ASSESSING HEAVY METAL CONTAMINATION IN TEA AND TOPSOIL DUE TO APPLICATION OF HERBICIDES: DAMBETENNA TEA ESTATES, SRI LANKA

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ABSTRACT

Excessive accumulation of heavy metals in tea plantations may not only result in environmental contamination but also affect the quality and safety of tea production in Sri Lanka. Thus, the prime aim of this study is to assess the levels of Potassium (K), Magnesium (Mg), Copper (Cu), Zinc (Zn), Iron (Fe), Manganese (Mn), Lead (Pb), and Cadmium (Cd) in fresh tea leaves (green), processed (black) tea samples and soil of herbicides applied and non-applied tea plantation plots in Dambetenna tea estates, Sri Lanka. Soil and tea leave samples were collected using simple random sampling technique representing both the herbicide applied (treated) and the non-applied (controlled) tea plantation plots within six months period of time (n=36). The Microwave digestion system and Atomic Absorption Spectrometer (AAS) were used to analyse the levels of metal concentrations and the data were statistically analysed using the student's t-test (95% confidence interval) in order to compare two plots in terms of heavy metal concentrations. Results revealed that in herbicides applied plots, the concentrations of heavy metals *viz.* Zn, Fe, and Pb are significantly higher ($p<0.05$) in soil and the levels of Pb are slightly higher ($p<0.05$) in green tea leaves and black tea samples. Overall, the present study gives insights into the heavy metal contamination levels in tea estate soil, green tea leaves, and black/processed tea samples under chemical weeding systems in Sri Lanka.

Keywords: *contamination, heavy metals, herbicides, soil, tea*

1. INTRODUCTION

Tea *(Camellia sinensis L.)* is one of the most popular beverages consumed by over two-thirds of the world's population for its refreshing, medicinal, mild stimulant effects (Karak & Bhagat, 2010) and it is estimated that 18 to 20 billion cups of tea are consumed daily worldwide (Achudume & Owoeye, 2010). Thus, managing sustainable tea cultivation practices is essential to produce good quality tea to fulfill the worlds' demand for tea (Li et al., 2013). However, the weeds in tea plantations cause huge economic losses to the tea industry posing a challenge despite the technological advancements available in the world (Auld, 2004) and thus, controlling of harmful weeds in a plantation is crucial to maintain healthy crop yield and fertility of the soil in tea plantations (Peiris et al., 2016). As explained by Pannell et al. (2004), production and utilization of herbicides in the tea industry emerged and substantially widespread as a weed management option in the world starting from the 1940s, and ultimately tea soils were severely degraded owing to its harmful heavy metal contaminants (Peiris, 2016). However, tea should be free from toxic contaminants (Sharma et al., 2007) and as a new sustainable weed management option, herbicides free integrated weed management (HFIWM) has been started to practice in Sri Lanka from 2016 (Peiris et al., 2016). Hence, the purpose of the study was to assess and compare the heavy metal levels of tea soil, green tea leaves and black tea samples under herbicides contaminated tea plantation and herbicides free tea plantations in Dambetenna tea estates, Sri Lanka.

2. LITERATURE REVIEW

2.1. Tea Industry in Sri Lanka

Tea is a perennial crop with three kinds of varieties *viz. Camellia sinensis, Camellia assamica,* and *Cambodiensis* (Karak & Bhagat, 2010) that is grown in more than 45 countries all over the world (Baruah, 2017). Tea grows best in tropical and subtropical areas where adequate rainfall and acidic soil is available (Karak et al., 2015). In Sri Lanka, particularly tea is a key contributor to the country's economy in terms of foreign exchange earnings, employment, and food supply (Gunathilaka et al., 2017), whereas Sri Lanka contributed 9% of the world tea production, being one of the most prominent green tea producer in the world (Basu Majumder et al., 2010).

