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Effect of agrochemicals applicationon accumulation of heavymetals on soil of different landuses with respect to its nutrient status.

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Abstract: *There is a growing public concern over the potential accumulation of heavy metals in agricultural soils owing to rapid urban and industrial development and increasing reliance on agrochemicals in the last several decades.*

Excessive accumulation of heavy metals in agricultural soils may not only result in environmental contamination, but elevated heavy metal uptake by crops may also affect food quality and safety. The present study is aimed at studying heavy metal concentrations of soils in different agrochemicals applying land uses in Dimoria Tribal Development Block, Kamrup(M), Assam to assess its soil quality in terms of its physic-chemical properties. Six heavy metals were analyzed (Cd, Cu, Cr, Ni, Pb, and Zn) using Flame Atomic Absorption Spectroscopy. The average contents of Cd, Cu, Cr, Ni, Pb, and Zn in surface soils (0-15 cm depth) ranges in the following order; Cd (0.16-0.83) < Ni (2.56-29.06) < Cu (4.66-27.16) < Cr (8.03-46.06) < Zn (35.13-99.83). In terms of NPK availability the soil status can be regarded as of moderate quality. The soils could not be said to be contaminated for now because metal content levels conformed to the world-wide background content of metals range in the soil.

Keywords:*Agrochemicals, Agricultural soils, Heavy Metals, Soil Quality*

I. Introduction

Soil is a complex structure and contains mainly five major components i.e. mineral matter, water, air, organic matter and living organisms. The quantity of these components in the soil does not remain the same but varies with the locality. Soil possesses not only a nucleus position for existence of living being but also ensures their future existence. Therefore, it is essential to make an adequate land management to maintain the quality of soil in both rural and urban soil.

Soil serves many vital functions in our society, particularly for food production. It is thus of extreme importance to protect this resource and ensure its sustainability. Modern, or conventional, agricultural practices use intensive tillage, monoculture, irrigation, application of inorganic fertilizers, chemical pest control, and plant genome modification to maximize profit and production (Gliessman 1998). These practices greatly increased crop yields, and agricultural production rose steadily after World War II. However extensive rely on these practices have led to soil degradation which is one of the most serious consequences of conventional agriculture. Agrochemicals (or agrichemicals) are the various chemical products used in agriculturethat improves the production of crops. In most cases, agrochemical refers to the broad range of pesticides, including insecticides, herbicides, and fungicides. It may also include synthetic fertilizers, hormones and other chemical growth agents, and concentrated stores of raw animal manure. Agrochemicals are used in agricultural setting in an effort to ensure an abundant food supply. There are, however, many negative effects of agrochemicals. Some of these agrochemicals, more commonly called pesticides, reach many organisms that were not the intended target. Adding any chemicals to the soil can have far-reaching effects due to the fact that producers rely on soil for their growth.

Heavy metals are natural constituents of the Earth's crust but human activities have altered the balance and biochemical and geochemical cycles of some of them. (Alloway 2004, Abollino et al., 2002) Once in soil, some of these metals will persist in soils for a very long time because of their fairly immobile nature leading to environmental pollution in aquatic systems. (SOIL QUALITY, 2000). Deteriorating environmental conditions and increasing reliance on agrochemicals have led to a growing public concern over the potential accumulation of heavy metals and other contaminants in agricultural soils (Nriagu, 1988; Alloway, 1990; Kabata-Pendias and Pendias, 1995).

Soil represents a major sink for metals released into the environment from a variety of anthropogenic activities such as agricultural practices, transport, industrial activities and waste disposal. (Makino et al., 2010, Alloway, 2004, Abollino et al., 2002) Heavy metal contamination is now widespread (Nriagu, 1990). Different anthropogenic activities, such as mining, smelting, power station industry, sewage water and sewage sludge land spreading, application of metal- containing pesticides and fertilizers may contribute to soil pollution with heavy metals (Chaudharyet al., 2004; Gimeno-Garcíaet al., 1996; Pur chase et al., 1997; Robinson et al., 2001; Turgut, 2003).

