International Journal of Agricultural Technology 2020 Vol. 16(1): 27-36
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Heavy metal accumulation in scallion (*Allium cepa* var. *aggregatum*) fields in Uttaradit Province, Thailand

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Chattanong, P. and Jutamas, M. (2020). Heavy metal accumulation in scallion (*Allium cepa* var. *aggregatum*) fields in Uttaradit Province, Thailand. International Journal of Agricultural Technology 16(1): 27-36.

Abstract The research finding was explored heavy metal fixation in scallion plants cultivated in rural destinations in Uttaradit Province, Thailand. The heavy metals: Arsenic (As), Zinc (Zn), Lead (Pb), Copper (Cu) and Cadmium (Cd) were extracted from scallion plant parts (consumable stalk and stem). The extraction was done using the digestion method, aqua regia then dry ashing followed by aqua regia, nitric acid and hydrochloric acid. The results showed that the concentrations of Cu, Pb, Zn, Cd and As in the soil samples exceeded the background values in Uttaradit Province. All heavy metals were nearness in an alternate fixation in each piece of the plant. With the exceptions of Zn and Cu, the metal concentrations in the scallion and soil samples surpassed the standards set by the FAO/WHO. The translocations factor examination demonstrated that scallion had the ability to move every substantial metal from the roots to the stalks.

Keywords: Heavy Metals, Soil plantation, Scallion, *Allium cepa var. aggregatum*

Introduction

Heavy metal pollution is a noteworthy ecological issue. With technological development, the generation and dispersal of heavy metals has expanded. The bio-aggregation of heavy metals has poisonous effects on living systems including humans, animals, microorganisms and plants. In addition to these negative biological effects, accumulated heavy metals can decrease soil quality and decrease harvest production and character (Nagajyoti *et al*., 2010). A few metals, for example, manganese (Mg), copper (Cu), zinc (Zn) and nickel (Ni), are main and helpful to vegetations and animals in moderation, but high densities of these metals have harmful impacts and represent an ecological risk (Nodelkoska, 2000). The heavy metals are of significant ecological concern because of their danger, widespread sources, non-biodegradability and accumulative properties (Wang and Chen, 2000). The increasing levels of heavy metals polluting the earth may have come about because of anthropogenic activities, for example, modern processes, horticultural and aquaculture practices, residential waste and emissions from vehicles (Demirak *et al*., 2006). Heavy

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metals are naturally present in soil at a very low level due to contributions from the parent materials but can occur at elevated levels due to human activities (human sources). Anthropogenic heavy metal sources are associated with modern undertaking and cultivating work, for example, environmental statement, vehicle exhaust, shopper squander, squander handling, urban development, compost application and the standard utilization of sewage as manure in developed areas (Yap *et al*., 2009; Bilos *et al*., 2001; Hlavay *et al*., 2001; Koch and Rotard, 2001). Developed plant species have varying capacities to take up and increment metals in their different parts, with a wide go in metal take-up and translocation between plant species and even between cultivars of similar species (Kibria and Alamgir, 2012; Singh *et al*., 2010; Kurz *et al*., 1999; Arao and Ac, 2003; Liu *et al*., 2005; Yu *et al*., 2006). Plants ingest heavy metals from the best 25 cm of the soil, where the underlying foundations of most developed species are found (Reena *et al*., 2011; Ross, 1994; Mico *et al*., 2007). At the point when the limit of the dirt to hold overwhelming metals is decreased because of rehashed use of wastewater, the metals drain into groundwater, expanding their bioavailability (Sridhara *et al*., 2008). High centralizations of substantial metals in soil will expand the limit of plants to take up the metals. The contaminants will at that point be translocated from roots to shoots and afterwards to the grains, which are consumed by people. Perilous metals are commonly geochemically conservative, with the goal that they are quickly taken up by plant roots and translocated to over-the-ground parts (Saturug *et al*., 2003).

