FINAL REPORT

Research on determining the causes of lead (Pb), cadmium (Cd), arsenic (As), and mercury (Hg) residues in Vietnamese cinnamon/cassia products and proposing management and mitigation solutions

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ABBREVIATIONS

ASTA	American Spice Trade Association
MARD	Ministry of Agriculture and Rural Development
MONRE	Ministry of Natural Resources and Environment
MoH	Ministry of Health
GREAT	"Gender Responsive and Equitable Agriculture and Tourism" (GREAT) program
CRED	Center for Rural Economy Development
EU	European Union
FAO	Food and Agriculture Organization
IDH	The Sustainable Trade Initiative IDH
MRL	Maximum Residue Limit
SNV	Netherlands Development Organization
SHS	Son Ha Spice & Flavorings Co., Ltd
QCVN	National Technical Regulations
TCVN	Vietnamese standard
WB	World Bank
WHO	World Health Organization

INTRODUCTION

1. Rationale

Cinnamon is a popular and economically important spice. Like other plants, cinnamon may acquire heavy metals from the environments in which it is grown. Heavy metal contamination of spices, including cinnamon, has been reported in many countries (Umit. D et al. 2006; Baye et al. 2010; Nordin. N et al. 2013).

Regulatory authorities around the globe have recognized the occurrence of heavy metals in food, including cinnamon and its negative impact on consumers' health. Therefore, they have established or are in the process of considering establishing heavy metal limits. In order to find out the solutions to these issues, the Center for Rural Economy Development (CRED), IDH, GREAT, ASTA, and cinnamon exporting companies have initiated a study to identify the contributing factors to heavy metals in cinnamon and propose potential solutions to reduce heavy metal contamination for Vietnam's cinnamon industry.

2. Research objectives

- Identify potential pathways of heavy metal uptake by cinnamon trees;
- Propose potential solutions and future research to minimize heavy metal residues in cinnamon

CHAPTER 1: RESEARCH OVERVIEW

1.1. Global economic and trade perspective for Vietnamese cinnamon

Vietnamese cinnamon distribution and products

In Vietnam, cinnamon is naturally planted at an altitude of 300 - 800 m above the sea level in many provinces, including Yen Bai, Lao Cai, Quang Ninh, Thanh Hoa, Nghe An, Quang Nam, Quang Ngai, and at a height of 1,000 m in the mountains of Ninh Thuan province.

There are three species that have been popularly cultivated in Vietnam, including Cinnamon or China cinnamon (Cinnamomum cassia), Cinnamon stick or Vietnamese cinnamon (Cinnamomum loureirii), and Cinnamomum burmanii.

Cinnamon planting areas in Lao Cai and Yen Bai provinces

Cinnamon is grown in many places in Lao Cai province, mainly in Van Ban, Bao Yen, Bao Thang and Bac Ha districts. As at the end of 2021, the total area reached over 45,000 hectares.

Yen Bai has more than 80,000 hectares of cinnamon, distributing primarily in Tran Yen, Van Yen, Van Chan, Luc Yen, and Yen Binh districts, among which the area in Van Yen district is over 45,000 hectares, accounting for 55.7% of the cinnamon planting area within the province.

Cinnamon planting areas in Thanh Hoa province

Thanh Hoa currently has about 100 hectares of cinnamon plantation throughout the province. Cinnamon is often grown scatteredly in household gardens while being mixed with other species.