2.2. Weed Management Practices in Tea Industry

As explained by Prematilake et al. (2004), among the critical factors that limit the optimum productivity of tea plantations, weeds are counted as one of the prominent in the list since uncontrolled weed growth can cause a loss of tea productivity to the extent of 50-70 percent (Prematilake et al., 2004). Thus, weeds in tea are managed both manually and chemically whereas chemical control has proved to be more efficient (Onsando, 1989), and applying herbicides is the most widespread method in Sri Lanka (Peiris, 2016). However, according to the previous studies, Glyphosate is the commonly used type of herbicide (Kools et al., 2005) that contains a considerable amount of heavy metals.

2.3. Adverse Health Effects of Heavy Metals

Heavy metals are possible to absorb by tea plants through the contaminated tea soil (Defarge et al., 2018; Jayasumana et al., 2015; Kools et al., 2005; Tsui et al., 2005) which can ultimately have adverse effects on human health (Karak & Bhagat, 2010). For an instance, Aluminum (Al) is associated with Alzheimer's disease (Matsumoto et al., 1976), Arsenic (As), Lead (Pb), and Cadmium (Cd) is mutagenic and carcinogenic elements (Pais & Jones Jr, 1997; Waalkes, 2000). Thus, the quality of tea products should be properly monitored in order to ensure food safety from excessive contamination of heavy metals due to frequent herbicide applications.

2.4. Investigating Heavy Metal Contamination in Tea

In many South Asian countries where tea is economically produced, have carried out many studies to investigate heavy metal contamination of fresh tea leaves and processed black tea. For an instance, such studies have been carried out in India by Seenivasan et al. (2008), in Pakistan by Al-Oud (2003), in Bangladesh by (Rashid et al., 2016). However, In Sri Lanka, a very limited amount of extensive studies has been carried out in order to assess heavy metal contamination of soil, fresh tea leaves, and processed tea. In order to ensure food safety in Sri Lanka, proper monitoring of the heavy metal contamination due to herbicides is vital, since tea is consumed extensively by Sri Lankan people.

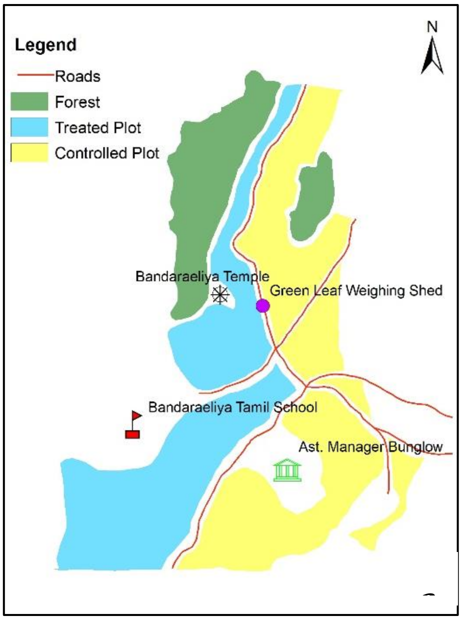
3. METHODOLOGY

3.1. Study Area

The study area (Figure 1) consists of 3 ha of controlled plots of Vegetatively Propagated (VP) tea where manual weeding methods are practiced and another 3 ha of treated plots where chemical herbicides application methods are practiced in Dambetenna Tea Estates in Haputale, Uva Province, Sri Lanka, that lies between latitudes 6.786° and 6.791°N and, longitudes 81.017° and 81.019° in elevation of 1300 m.

3.2. Collection of Soil and Tea Leaves Samples

Soil samples were randomly collected (n=36) from both controlled and treated plots representing the entire plots (Figure 2) for six months. Also, fresh green tea leaves samples were randomly collected from both plots. The collected samples were stored in clean, sterilized polyethylene bags and were properly labeled. A fraction of collected green leaves from each plot were processed under the laboratory conditions in order to prepare black tea samples for further analyses.