1.1 Sources of heavy metals on soil and environment.

Heavy metals are the stable metals or metalloids whose density is greater than 4.5 g/cm3, namely Pb, Cu, Ni, Cd, Zn, Hg and Cr etc. They are stable and cannot be degraded or destroyed, and therefore they tend to accumulate in soils and sediments. There are several sources of heavy metals in the environment: 1) air which contains mining, smelting and refining of fossil fuels, production and use of metallic commercial products and vehicular exhaust, 2) water having domestic sewage, sewage and industrial effluents, thermal power plants and atmospheric fallout and 3) soil like – agricultural and animal wastes, municipal and industrial sewage, coal ashes, fertilizers, discarded manufacture goods and atmospheric fallout.

According to several bibliographical sources, the categories of sources of soil contamination with heavy metals, which are both primary sources: fertilizers, irrigation water, organic fertilizers and composts, pesticides, biosolid sludge, amendments (lime and gypsum), and secondary sources: automobile exhaust, thermal coal combustion with effluents, non-ferrous metals industry, spray paint, tire wear, waste combustion.

In connection with the classification, the contribution of these sources of heavy metals is mentioned for such contents that present a high risk for soil, plants, soil microorganisms and obviously their polluting effect for humans and animals.

Soil pollution with heavy metals has become a critical environmental concern due to its potential adverse ecological effects. Heavy metals occur naturally at low concentrations in soils. However, they are considered as soil contaminants due to their widespread occurrence, acute and chronic toxicity. These metals are extremely persistent in the environment. They are non-biodegradable, non thermo-degradable and thus readily accumulate to toxic levels. Since they do not break down, they might affect the biosphere for a long time. It is known that heavy metals form an important polluting group. They have not only toxic and carcinogenic effect but also tend to accumulate in living organisms.

Environmental risk due to soil pollution is of particular importance for agricultural areas, as extensive reliance on agrochemicals for agricultural productions have immensely resulted in the accumulation of various heavy metals in the soil leading to serious consequences. Thus pollution of heavy metals poses a threat to a country's food production. There is a growing public concern over the potential accumulation of heavy metals in agricultural soils globally owing to rapid urban and industrial development and increasing reliance on agrochemicals in the last decades.

However, extensive application of external agricultural inputs to agricultural production systems leads to deterioration of soil quality. The assessment of soil quality requires quantification of critical soil attributes, which includes the combination of chemical, physical, and biological characteristics that enables soils to perform a wide range of functions.

Heavy metals are the most dangerous substances in the environment due to their high level of durability and toxicity to the biota (Alkorta et al, 2004). Heavy metals will tend to adsorb very firmly to the soil matrix, and once released to the environment, it won't degrade like organics by microbial activity or through chemical oxidation (Beiergrohslein, 1998).

Some fertilizers and pesticides are known to contain various levels of heavy metals, including Cd and Cu (Kabata-Pendias and Pendias, 1992). Therefore, continuous and heavy application of these agrochemicals and other soil amendments can potentially exacerbate the accumulation of heavy metals in agricultural soils over time (Siamwalla, 1996; Chen et al. 1999).

1.2 Contamination situation

Based on the previous work done by several researchers, the content of heavy metals in agricultural soils worldwide is listed in Table 1. In order to facilitate research and comparative analysis, environmental background values in the tables use the standard values issued by Chinese Ministry of Environmental Protection in 1990 (CEPA, 1990). The maximum permissible concentrations of potential toxic metals, namely PTE-MPC, adopt the environment capacity (CEPA, 1995).

Table 1 The content of heavy metals in the agricultural soils (mg/kg^{-1})

City/Country	Cr	Cu	Pb	Zn	Ni	Cd	Hg	As	Reference
Beijing	75.74	28.05	18.48	81.10	-	0.18	-	-	Liu et al., 2005
Guangzhou	64.65	24.00	58.00	162.60	-	0.28	0.73	10.90	Li et al., 2009
Yangzhou	77.20	33.90	35.70	98.10	38.50	0.30	0.20	10.20	Huang et al., 2007