Cinnamon planting areas in Quang Nam and Quang Ngai provinces

The area of cinnamon cultivation in Quang Nam (2021) is 4,566 ha, mainly in the districts of Nam Tra My, Bac Tra My, Tien Phuoc and Phuoc Son, among which Tra My cinnamon accounts for more than 4,419 ha **(**Khuyennongquangnam.gov.vn**).**

1.2. Heavy metals residues in food

1.2.1. Heavy metals and their effects on humans

Heavy metals (HMs) are widely distributed in the earth's crust. They are weathered from natural rock formations and exist in the environment in the form of silt dissolved in lake water, sea water, and sediments. Heavy metals also arise from human activities such as mining, agricultural activities, domestic wastewater and transport vehicles. Regarding health perspectives, some heavy metals are essential for living organisms and humans, and they are indispensable trace elements (e.g., iron, zinc). However, other heavy metals are highly toxic and pose harmful effects on human and livestock health. This group of heavy metals include mercury (Hg), Pb (Pb), cadmium (Cd) and arsenic (As) [Abernathy., C et al. 1999 and US Department Health and Human Services, 2020).

Several studies confirm that toxic heavy metals such as Hg, Pb, As and Cd exist in herb and spice plants (Jarup L., et al, 2009; Kippler M., et al. 2007; , Mirosławski, J., et al. 2018; Wang P.F., et al. 2016). Heavy metal pollution in soil has become a serious global environmental problem (Hazrat, A., et al. 2019). Heavy metals exist in plants for a variety of reasons. This can be due to heavy metal adsorption in the environment and human activities such as farming, industrial activity, automobile exhaust, or contamination introduced during processing and preservation of cinnamon. When people are exposed to high levels of these toxic heavy metals in consumer products, they can have a negative impact on human health in the long run (Dghaim, R. et al. 2015; Valko M. et al. 2006).

The Codex Committee on Contaminants in Foods (CCCF) is in the process of proposing MRLs for Pb (pb) in spices (FAO.org). The CCCF collected more than 15,000 data points on Pb in herbs, spices, and condiments. Based on their data analysis, CCCF is proposing the establishment of different limits by category of herbs and spices ranging from 0.4-2.5ppm, including a category for bark spices that covers cinnamon and cassia based on 448 samples of bark spices. The bark samples showed a range of Pb levels from 0.001ppm-23.8ppm, with a mean level of 0.67 ppm and a 95th percentile of 2.48ppm (FAO.org).

Previously, variability in heavy metal content across spices has been reported in the literature. In 2010, Marian AsanteWah. N reported that the concentration of Pb found in 15 samples, (including the cinnamon and ginger samples) originated from Ghana was 107 and119 mg kg-1 respectively. Bua., D et al. (2016) also measured the Pb content in spice products in the Italian market. The results showed that the Pb content found in cinnamon, ginger, and turmeric ranged from 0.164 to 2.923 mg/kg. The highest reported value (2,224 ± 0.708 mg/kg) was similar to results from a Korean market study, which reported 2,635 mg/kg (Jaeyoung Shim, et al. 2019).

Krejpcio, Z., (2006) indicated that the Polish Ministry of Health established an MRL of 1.0 mg/kg for Pb and 0.1 mg/kg of Cd applicable to "other foods and condiments," which includes cinnamon amongst other herbs and spices. The report also provided data that showed that nearly half of the samples tested did not meet these limits. The mean values of the content were 1.49 mg/kg for Pb and 0.14 mg/kg for Cd in the 12 samples of cinnamon tested. Previously, BuLińSki r., et al (1995) found higher levels of heavy metal contamination in cinnamon on the Polish market with average levels of Pb and Cd at 6.24 mg/kg and 0.2 mg/kg respectively. CHizzoLa r., et al. 2003 also reported that the concentration of Pb found in leaves of spices plants including cinnamon was usually higher than other parts of the plants such as stem, suggesting that Pb contamination might be caused by air pollutions, since leaves absorb Pb from the air, whereas other parts of plants have a low capability to absorb Pb.

1.2.2. Allowable limits of heavy metals in food in major markets

In 2021, new European Commission (EC) regulations on maximum residue limit (MRL) for lead (Pb) for spices were established as below.