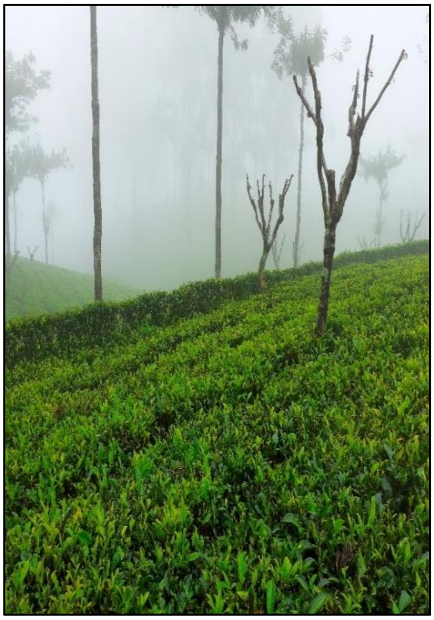


Figure 1: (a) Map of the study area (b) Present status of the study area

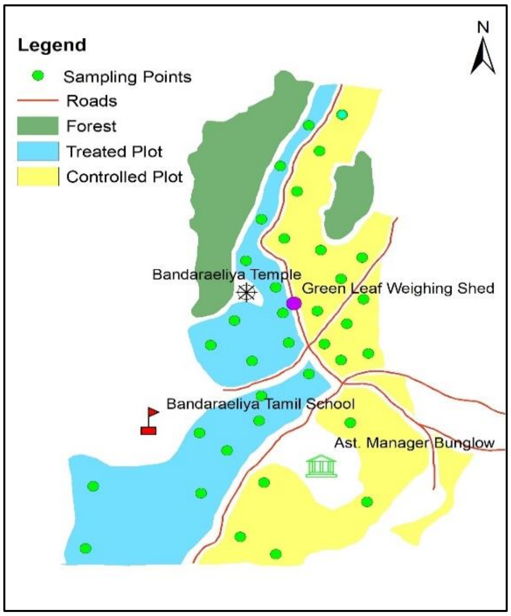


Figure 2: Sampling locations

3.3. Chemical Analysis

The collected soil samples were oven-dried at 60 °C for 24 h before being ground into a fine powder using a sterile mortar and pestle. Green tea leaves and black tea samples were also crushed and ground for further chemical analyses. The powdered soil samples were digested using Milestone ETHOS EASY™ advanced microwave digestion system according to the method EPA 3051 (EPA, 2007) and green leaves/ black tea were digested according to the method explained by Milestonesrl (2019). After the digestion, samples were filtered through Whatman™ No. 42 filter paper and 0.45 µm micro-filters prior to analysis by VARIAN AA240FS™ Atomic Absorption Spectrometer (AAS) for its K, Mg, Cu, Zn, Fe, Mn, Pb and Cd levels.

4. DATA ANALYSIS & RESULTS

Data were statistically analyzed using student's t-test under a 95% confidence interval to compare and to find any significant difference between the controlled and treated plots in terms of the metal concentrations of soil, green tea leaves, and black tea samples. The results of metal concentrations and the results of statistical analysis are shown in Tables 1, Table 2, and Table 3.

Table 1: Results of soil analyses

Parameter	Controlled		Treated		t value	P-value
(mg/Kg)	Mean	SD	Mean	SD		
K	1583	±684	1351	±457	1.20	0.240
Mg	1632	±634	1619	±379	0.08	0.939
Cu	38.1	±17.5	35.20	±9.72	0.62	0.541
Zn	70.6	±22.2	114.1	±37.6	-4.23	0.000
Fe	49752	±4459	66925	±6787	-8.97	0.000
Mn	88.3	±20.2	76.3	±15.8	1.99	0.055
Pb	35.36	±7.28	47.3	±10.3	-4.14	0.000
Cd	3.67	±1.20	4.36	±1.38	-1.66	0.106

Table 2: Results of green tea leaves analyses

Parameter	Controlled		Treated		t value	P-value
(mg/Kg)	Mean	SD	Mean	SD		
K	21847	±1480	21319	±1393	0.64	0.539
Mg	2147	±309	1921	±255	1.38	0.198
Cu	9.175	±0.715	8.950	±0.754	0.53	0.608
Zn	56.20	±6.72	54.3	±20.0	0.22	0.830
Fe	112.15	±4.75	135.15	±5.32	-7.90	0.000
Mn	42.90	±6.67	46.0	±18.0	-0.39	0.703
Pb	0.0327	±0.01	0.210	±0.107	-4.02	0.002
Cd	BDL*	-	BDL*	-	-	-