Materials and methods

The studied scallion fields are located in the Fly-Luang district, Lab-Lare district, Uttaradit Province, within the area of latitude 16◦ 09$^{/}$ 11.6$^{//}$ N to 16◦ 09$^{/}$ 69.6$^{//}$ N and longitude 100◦ 55$^{/}$ 13.6$^{//}$ E to 100◦ 55$^{/}$ 13.6$^{//}$ E. Fifteen stations within five locations in that region, three stations per location, were selected for this investigation and are listed in Figure 1. The precise position of each station is listed in Table 1. In addition to plant samples, soil samples were move from the root zone.

Sampling was completed at the sampling station and each test was repeated multiple times. The samples were collected from the field before harvest time, with a total of fifteen (15) samples involved in this study. The acreage of scallion fields used for the sampling areas was approximately five (5) acres in total. The soil samples were gathered from the soil surrounding the scallion plant utilizing a soil forecast sampler at depths of 0-10 cm, 10-20 cm, 20-40 cm, and 40-60 cm from the soil surface (Machiwa, 2010). The scallion plant and soil samples were placed into labeled plastic bags, placed on ice and transported to the research facility, where they were kept in the cooler at 4 ℃ for preservation before examination.

Table 1. Locations of scallion field sampling stations for plant and soil samples

Station NO.	Geographical coordinates	Location
11	N 16◦ 09/ 11.6//, E 100◦ 05/ 13.6//	Ban Chaing-San, Fly-Luang district, Lab-Lare district, Uttaradit Province (SN1)
12	N 16◦ 09/ 16. //1, E 100◦ 05/ 01.5//	
13	N 16◦ 09/ 73.4//, E 100◦ 03/ 28.3//	
21	N 16◦ 09/ 58.5//, E 100◦ 05/ 31.3//	Ban Nam-Thum, Fly-Luang district, Lab-Lare district, Uttaradit Province (SN2)
22	N 16◦ 09/ 11.3//, E 100◦ 05/ 28.4//	
23	N 16◦ 09/ 11.1//, E 100◦ 05/ 18.4//	
51	N 16◦ 09/ 16.5//, E 100◦ 03/ 64.2//	Ban Thung-Eang, Fly-Luang district, Lab-Lare district, Uttaradit Province (SN5)
52	N 16◦ 09/ 63.7//, E 100◦ 03/ 64.2//	
53	N 16◦ 09/ 63.7//, E 100◦ 03/ 64.4//	
61	N 16◦ 09/ 76.2//, E 100◦ 03/ 26.1//	Ban Na-Pong, Fly-Luang district, Lab-Lare district, Uttaradit Province (SN6)
62	N 16◦ 09/ 71.0//, E 100◦ 03/ 30.6//	
63	N 16◦ 09/ 73.4//, E 100◦ 03/ 28.3//	
91	N 16◦ 09/ 65.7//, E 100◦ 04/ 48.3//	Ban Wat-Pha, Fly-Luang district, Lab-Lare district, Uttaradit Province (SN9)
92	N 16◦ 09/ 67.5//, E 100◦ 04/ 59.0//	
93	N 16◦ 09/ 69.9//, E 100◦ 03/ 45.2//	

Soil sampling were physically cleaned to evacuate scraps of roots, stones, twigs and distinctive polluting impacts. The soil samples were then homogenized and dried at room temperature. The dried soil were pummeled using a mortar and pestle, and sieved to have < 63 µm in size.

Dried 1g soil and the roots, stems, leaves, and seeds of *Allium cepa* were set in a 50-ml channel formed carafe. Each bit of the examined *Allium cepa* was handled in 10 ml of 65% nitric corrosive arrangement and warmed on a hot plate at a temperature of 120 ℃ for 2 hours until a reasonable arrangement structures were formed. The 1g soil tests was treated with 10 ml of water regia (HNO_3: HCL at a 3:1) then warmed on a hot plate at 70 ℃ for 4 hours. After cooling, the *Allium cepa* and soil were washed in 50 ml of deionized water and separated through 45 µm Whatman channel paper. The samples were then placed into polyethylene bottles and stored at 4 ℃ until required.

