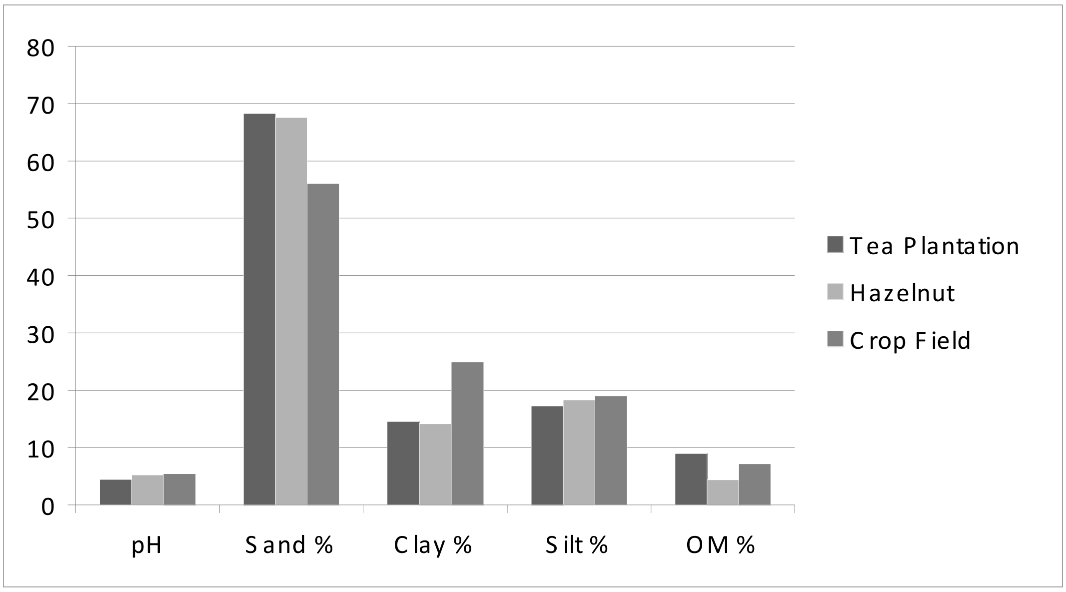

FIGURE 5 - Some properties of soil samples taken 0.5 m away from the utility poles.

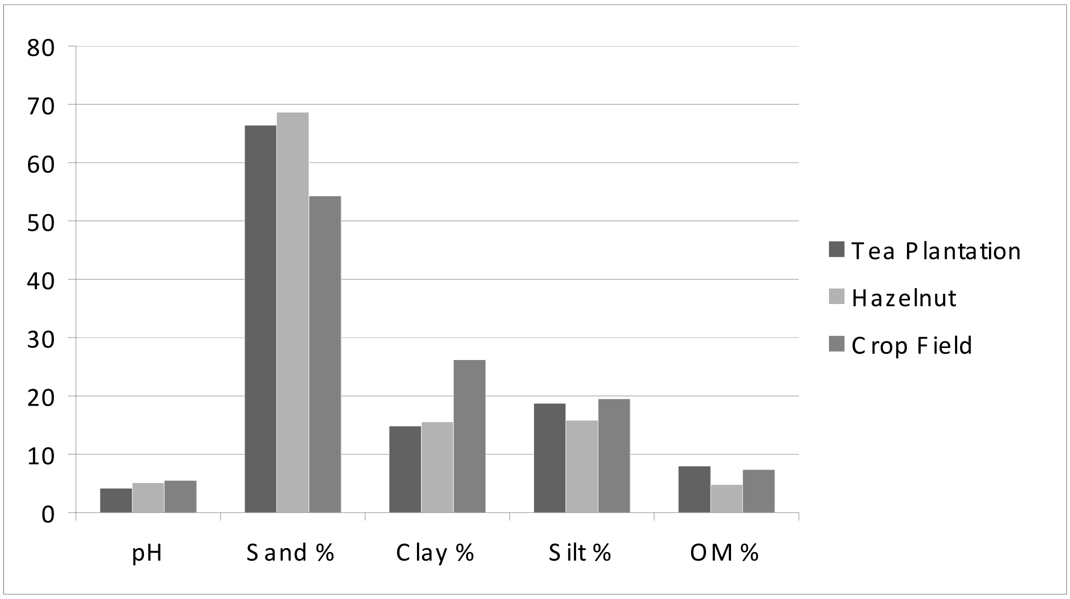

FIGURE 6 - Some properties of soil samples taken from control sites.

Soil sand, clay and organic matter content varied significantly with land-use types (Tables 2 & 3, Figs. 4-6). Soil organic matter was significantly higher in tea than hazelnut plantations and crop fields. The main reason for low organic matter in hazelnut plantations was the collection of litter-fall by the villagers as a bedding material for livestock. Clarke et al. [29] reported that soil organic matter level was significantly influenced by the above-ground litterfall input. We also found that crop fields had significantly higher clay content than the tea plantations (Figs. 4-6). Soil sand, silt, clay and organic matter contents did not vary significantly with distance from the utility poles (Table 3).

CONCLUSIONS

Elevated As, Cr and Cu contents were observed in soils adjacent to utility poles, but they decreased significantly with the distance from the poles. Soil Cr concentrations were significantly higher in tea plantations than in crop fields ($P<0.05$). Cr and Cu concentrations in combined tea samples (leaves and young twigs) differed significantly with distance from the utility poles. Arsenic levels in combined tea samples were found to be below detectable limit (<1 mg kg^{-1}). Our results indicate that there is the potential for soil and environmental contamination by Cr, Cu and As, wherever CCA-treated wood is used for utility poles. There should be no cultivation closer than 1 m to the utility poles in tea gardens and crop fields.

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