*BDL – Below detection limit

Table 3: Results of black tea sample analyses

Parameter (mg/Kg)	Controlled		Treated		t value	P-value
	Mean	SD	Mean	SD		
K	20202	±1291	19302	±258	1.67	0.125
Mg	2147	±309	1921	±255	1.38	0.198
Cu	9.370	±0.861	9.477	±0.282	-0.29	0.779
Zn	44.89	±9.75	41.82	±9.22	0.56	0.587
Fe	113.05	±8.41	125.5	±18.1	-1.53	0.156
Mn	46.27	±9.28	57.7	±16.3	-1.49	0.168
Pb	0.025	±0.005	0.1923	±0.0607	-6.73	0.000
Cd	BDL*	-	BDL*	-	-	-

*BDL – Below detection limit

5. DISCUSSION OF THE FINDINGS

According to the results of soil analysis, levels of K, Mg, Cu, Mn, and Cd haven't shown any significant difference ($p>0.05$) between controlled and the treated plots in 95% confidence interval, whereas Zn, Fe, and Pb levels of treated plots show significantly higher levels ($p<0.05$) than controlled plots. However, the results of green tea leaves and black tea sample analyses, levels of K, Mg, Cu, Zn, Fe, and Mn haven't shown any significant difference ($p>0.05$) between the two plots and Pb levels of green tea leaves and black tea samples in the treated plots are significantly higher ($p<0.05$) than the Pb levels in controlled plots while Cd levels remain below detection limits of the Atomic Absorption Spectrometer (AAS).

This study has found that the contents of several heavy metals (Zn, Fe, and Pb) were lower in the soil of controlled plots compared to the treated plots and these findings adhere to the previously conducted research by Lin et al. (2019) and Enerijiofi and Obade (2018). Furthermore, the results reveal that Pb levels of green tea leaves/ black tea are comparatively higher in the treated plots while the SLSI maximum permissible level of Pb is 0.01 mg/Kg. Moreover, as explained by Baishya and Sharma (2017), the available Cu, Zn, Fe, and Mn are the micronutrients which is essential for plant growth and when the threshold limits exceed, those become toxic to plants and it will degrade the soil quality.

6. CONCLUSION & CONTRIBUTIONS

It can be concluded that long-term application of herbicides in tea plantation significantly affects the tea soil quality and quality of tea production in terms of its heavy metal contamination and thus, the HFIWM approach exhibits many indirect benefits over chemical weeding in terms of environmental health and public health.

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REFERENCES

Achudume, A., & Owoeye, D. (2010). Quantitative assessment of heavy metals in some tea marketed in Nigeria. *Health, 2*(9), 1097-1100.

Al-Oud, S. (2003). Heavy metal contents in tea and herb leaves. *Pakistan Journal of Biological Sciences (Pakistan)*.

Auld, B. A. (2004). The persistence of weeds and their social impact. *International Journal of Social Economics*.

Baishya, J., & Sharma, S. (2017). Analysis of physico-chemicals properties of soil under different land use system with special reference to agro ecosystem in Dimoria Development Block of Assam, India. *Int J Sci Res Educ, 5*, 6526-6532.

Baruah, P. (2017). Wild Teas of Assam and North East India. *Journal of Tea Science Research, 7*.

Basu Majumder, A., Bera, B., & Rajan, A. (2010). Tea statistics: global scenario. *Inc J Tea Sci, 8*(1), 121-124.

Defarge, N., De Vendômois, J. S., & Séralini, G. (2018). Toxicity of formulants and heavy metals in glyphosate-based herbicides and other pesticides. *Toxicology reports, 5*, 156-163.

Enerijiofi, K., & Obade, E. (2018). Assessment of the impact of herbicide contaminated top soils on its physiochemical, microbiological and enzymatic properties.