Table 1. Maximum residue level for Pb in spices

Food	**MRL (mg/kg)**
Fruit spices	0.6
Root and rhizome spices	1.5
Bark spices (including cinnamon)	2.0
Bud spices and flower pistil sp	1.0
Seed spices.	0.9

As mentioned above, Codex Alimentarius is in the process of establishing limits for lead in spices. The current draft proposed limits which took effect as of February 2022, as follows:

Table 2. Codex Alimentarius is in the process of establishing limits for lead in spices

Food	ML (mg/kg)
Culinary herbs	
Culinary herbs (fresh) (except Rosemary)	0.25
Rosemary (fresh)	0.5
Culinary herbs (dried)	2.0
Dried spices	
Floral parts (cloves, excluding saffron)	2.5
Fruits and berries spices (excluding star anise and sumac)	0.8
Rhizomes, bulbs and roots spice (excluding garlic)	3.5
Garlic	0.4
Bark	2.5
Seeds spices (excluding, carom, celery, dill, mahlab, mustard and poppy)	0.8
Celery seeds	1.5

In China, the MRL for Pb in spices, including cinnamon products is 3.0 mg/kg. The MRL for Mercury (limit Hg (in Hg basis) in cinnamon is 0.02 mg/kg (total Hg), as food intended for special dietary use. The MRLs of Arsenic (As) set by 0.5 mg/kg, and for Cadmium by 0.5 mg/kg [(USDA, 2018).

In the United States, there is no federal limit established for As, Pb, Hg, and Cd in spices. Rather, the U.S. FDA evaluates the safety of heavy metals on a case by case basis. However, some states have set their own limits. For example, New York State has a limit of 1 ppm for Pb in spices, and has proposed establishing lower limits for Pb, inorganic arsenic, and cadmium in spices. Likewise, the state of California requires a warning statement on products that contain certain levels of heavy metals (https://www.foodchemicalscodex.org/).

Other globally recognized standards setting bodies have also established standards for spices, including ISO and Food Chemical Codex (FCC). It is noteworthy that FCC standards include limits for heavy metals in spices used as dietary supplements, but not as foods (https://www.foodchemicalscodex.org/).

1.2.3. Impact of tightened regulations on MRLs for heavy metals on cinnamon exports

Vietnam's total cinnamon production is growing and will continue to expand. Cinnamon exports increased from $63 million in 2016 to $127 million in 2019. The cinnamon growing area in Vietnam has increased from 60,000 hectares in 2016 to 110,000 hectares in 2021. In the future, Vietnam's total cinnamon production is estimated to exceed 40,000 tons [18]. The total demand from the Middle East, India, and Turkey will not likely be able to absorb the total output of cinnamon exploited in Vietnam, therefore Vietnam's cinnamon industry will have an opportunity to further expand to high-end markets, including the U.S. and EU (SNV, 2021).

However, in recent years, the governments of some developed countries have reduced the MRLs of heavy metals in spices. This can lead to cost increase and the risk of losing the market for some spice exporters, in general, and cinnamon exporters in particular.

Some export shipments of Vietnamese cinnamon have been rejected from entry by regulatory authorities into the US and EU markets due to heavy metal residues. This affects not only the company’s business operations, but also the cinnamon branding of Vietnam, and the market share of cinnamon exports in the future, with an impact value of up to nearly USD 50 million (based on the nominal value in 2019) (SNV, 2021).

Therefore, it is essential to conduct a research to identify the causes of heavy metal residues in cinnamon products and to propose solutions. The research is potential to contribute to protecting consumers, and is essential to stabilize the global cinnamon market and ensure the sustainable development of Vietnam’s cinnamon industry.

CHAPTER 2. RESEARCH TARGET AND METHODS

2.1. Geographic focus and scope of the research

2.1.1. Geographic focus

The research was carried out in two main cinnamon producing regions: Lao Cai and Yen Bai provinces. Additionally, a minor number of samples were collected from other three provinces, including Thanh Hoa, Quang Ninh and Quang Nam.

2.1.2. Research scope

The research was conducted between December 2021 and September 2022.