The sample were analyzed for Fe, Zn, Pb, Cu, Cd and Ni using atomic absorption spectrophotometry (AAS) at the laboratory in the Science Laboratory Center, Uttaradit Rajabhat University, Thailand.

The enhancement factor (EF) and translocation factor (TF) were determined as they appeared in condition (I), following Lorestani *et al*. (2011), and condition (II), following Singh *et al*. (2010), individually. The estimation of the advancement factor evaluates the vehicle of substantial metals from the dirt to *Allium cepa*, while the translocation factor is utilized to look at the vehicle or movement of the metals from roots to shoots of *Allium cepa*. The EF and TF values for the metals that were investigated in this assessment are in mg/kg.

$$\text{Enrichment Factor (EF)} = Cp/Cs \qquad \text{(i)}$$

where: Cp = heavy metal concentration in plant
Cs = heavy metal concentration in soil

$$\text{Translocation Factor (TF)} = Cs/Cr \qquad \text{(ii)}$$

where: Cs = heavy metal concentration in plant shoot
Cr = heavy metal concentration in plant roots

Results

Heavy metals in scallion

The results showed that for the five sampling locations (SNs), Cu was the metal present at the highest concentration in the stalk except in SN 6, for which Zn was highest in the stalk. With respect to the root samples, Zn was present at the highest concentration in the root for all sampling locations except SN 2, where Cd was highest in the root. The highest coefficient of variance (CV) values for each metal were as follows: for As, CV was highest in the stalk at SN 1 and in the root at SN 5, for Zn in the stalk and root at SN 1, for Pb in the stalk at SN 1 and in the root SN 5, for Cu in the stalk at SN 5 and in the root at SN 1 and for Cd in the stalk at SN 2 and in the root at SN 1 (Table 2).

For the most part, among the metals that were measured, the accumulated levels of Pb and Cu in scallion plants exceeded the levels stipulated by the Thailand FDA of 1 mg/kg and 20 mg/kg, respectively. Both Pb and Cu were the most elevated in the stalk parts. This could indicate that the application of fertilizer and pesticide to Fly-Luang scallion fields has caused the elevation of Pb and Cu concentrations in the scallion.

Heavy Metal Concentration in Soil

The convergences of As, Zn, Pb, Cu and Cd in practically all soil examples were higher than the foundation esteems for characteristic soil in Thailand (Table 3). The results showed that As, Cu and Cd concentrations were not significantly different between sites, and the topsoil concentrations at all sites exceeded the MACs for those metals. Zn and Pb concentrations were not significantly different between sites and all topsoil concentrations were lower than the MACs (Table 3).

Enrichment Factor (EF) and Translocation Factor (TF)

The concentrations of heavy metals in different components of scallion (*Allium cepa* var. *aggregatum*) was analyzed by examining the enrichment and translocation factors. Result demonstrated the enrichment factors of metals from the soil to different parts of the scallion plant (Figure 1). In diminishing order, the mean EFs of the measured metals were zinc (0.771) > copper (0.733) > lead (0.316) > arsenic (0.010) > cadmium (0.008).