Wuxi	58.60	40.40	46.70	112.90	-	0.14	0.16	14.30	Zhao et al., 2007
Chengdu	59.50	42.52	77.27	227.00	-	0.36	0.31	11.27	Liu et al., 2006
Xuzhou	-	35.28	56.20	149.68	-	2.57	-	-	Liu et al., 2006
Kunshan	87.73	34.27	30.48	105.93	31.08	0.20	0.20	8.15	Chen and Pu, 2007
Spain	63.48	107.65	213.93	427.80	34.75	1.42	-	-	Zimakowska-Gnoinska et al., 2000
America	-	95.00	23.00	-	57.00	0.78	-	-	Han et al.., 2002
Korea	-	2.98	5.25	4.78	-	0.12	0.05	0.78	Kim and Kim, 1999
Changde	-	-	-	-	-	-	-	92.7	PSTV, 2014
Slovakia	-	65.00	139.00	140.00	29.00	-	-	-	Wilcke, 2005
USA	48.5	48	55	88.5	29	13.5	-	-	Jean-Philippe etal., 2012
India	2.19	1.20	0.95	28.24	4.34	0.82	-	-	Raju et al., 2013
India	1.23	2.62	2.82	4.65	0.14	0.05	-	-	Prajapati and Meravi, 2014
Iran	10.36	9.62	5.17	11.56	11.28	0.34	-	-	Sayyed and Sayadi, 2011
Iran	11.15	-	-	-	-	-	-	-	Zojaji et al., 2014
Range	1.23~ 87.73	1.20~ 107.65	0.95~ 213.93	4.65~ 427.8	0.14~ 57.00	0.05~ 13.50	0.05~ 0.73	0.78~ 92.7	
Average	46.69	38.08	51.19	117.35	26.12	1.50	0.28	21.19	
Background	61	22.6	26	74.2	26.9	0.097	0.065	11.2	CEPA, 1995
Environ. Capacity	200	100	300	250	50	0.3	0.3	30	Zheng et al., 2008

1.3. Study area

The study area, Dimoria is a part of Kamrup district located in the fringe of Meghalaya plateau with peculiarities of unity among diversity. The area enjoy hot and humid climate with annual rainfall of about 1740 mm. The seasonal variation of temperature is observed in this area. July is the warmest month and January is the driest month of the year. The average temperature in the summer is about 32^{o}c while winter is about 10^{o}c.

Dimoria has some of the most impressive hills and hillocks like Dhoumarapahar in the south, Mata pahar, Dhaudangpahar etc., scattered throughout the region lying mostly in the north-south and east-west directions. They are covered with broad leaves evergreen forests, deciduous forest and a variety of fire trees.

The area has various type of soil with their respective characteristics. Large quantities of alluvial soils are brought down from the nearby hills, which contain some of their physical and chemical properties. In the low-lying swamps, especially among the flood plain of Kolong and Digaru River, marshy soils are seen which contain high percentage of humus. So, the area is rich in agriculture. The principal crops are paddy, wheat, oil seed and so forth. The hilltops are covered with a thin layer of red soil. On the slope of the hill, tribes do jhum cultivation. Moreover the area also has many Tea Estates.

The people of this region practice different land use systems like Food agriculture, Bamboo plantation, Horticulture, Agro-forestry, Natural forest, Shifting cultivation, etc. Several agrochemicals (chemical fertilizers, pesticides etc.) of different chemical nature are known to be used in different land-use systems which may be associated with a number of environmental concerns viz. persistence in the environment, accumulation of heavy metals, toxicity in soil, vegetation and water supplies and impact beyond the target organism including bioaccumulation and its implication for human health.

1.4 Objectives of the study

The contamination of agricultural soils can pose long-term environmental and health implications (Needleman, 1980; Mueller, 1994; McLaughlin, et al., 1999). Hence, there is an increasing need to study heavy metal distribution and accumulation in agricultural soils (Li et al., 1997a&b). Assessing the concentration of potentially harmful heavy metals in agricultural soil is imperative in order to evaluate the potential risks to residents.

The present study is therefore aimed at studying heavy metal concentrations of Cd, Cu, Mg, Ni, Pb and Zn in agricultural soils to evaluate the environmental quality of the soils and the potential risks to residents.
The aim of this study was to explore:
(i) the main soil properties and topsoil accumulation of heavy metals in different landuses under long-term cultivation in Dimoria Tribal development Block, Assam, and
(ii) the quality of the soil in terms of its nutrient status.

II. Methodology

2.1 Selection of sampling station

For the purpose of this study samples were collected from different agrochemicals using land uses of the area. In all study areas the same method was used to collect soil sample. In total 7 stations were selected. Two stations each from Tea plantation, low land rice field, vegetable farms and one station from natural forest (Control sample) was selected. Three soil samples at 0-15 cm depth were collected randomly from each station.