It was conducted in the following communes which were selected by their cinnamon output:

- Lao Cai provinces: Ban Cai, Nam Det (Bac Ha district), Tang Loong, Son Ha, Phu Nhuan (Bao Thang district), Liem Phu, Nam Tha (Van Ban district) communes
- Yen Bai province: Dao Thinh, Xuan Tai (Tran Yen district), Vien Son (Van Yen district), An Luong (Van Tran district) communes
- Quang Ninh province: Quang An commune (Dam Ha district)
- Thanh Hoa province: Thuong Xuan town and Xuan Loc commune (Thuong Xuan district)
- Quang Nam province: Phuoc Kim commune (Phuoc Loc district)

2.2. Research objectives

- Identify potential pathways of heavy metal uptake by cinnamon trees;
- Propose potential solutions and future research to minimize heavy metal residues in cinnamon.

2.3. Research methodology

2.3.1. Research approach

To determine the pathway of heavy metal uptake by cinnamon, it is first necessary to determine the factors affecting the growth and development of the plant as well as the factors affecting the finished products.

2.3.2. Secondary data collection method

The researchers reviewed relevant research documents and findings from both in-country and international sources, including technical documents, regulations and standards.

The research team also reviewed data on environmental conditions (climate, geological features, topography, soil, hydrological system) and land use planning, especially the planning of areas having potential risk of heavy metal spread into existing or future cinnamon planting areas.

2.3.3. Method for stakeholder survey

The researchers engaged various stakeholders, including companies' managers, factory workers, managers of local government bodies, and farmers to collect the information in terms of production process, the amount of used agricultural input, transportation and processing procedures, and risks of heavy metal exposure in cinnamon products.

In-depth interviews were conducted with managers of local governments at the district level and local authorities at the commune level.

Survey forms were administered to leaders or managers of cinnamon companies and factory workers to collect information on manufacturing processes. The questionnaire can be viewed at: https://forms.gle/t23jVnF7i3oqueds6

The researchers also led group discussions and interviews with farmers from each commune (10 farmers/commune * 6 communes).

2.3.4. On site sampling method

Sampling was carried out following the instructions of the consultants. Accordingly, the samples were only taken in the areas with high risk in priority order: areas that have high heavy metal content in cinnamon products, areas adjacent to industrial zones and clusters, and areas having geological tectonic characteristics of high heavy metal composition in the parent rock.

(i) Soil samples: were taken according to TCVN 7538-2:2005 (ISO 10381 - 2:2002) in cinnamon growing areas by routes, topographical cross-sections and geological characteristics at three positions, including the peaks, middle and foot-hills. The samples were collected at depths of 0-30 cm and >70 cm.

Soil samples were also taken at Iron Mine in Chieng Ken commune, Van Ban district, Lao Cai province.

The samples were analyzed for Pb (Pb), Cadmium (Cd), Arsenic (As), and Mercury (Hg).

(ii) Air samples:

Air samples were collected to assess the current status of heavy metal concentration in the air, thereby testing the hypothesis that heavy metals were likely to be absorbed from the air by the tree. The research team only collected samples around the Tang Loong industrial zone because this is the place with the highest traffic density among all the communes within the research scope. In addition, around this area, there are factories that discharge emissions during the production of fertilizers, ore refining, etc.

The total number of samples taken is 8 samples, of which sample no. 8 was taken in front of the factory, the remaining samples were taken at the affected area.

Figure 1. Diagram of air sampling around Tang Loong area

Samples were taken under NIOSH 6009 and NIOSH 7300 of the National Institute of Occupational Safety and Health. The samples were analyzed for Pb (Pb), Cadmium (Cd), Arsenic (As), and Mercury (Hg).

(iii) Cinnamon samples

Fresh cinnamon samples of mature trees (at least 7 years old) were collected from the stems, leaves, and roots.