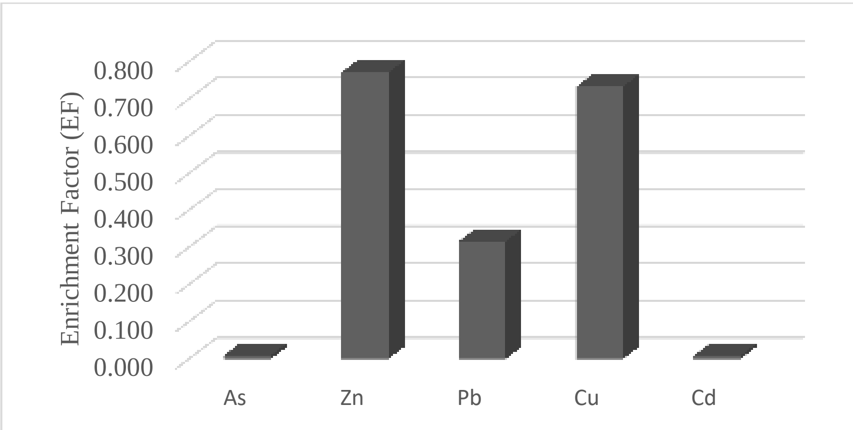

Figure 1. Enrichment Factor (EF) of scallions (*Allium cepa* var. *aggregatum*) cultivated in Uttaradit Province, Thailand

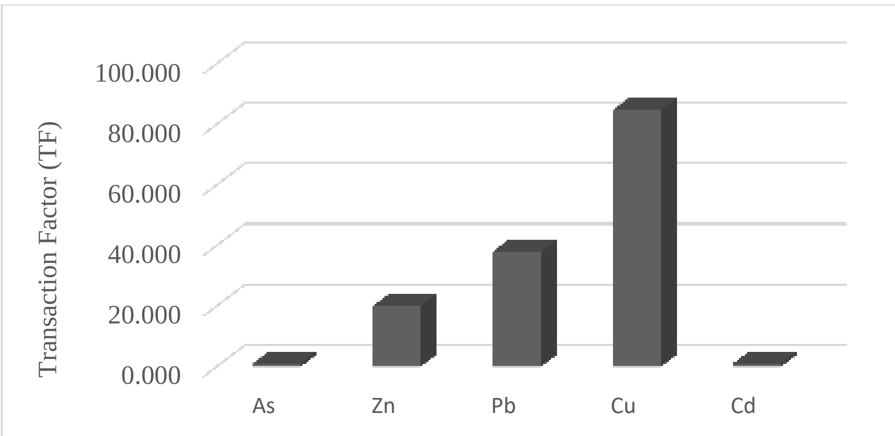

Figure 2. Translocation Factors (TF) for different heavy metals of scallion (*Allium cepa* var. *aggregatum*) cultivated in Uttaradit Province, Thailand

Table 2. Concentration of heavy metal (mg/kg) in scallion plants from Fly-Luang district, Lab-Lare district, Uttaradit province

Mean Concentration of heavy metals in scallion mg/kg					
	Arsenic (As)	**Zinc (Zn)**	**Lead (Pb)**	**Copper (Cu)**	**Cadmium (Cd)**
			SN.1		
Stalk	0.33±0.08	15.71±2.50	10.61±0.44	25.58±1.48	0.15±0.06
Range	0.23-0.41	12.37-18.37	10.24-11.24	23.75-27.36	0.10-0.24
CV (%)	23.78	15.90	4.18	5.77	38.30
Root	0.23±0.06	5.06±0.76	0.19±0.05	0.40±0.03	0.44±0.05
Range	0.13-0.22	9.33-10.81	5.12-8.33	18.30-22.02	0.11-0.37
CV (%)	23.15	6.12	20.48	8.87	49.83
			SN.2		
Stalk	0.19±0.04	10.17±0.62	6.53±1.34	19.56±1.74	0.22±0.11
Range	0.13-0.22	9.33-10.81	5.12-8.33	18.30-22.02	0.11-0.37
CV (%)	23.15	6.12	20.48	8.87	0.11
Root	0.17±0.04	0.32±0.01	0.17±0.02	0.23±0.04	0.35±0.03
Range	0.11-0.20	0.31-0.33	0.14-0.19	0.20-0.28	0.32-0.39
CV (%)	24.09	2.43	13.42	16.13	9.21
			SN.5		
Stalk	0.16±0.04	13.15±0.69	3.53±0.50	31.05±0.79	0.12±0.01
Range	0.11-0.20	12.36-13.05	3.17-4.24	30.11-31.10	0.11-0.14
CV (%)	23.87	5.22	14.15	2.53	9.28
Root	0.27±0.03	0.66±0.03	0.25±0.05	0.21±0.05	0.06±0.03
Range	0.23-0.31	0.63-0.71	0.21-0.32	0.17-0.29	0.02-0.09
CV (%)	12.13	5.15	19.20	25.81	49.47
			SN.6		
Stalk	0.18±0.05	15.34±0.74	4.16±0.29	14.52±1.82	0.16±0.05
Range	0.11-0.23	14.32-16.02	3.76-4.41	12.04-16.33	0.12-0.3
CV (%)	28.67	4.80	6.90	12.50	34.00
Root	0.18±0.04	0.46±0.06	0.18±0.02	0.22±0.03	0.14±0.02
Range	0.12-0.21	0.41-0.55	0.15-0.20	0.19-0.25	0.11-0.16
CV (%)	24.01	13.29	13.69	13.14	16.10
			SN.9		
Stalk	0.10±0.01	11.35±0.58	7.28±0.31	20.87±0.49	0.16±0.03
Range	0.10-0.11	10.62-12.05	6.88-7.63	20.20-21.37	0.12-0.19
CV (%)	5.50	5.14	4.23	2.34	19.51
Root	0.10±0.01	0.91±0.07	0.13±0.03	0.35±0.04	0.12±0.02
Range	0.09-0.11	0.82-1.00	0.10-0.17	0.31-0.40	0.10-0.14
CV (%)	8.29	7.77	21.14	10.53	13.25
MAC*	2.0	100	1	20	3
Thailand FAO/WHO Standard	2	50	0.2	20	0.2