Gunathilaka, R. D., Smart, J. C., & Fleming, C. M. (2017). The impact of changing climate on perennial crops: the case of tea production in Sri Lanka. *Climatic Change, 140*(3-4), 577-592.

Jayasumana, C., Gunatilake, S., & Siribaddana, S. (2015). Simultaneous exposure to multiple heavy metals and glyphosate may contribute to Sri Lankan agricultural nephropathy. *BMC nephrology, 16*(1), 103.

Karak, T., & Bhagat, R. (2010). Trace elements in tea leaves, made tea and tea infusion: A review. *Food Research International, 43*(9), 2234-2252.

Karak, T., Paul, R. K., Boruah, R. K., Sonar, I., Bordoloi, B., Dutta, A. K., & Borkotoky, B. (2015). Major soil chemical properties of the major tea-growing areas in India. *Pedosphere, 25*(2), 316-328.

Kools, S., Van Roovert, M., Van Gestel, C., & Van Straalen, N. (2005). Glyphosate degradation as a soil health indicator for heavy metal polluted soils. *Soil Biology and Biochemistry, 37*(7), 1303-1307.

Li, X., Zhang, Z., Li, P., Zhang, Q., Zhang, W., & Ding, X. (2013). Determination for major chemical contaminants in tea (Camellia sinensis) matrices: A review. *Food Research International, 53*(2), 649-658.

Lin, W., Lin, M., Zhou, H., Wu, H., Li, Z., & Lin, W. (2019). The effects of chemical and organic fertilizer usage on rhizosphere soil in tea orchards. *PloS one, 14*(5).

Matsumoto, H., Hirasawa, E., Morimura, S., & Takahashi, E. (1976). Localization of aluminium in tea leaves. *Plant and Cell Physiology, 17*(3), 627-631.

Milestonesrl. (2019). Milestone Application Note for Acid Digestion SK-Agriculture-005.

Onsando, J. (1989). Chemical tea weed management in Kenya to date. *Tea-Tea Research Foundation (Kenya)*.

Pais, I., & Jones Jr, J. B. (1997). *The handbook of trace elements*: CRC Press.

Pannell, D. J., Stewart, V., Bennett, A., Monjardino, M., Schmidt, C., & Powles, S. B. (2004). RIM: a bioeconomic model for integrated weed management of Lolium rigidum in Western Australia. *Agricultural systems, 79*(3), 305-325.

Peiris, H. (2016). Diversity and behaviour of the naturally regenerated vegetation in commercial tea soils under herbicide free integrated weed management. *Procedia food science, 6*, 314-317.

Peiris, H., Gunarathne, A., & Lee, K. (2016). *Eco-control for Sustainable Agriculture Management in Commercial Tea Industry*.

Prematilake, K. G., Froud-Williams, R. J., & Ekanayake, P. B. (2004). Weed infestation and tea growth under various weed management methods in a young tea (Camellia sinensis [L.] Kuntze) plantation. *Weed Biology and Management, 4*(4), 239-248.

Rashid, M. H., Fardous, Z., Chowdhury, M. A. Z., Alam, M. K., Bari, M. L., Moniruzzaman, M., & Gan, S. H. (2016). Determination of heavy metals in the soils of tea plantations and in fresh and processed tea leaves: an evaluation of six digestion methods. *Chemistry Central Journal, 10*(1), 7.

Seenivasan, S., Manikandan, N., Muraleedharan, N. N., & Selvasundaram, R. (2008). Heavy metal content of black teas from south India. *Food control, 19*(8), 746-749.

Sharma, R. K., Agrawal, M., & Marshall, F. (2007). Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. *Ecotoxicology and environmental safety, 66*(2), 258-266.

Tsui, M. T., Wang, W.-X., & Chu, L. (2005). Influence of glyphosate and its formulation (Roundup®) on the toxicity and bioavailability of metals to Ceriodaphnia dubia. *Environmental pollution, 138*(1), 59-68.

Waalkes, M. P. (2000). Cadmium carcinogenesis in review. *Journal of inorganic biochemistry, 79*(1-4), 241-244.