Dry/pre-processed cinnamon samples were randomly taken at the washing, outer layer removal, and drying stages.

Finished cinnamon products were randomly taken by batch of products.

- *Analytical indicators*

The cinnamon samples were analyzed for Pb, Cd, As, and Hg.

(iv) Water samples

Water samples were taken under Vietnamese standards: TCVN 6663-1:2011 (ISO 5667-1:2006), TCVN 6663-3:2016 (ISO 5667-3:2012), TCVN 5994:1995 (ISO 5667-4). :1987), TCVN 6663-6:2018 (ISO 5667-6; 2014).

(v) Vegetation samples

Some samples of plants mainly grown in cinnamon forest were taken to assess the content of Pb, Cd, As, and Hg.

Table 3. Summary of all samples taken

Province	Commune (district)	# Soil samples taken	# Water samples taken	# Cinnamon samples taken	# Soil samples taken (in mine land)	# Air samples taken
Lao Cai	Ban Cai (Bac Hà)	24		12		
	Nam Luc (Bac Hà)	12		6		
	Nam Det (Bac Ha)	24		12		
	Son Ha (Bao Thang)	6		3		6
	Phu Nhuan (Bao Thang)	18		9		1
	Tang Loong (Bao Thang)					1
	Liem Phu (Van Ban)	24		12		
	Chieng ken (Van Ban)				3	
	Nam Tha (Van Ban)	24		12		
Yen Bai	Dao Thinh (Tran Yen)	24		12		
	An Luong (Van Tran)	24	4	12		
	Vien Son (Van Yen)	24		12		
	Xuan Ai (Tran Yen)	24		12		
Quang Ninh	Quang An (Dam Ha)	12		6		
Quang Nam	Phuoc Kim (Phuoc Loc)	12		6		
Thanh Hoa	Thuong Xuan town	4		2		
	Xuan Loc (Thuong Xuan)	8		4		
Total		**264**	**4**	**108**	**3**	**8**