2.2 Sampling procedure

In order to collect soil samples (0-15 cm depth) grasses, mosses, litter and other plant residues were removed from soil surface. Collection of soil samples was done by using an auger. In each case, a triangular block was cut with the help of the auger. Soils were collected in plastic bags, which were sealed and labeled properly. Three soil samples from a rooting depth of 15 cm were collected randomly from each sampling station. Three samples from each site were also taken from 0 to 15 cm layer for bulk density determination.

Soil samples were brought to the laboratory for analysis. Before analysis, the samples were spread out thinly on a piece of hard paper for drying in air in a shade. The big lumps were broken down, and plant roots, pebbles and other undesirable matters were removed. After the soil become completely dry, and after homogenization, half of each sample was passed through a 2-mm mesh screen. The samples were preserved in clean sealed polythene bags for analysis. The other half was sieved through a 500 μm mesh (Fritsch laboratory sieving set used) and used for determining soil "total" Cd, Cr, Cu, Ni, Pb, and Zn.

2.3 Soil quality parameters and methodology for their study

A large number of parameters are generally used to characterize the soil quality criteria. The most important consideration should be those properties of soil, which influence the movement and retention of water that contribute to store and supply of nutrients. In this study some selected physical and chemical parameters were determined.

2.3.1. Physical parameters

- Temperature
- Texture
- Bulk density
- Moisture content
- Water holding capacity

2.3.2. Chemical parameters

- P^H
- Electrical Conductivity
- Organic matter
- Nitrate
- Phosphorus
- Potassium

The different parameters that were used to assess soil quality of different land uses are shown in Table 2.

Table 2: Soil properties under study with their methods of measurement

Soil properties	Methods
Bulk density	Core sampling method (Blake and Hartge, 1986)
Texture	Feel method
Temperature	Soil thermometer
Moisture content	Moisture meter
pH	Potentiometrically in 1:2.5 (v/v) soil suspension in water (pH meter)
Electrical Conductivity	Conductivitimeter
Organic matter	Titrimetric method (Walkley and Black, 1934). % Soil organic matter =% organic carbon x 1.724 (Allison, L.E., 1965)
Nitrate nitrogen	Spectrophotometric method
Available phosphorus	Spectrophotometric method
Available potassium	Flame photometer method (1986)

2.4 Heavy metal analysis of soil samples:

For determining metal concentration in soil, at first the soil samples were prepared for digestion. For digestion, 1gm of soil from each sample was taken and mixed with 1ml sulphuric acid, 10ml nitric acid and 4ml perchloric acid and heated in a hot plate in digestion chamber at temperature 100°C. When a white fume appears it indicates the completion of digestion process. Then the samples were filtered by Whatman filter paper and kept in a narrow mouth plastic bottle. The total volume of prepared samples was made upto10ml and analyzed by Atomic Absorption Spectroscopy (AAS). During digestion process all the apparatus was cleaned properly and glass wares was washed with tap water and then distilled water to prevent cross contamination.

In AAS, for the determination of heavy metals Cd, Cr, Cu, Ni, Pb, and Zn the calibration is done by standard solution of each metal.

III. Results And Discussion

3.1 Results of soil physico-chemical parameters analyzed

The soil quality has been discussed with respect to some representative physic- chemical parameters. The results of the analysis has been shown on table 3 and 4 and discussed on the basis of existing literature.

Depending on soil conditions like nutrient availability, pH, aeration, temperature, moisture etc. the soil quality varies. Rice is generally cultivated in basic or low acidic pH soils and rice straws are left in the field, hence due to decomposition and recycling of straw organic phosphates, the rice field was rich with available phosphorus in comparison to other land uses. However, amount of available phosphorus was low in all the landuses. The amount of nitrate nitrogen, P and K in the rice field, vegetable farm and tea garden exceeded natural forest may be due to the use of NPK fertilizers in the field. Moreover easy and rapid grazing of cattle in the paddy field enhances the nitrate content of the soil. In terms of NPK availability the soil status can be regarded as of moderate quality.

Most of the soil samples revealed organic matter near-by or above 3%, which were moderate according to ICAR rating, 1997.