* Maximum allowable concentrations for these heavy metals in foods

Table 3. Concentrations of heavy metals (mg/kg) in agriculture topsoil from Fly-Luang district, Lab-Lare district, Uttaradit Province

Mean concentrations of heavy metals in topsoil from scallion fields (mg/kg)					
	Arsenic (As)	**Zinc (Zn)**	**Lead (Pb)**	**Copper (Cu)**	**Cadmium (Cd)**
SN.1					
Range	17.50-19.36	5.42-6.85	11.94-12.25	11.87-12.01	20.25-27.11
Mean ±SD.	18.32 ±0.95	6.74 ±1.27	12.25 ±0.17	13.36 ±2.46	24.19 ±3.54
CV (%)	5.17	18.88	2.29	18.42	14.64
SN.2					
Range	19.36-21.23	9.99-17.10	8.73-12.34	11.97-14.21	24.23-26.32
Mean ±SD.	20.02 ±1.05	12.38 ±4.09	9.38 ±0.37	13.46 ±1.29	25.52 ±1.13
CV (%)	5.24	33.02	17.38	9.57	4.43
SN.5					
Range	17.39-21.36	7.41-15.41	12.19-13.39	12.13-20.12	20.36-23.01
Mean ±SD.	18.95 ±2.12	10.08 ±4.14	12.96 ±1.19	15.59 ±4.01	21.40 ±1.41
CV (%)	11.16	38.28	5.14	25.13	6.60
SN.6					
Range	19.39-21.46	4.38-14.24	7.06-7.68	9.74-18.56	21.36-23.20
Mean ±SD.	20.33 ±1.05	9.25 ±4.93	7.30 ±0.83	14.82 ±4.56	22.05 ±1.00
CV (%)	5.15	53.31	4.56	30.77	4.56
SN.9					
Range	17.69-19.57	14.11-16.47	8.36-14.16	22.51-19.86	22.48-23.44
Mean ±SD.	18.54 ±5.14	15.35 ±1.18	10.90 ±0.66	22.12 ±2.10	22.87 ±0.50
CV (%)	5.14	7.72	27.19	9.48	2.21
MAC* Thailand	2.0	100	1	20	3
FAO/WHO Standard	2	50	0.2	20	0.2

***** Maximum allowable concentrations for these heavy metals in foods

Discussion

Shrivastav (2001) reported that heavy metals are present in the atmosphere in particulate form and the primary phase of atmospheric heavy metals is composed by the exchange of particles between the atmosphere and land or water surfaces via dry, wet and unknown pathways. So as to assess the potential danger of heavy metals to human wellbeing, the groupings of metals in the eatable pieces of the scallions were contrasted with the Thailand maximum allowable concentrations (MACs) for these heavy metals in foods.