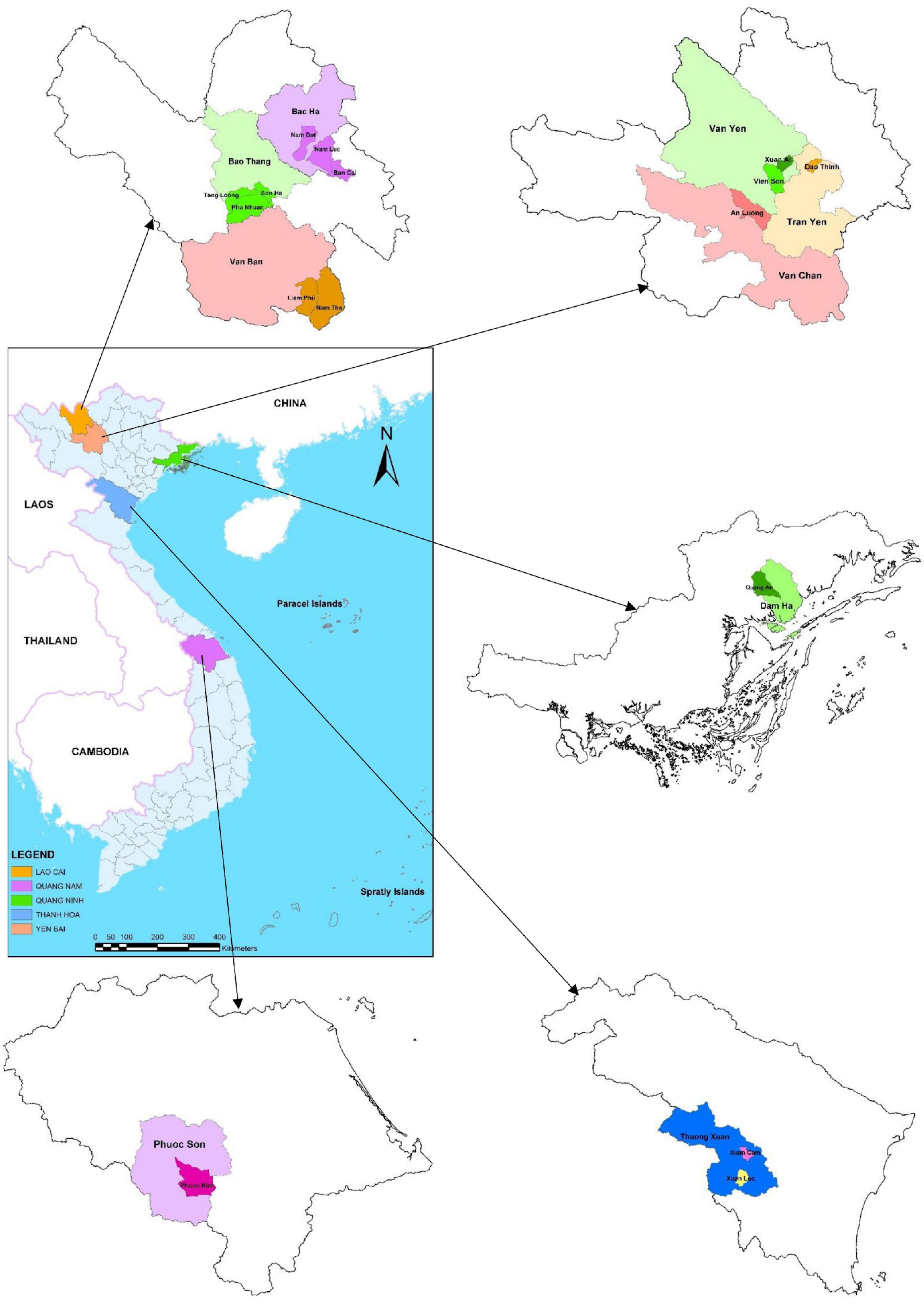


Figure 2. Sampling diagram

2.3.5. Analytical method

The ISO/IEC 17025:2017 certified laboratory, Eurofins, analyzed the samples by following methods:

Table 4. Analytical methods and detection limits

No	Code test	Sample	Criteria	LOD	LOQ	Unit	Standard	Method
1	VE0FX	Soil	As	0.06	0.2	mg/kg	TCVN 8467:2010 (ISO 20280:2007)	HG-AAS
2	VE0G3		Cd	0.01	0.03	mg/kg	TCVN 6496:2009 (ISO 11047:1998)	F-AAS
3	VE0G8		Pb	0.1	0.3	mg/kg	TCVN 6496:2009 (ISO 11047:1998)	F-AAS
4	VE0JF		Hg	0.03	0.1	mg/kg	TCVN 8882:2011 (ISO 16772:2004)	CV-AAS
5	VW071	Cinnamon tree	As	0.01	0.03	mg/kg	AOAC 2015.01	ICP-MS
6	VW073		Cd	0.01	0.03	mg/kg	AOAC 2015.01	ICP-MS
7	VW072		Pb	0.02	0.05	mg/kg	AOAC 2015.01	ICP-MS
8	VW074		Hg	0.01	0.02	mg/kg	AOAC 2015.01	ICP-MS
9	VW071	Cinnamon product	As	0.01	0.03	mg/kg	AOAC 2015.01	ICP-MS
10	VW073		Cd	0.01	0.03	mg/kg	AOAC 2015.01	ICP-MS
11	VW072		Pb	0.02	0.05	mg/kg	AOAC 2015.01	ICP-MS
12	VW074		Hg	0.01	0.02	mg/kg	AOAC 2015.01	ICP-MS
13	VE0FU	Water	As	0.00093	0.0031	mg/l	SMEWW 3114B:2017	HG-AAS
14	VE0G0		Cd	0.000097	0.00032	mg/l	SMEWW 3113B:2017	GF-AAS
15	VE0G5		Pb	0.00095	0.00317	mg/l	SMEWW 3113B:2017	GF-AAS
16	VE0HM		Hg	0.00029	0.00097	mg/l	SMEWW 3112B:2017	CV-AAS
17	VW072	Air	Pb	0.02	0.06	ug/m^3	Internal(Ref AOAC 2015.01)	ICP-MS