Table 3: Mean ± SE of selected soil (0-15 cm) physical properties in the land use systems

Properties	Land use systems						
	Tea Garden (1)	Tea Garden (2)	Vegetable Farm (1)	Vegetable Farm (2)	Rice Field (1)	Rice Field (2)	Natural Forest (Control)
	Mean S.E	Mean S.E	Mean S.E	Mean S.E	Mean S.E	Mean S.E	Mean S.E
Temperature (°C)	19.3 ±0.33	26 ±0.00	20.33 ±0.66	20.66 ±0.33	21.33 ±0.33	28.0 ±0.33	21.67 ±0.33
Moisture (%)	10.7 ±0.29	21.73 ±0.05	3.61 ±0.14	7.0 ±0.80	12.31 ±0.42	17.0 ±4.90	22.24 ±8.34
Bulk density (g/cm^3)	1.43 ±0.026	1.24 ±0.023	1.38 ±0.02	1.34 ±0.03	1.07 ±0.07	1.34 ±0.03	1.33 ±0.02
Water-holding capacity (%)	50.66 ±0.49	51.34 ±0.77	51.21 ±0.27	65.51 ±1.16	54.40 ±0.25	51.17 0.20	55.81 ±1.49
Texture	Sandy clay loam	Clay loam	Sandy clay loam	Sandy clay loam	Clay loam	Clay loam	Silt loam

Table 4: Mean ± SE of selected soil (0-15 cm) chemical properties in the land use systems.

Properties	Land use systems						
	Tea Garden (1)	Tea Garden (2)	Vegetable Farm (1)	Vegetable Farm (2)	Rice Field (1)	Rice Field (2)	Natural Forest (Control)
	Mean S.E	Mean S.E	Mean S.E	Mean S.E	Mean S.E	Mean S.E	Mean S.E
pH	5.41 ±0.09	5.7 ±0.27	5.41 ±0.02	5.30 ±0.09	6.08 ± 0.47	6.26 ±0.32	5.13 ±0.79
E.C (µS/cm)	185.5 ±0.95	176.4 ±3.15	193.2 ±0.66	196.03 ±1.20	166.16 ±1.86	165.85 ±1.53	156.05 ±1.77
Organic Matter (%)	2.9 ±0.18	2.73 ±0.1	1.28 ±0.15	2.15 ±0.12	4.49 ±0.008	2.81 ±0.25	3.04 ±0.04
NO3 N (mg/kg)	3.5 ±0.3	2.3 ±0.014	4.5 ±0.47	6.0 ±0.81	4.18 ±0.10	4.6 ±0.25	1.9 ±0.00
AP (Kg/ha)	3.52 ±0.2	4.07 ±0.19	3.24 ±0.30	2.21 ±0.47	5.88 ±0.48	14.5 ±3.32	7.93 ±18.29
AK (Kg/ha)	133.1 ±0.38	158.7 ±0.13	129.9 ±4.90	117.27 ±3.43	130 ±4.78	82.5 ±19.7	43.29 ±9.33

3.2 Heavy metal concentrations

Descriptive statistics of heavy metal concentrations of the different land uses are presented in Table 5. The mean values of the heavy metal concentrations (mg/kg) in soils of different land uses ranges in the following order; Cd (0.16-0.83) < Ni (2.56-29.06) < Cu (4.66-27.16) < Cr (8.03-46.06) < Zn (35.13-99.83). However, not a single metal was detected in the control sample.

Table 5: Mean ± SE heavy metal concentration of selected soil (0-15 cm) in the land use systems

Heavy metal conc. (mg/kg)	Land use systems						
	Tea Garden (1)	Tea Garden (2)	Vegetable Farm(1)	Vegetable Farm(2)	Rice Field (1)	Rice Field (2)	Natural Forest (Control)
	Mean S.E	Mean S.E	Mean S.E	Mean S.E	Mean S.E	Mean S.E	Mean S.E
Cd	BDL	BDL	0.16 ±0.04	0.83 ±0.083	0.21 ±0.03	0.16 ±0.00	BDL
Cr	11.13 ±0.24	BDL	46.06 ±0.06	42.16 ±0.08	32.13 ±0.08	8.03 ±0.05	BDL
Cu	15.5 ±0.15	4.66 ±0.12	18.53 ±0.08	20.5 ±0.17	27.16 ±0.12	24.63 ±0.06	BDL
Ni	2.56 ±0.06	BDL	24.13 ±0.06	29.06 ±0.03	21.56 ±0.12	21.23 ±0.03	BDL
Pb	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zn	65.4 ±0.45	35.13 ±0.23	94.46 ±0.14	86.4 ±0.10	99.83 ±0.16	89.63 ±0.03	BDL

BDL: Below detection limit

Table 6: Mean values of heavy metals (Pb, Cd, Cu, Cr, Mn, and Zn) for uncontaminated paddy soils, mean values for worldwide normal surface soils, critical concentrations for contaminated soils, Indian standards, and European Union standards, compared with the values of present study.