As indicated by Hopkins (1999), metals, for example, Fe, Mn, Cu and Zn are taken up by plants since they are supplements that are required for photosynthesis and distinctive metabolic strategies in the plant. Pb and Cd are harmful metals that can aggregate in various pieces of the plant with no particular limit (Kabata-Pendias and Pendias, 1992).

Arsenic is a natural toxic substance that is regularly found in soil (Cullen and Reimer, 1989; Smedley and Kinniburgh, 2002). The typical natural exposure to As for people is through contaminated drinking water, for instance, on the Indian sub-continent (Nordstrom, 2002). Arsenic turns out to be a piece of the human strong evolved way of life when yields and grain become debased. The metalloid is present in many rock-forming minerals because it can substitute for other metals in a variety of basic geochemical structures (Smedley and Kinniburgh, 2002). Arsentic accumulates in soil over time through leaching from As-based pesticides, mining tailings, As-polluted groundwater and metropolitan solid wastes (Meharg *et al*., 2009). Zinc amasses in a plant as a direct result of the uptake of the metal by the roots (Jiang *et al.*, 2007). The favored scope of zinc fixations in the leaves of a plant is 15 to 50 mg/kg. At convergences of in excess of 200 mg/kg, zinc winds up harmful, avoiding root development and bringing about undersized leaves (Jiang *et al*., 2007).

The natural occurrence of lead in the earth impacts the accumulation of lead in plants (Kachenko and Singh, 2004). Motor vehicle exhaust may be a critical source of lead, which is diffused into the earth and taken up by roadside vegetation (Xuedong *et al*., 2012). Copper is one of the nutrients required for numerous physiological processes in plants (Hang *et al.*, 2009). However, elevated Cu concentrations in plants may cause impeded development of roots (Jiang *et al*., 2007). Cadmium is a non-essential heavy metal (Horng *et al*., 2013). It is adequately absorbed and spread throughout the whole plant and it is bioavailable in the soil. Cadmium metal is reliably dispersed in little concentrations, possibly because it is taken up by the plant and transported to plant parts paying little heed to its properties, as it does not serve essential functions for plants or animals (Yap *et al*., 2009).

In view of the results, the enrichment factor for every concentrated metal was less than 1, which showed that the scallion is a typical collector plant with high potential to ingest metals from the soil (Lorestani *et al*., 2011).

The translocation factors for movement of the studied metals from the roots to the shoots of scallion are indicated in Figure 2. The TFs of the metals varied from copper (84.773) > lead (37.993) > zinc (19.990) > cadmium (1.101) > arsenic (1.044). The results showed that all translocation factors were greater than 1, with scallion only being able to hyperaccumulate zinc lead and copper from roots to the shoots (Rezvani and Zaefarian, 2011).

Heavy metal pollution is a serious ecological issue. It is imperative to clarify the concentrations of heavy metals in soils and the uptake and translocation of these metals by cultivated plants. Heavy metals accumulated primarily in the stalk of scallion, aside from zinc, which demonstrated high accumulation in the roots at some sites. The outcomes demonstrated that concentrations of Cu, Pb, Zn, Cd and As in practically of the soil examples surpassed the background values for Uttaradit Province. Each heavy metal was closeness in a substitute concentration in each bit of the plant. The metal substance in the scallion and soil in this examination do meet the standard limits set by the FAO/WHO with the exception of Zn and Cu. The translocation factor investigation demonstrated that scallion moves every measured heavy metal from the root to the stalk.

Acknowledgement

The research was supported by Uttaradit Rajabhat University, Thailand.

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(Received: 24 June 2019, accepted: 30 December 2019)