(Source: Eurofins)

Note:

LOD: Limit of detection

LOQ: Limit of Quantification
AAS: atomic absorption spectroscopy
ICP – MS: Inductively coupled plasma mass spectroscopy

2.3.6. Data processing methods

The researchers used Excel, XLSTAT and SPSS software to process the survey data.

CHAPTER 3. KEY FINDINGS AND DISCUSSION POINTS

3.1. The pathways of heavy metal uptake by cinnamon

In order to determine the pathway of heavy metals into cinnamon, it is necessary to identify which factors affect the growth and development of the plant as well as the factors affect the finished product (Figure 3).

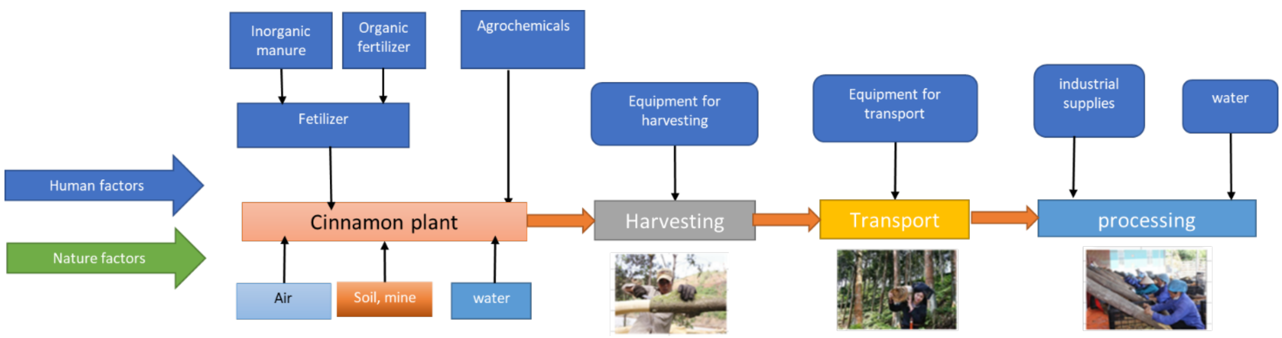


Figure 3. Diagram of tending and processing

3.1.1. Key findings from interviews and surveys

Table 5. Summary of heavy metal exposure risks

No.	Sources	Evaluation
1	Soil (and mineral mining/processing – if any)	Existent
2	Seedlings and intercropping	Uncertain
3	Weeds and other natural creatures	Unaffected
4	Organic fertilizer	Unaffected
5	Inorganic fertilizer	Unaffected
6	Irrigation water	Unaffected
7	Other agricultural inputs (e.g. pesticides)	Affected
8	Air	Uncertain
9	Water for production	Unaffected
10	Mining tools and materials	Unaffected
11	Processing materials (factory)	Uncertain

12	Processing materials (household)	Uncertain

(*Source: Surveyed consultants 2022 at locals*)

Thus, a general assessment of the factors believed by surveyed experts to affect heavy metal residues in cinnamon in Lao Cai and Yen Bai provinces showed that such factors as soil, agricultural inputs, and processing operations may contribute to a risk of high exposures to heavy metals in cinnamon products. Survey findings showed that experts believed that other factors may have influence but are not likely to be significant and were, therefore, not considered in this research. The evidence on the correlation among the causes of heavy metal residues and their influences is further described in the following section (3.1.2).