Elements (□g g^{-1})	Mean values for paddy soils[a]	Mean values for worldwide normal surface soils[b]	Critical soil concentration[c]	Indian standards[d]	European Union standards[e] (EU 2002) [69]	Present study (mg/kg)
Pb	23.3	22–44	100–400	250–500	300	BDL
Cd	0.34	0.37–0.78	3–8	3–6	3	0.16-0.83
Cu	20.7	13–24	60–125	135–270	140	4.66-27.16
Cr	64	12–83	75–100	-	150	8.03-46.06
Ni	-	-	-	75-150	75	2.56-29.06
Zn	61	45–100	70–400	300–600	300	35.13-99.83

[a]Mean of total concentrations of elements in uncontaminated paddy soils. Data are from Wong et al. (2002) [4]; Wang et al. (2003) [66]; Chandrajith et al. (2005) [67].

[b]Mean of total concentrations of elements in the surface horizon of worldwide normal soil, and normal means that the data do not include contaminated or mineralized soils. Data are from Kabata-Pendias (2001) [46]; Essington (2004) [68].

[c]Higher concentrations may be toxic to plants depending on speciation (Alloway, 1995) [48].

[d]Indian standards (Awashthi, 2000) [47] for agricultural soils.

[e]European standards (EU 2002) [69] for agricultural soils.

Table 7: Heavy metal concentrations in topsoils (mg·kg^{-1}) by Chinese Ministry of Environmental Protection in 1990 (CEPA, 1990)

		Cu	Zn	Pb	Cd	Hg	As
MAC	pH<6.5	50 (orchard) 150 (farmland)	200	250	0.3	0.3	30
	6.5<pH<7.5	100 (orchard) 200 (farmland)	250	300	0.6	0.50	25

MAC – "maximum allowable concentrations of heavy metal elements" for agricultural soils of China, issued by Chinese Ministry of Environmental Protection in 1990 (CEPA, 1990)

In accordance with the Environmental Quality Standard for Soils (National Environmental Protection Agency of China, 1995) only one fieldout of eight exceeded Chinese maximum allowable concentrationsfor Cd for agricultural soils. However, the rest were below the limit (Table: 7). The mean Co, Cr, Cu, Ni and Zn concentrations of the soils were generally below the threshold levels of European standards (EU 2002) [69] and Indian standards (Awashthi, 2000) for agricultural soils (Table: 6).

Among the soil properties tested, only electrical conductivity showed positive significant correlations with some metals.

IV. Conclusion

Heavy metal contamination is a severe environmental problem. The presence of different kinds of heavy metals such as Cd, Cu, Mn, Pb, Cr and Zn etc. in trace or in minimum level is a natural phenomenon but their enhanced level is an indicator of the degree of pollution load in that specific area. It is important to make clear analysis of the concentration level of heavy metals in soils and the characteristic of heavy metals uptaken and transferred by agricultural plants. The present study was carried out on analyzing the heavy metal concentration of soils in different land uses practicing extensive agricultural activities to assess its soil quality in terms of its physic-chemical properties. Investigation of physical and chemical properties of topsoil aimed at finding relationships between soil properties and total metal content, assessing its quality.

The results showed that the soils could not be said to be contaminated for now because metal content levels conformed to the world-wide background content of metals range in the soil, except in case of Cd, one field out of eight exceeded Chinese maximum allowable concentrations for Cd for agricultural soils, which might be due to extensive reliance on agrochemicals. Moreover, 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).

Although the heavy metal concentrations measured in this study do not pose a serious health risk, they do affect the quality of agricultural products. Higher concentrations of heavy metals in the vegetable farm and paddy field compared to those of the tea garden and natural soils were possibly attributed to high usage of agrochemicals and differences in cultivation method.

These results provide initial evidence that soils of different land-uses which rely on agrochemicals have elevated heavy metal concentrations, and emphasize the importance of extensive investigations on the extent of heavy metal contaminated soils 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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