3.1.2. Heavy metal analysis in air, water and soil

Industries, services and routine life activities have the potential to indirectly affect the heavy metal content in the trees through soil, water and air. According to the proposed plan, the research findings on soil and air in the suspected polluted areas were shown as follows:

(i) Results from air sampling

Air samples were taken at 8 locations (Table 4) identified as potentially high risk for containing heavy metals. The concentrations of heavy metals in all air samples were very low and complied with the QCVN standard for ambient air (Table 4).

The concentration of Pb in the air ranged from 0.02 to 0.15 $\mu g/m^3$ in the analyzed samples. The highest levels detected were from samples collected from areas along Highway 151. However, no air samples exceeded the QCVN standard for ambient air quality (QCVN 05: 2013 / BTNMT) applicable to Pb dust. In fact, the highest sample was about 10 times lower than QCVN.

Only 1 air sample was detected with a Cd content higher than the method's detection limit of 0.03 g/m^3. However, the sample was still 13 times lower than QCVN on hazardous substances in the ambient air (QCVN 06: 2019/BTNMT). The concentrations of As and Hg in the air in all 8 locations where samples were taken were lower than the detection limit of the method.

Table 6. Concentrations of heavy metals in air samples

No.	Name	Location	Pb	As	Hg	Cd
			$\mu g/m^3$			
1	VSCN-KK-Q1	Near the inter-commune road Xuan Giao-Son Ha	0.08	<0.05	<0.02	<0.05
2	VSCN-KK-Q2	Near the inter-commune road Xuan Giao-Son Ha	0.08	<0.05	<0.02	<0.05
3	VSCN-KK-Q3	Near the inter-commune road Xuan Giao-Son Ha	0.02	<0.05	<0.02	<0.05
4	VSCN-KK-Q4	Cinnamon growing area	0.05	<0.05	<0.02	<0.05
5	VSCN-KK-Q5	Cinnamon growing area	0.06	<0.05	<0.02	<0.05
6	VSCN-KK-Q6	Near provincial road 151	0.06	<0.05	<0.02	<0.05
7	VSCN-KK-Q7	Near provincial road 151	0.15	<0.05	<0.02	<0.05
8	VSCN-KK-Q8	Tang Long Industrial Park	0.03	<0.05	<0.02	0.03

(ii) Results from water samples

The testing results of 4 surface water samples showed that the pH value of the water was neutral, and the analytical values of all four heavy metals (As, Cd, Pb and Hg) were all below the detection threshold of the testing method (Table 7).

Table 7. Water results from Yen Bai province

Samples	Pb (mg/l)	Cd (mg/l)	Hg (mg/l)	As (mg/l)	pH
Upstream water	Not detected	Not detected	Not detected	Not detected	6.28
Downstream water	Not detected	Not detected	Not detected	Not detected	6.35

Domestic water (before flowing into the filter tank)	Not detected	Not detected	Not detected	Not detected	6.30
After flowing into filter tank	Not detected	Not detected	Not detected	Not detected	6.24
	LOD=0.001	(LOD=0.0001)	(LOD=0.0001)	(LOD=0.001)	

(iii) Results from soil samples

In the first soil layer (30 cm), Pb and As were detected in 100% of samples, while Hg was found in 60.2% of samples, and Cd in 9.0% of samples (Table 8). Similarly for the second soil layer (70 cm), Pb was detected in 100% of samples, As in 98.5% of samples, Hg in 55.6% of samples, and Cd in 2.3% of samples. All remaining samples which were below the detection limit of the soil quality analysis method were not valid for statistical analysis.

Pb concentrations in soils ranged from 2.7- 82.9 mg/kg in the 1st layer and 1.2-78.0 mg/kg in the 2nd layer. One sample in the 1st soil layer and one sample in the 2nd soil layer (accounting for 0.75% of the total of quantifiable samples) had a Pb content exceeding QCVN (QCVN 03-MT: 2015/BTNMT: 70 mg/kg). The soil samples which had Pb contents close to QCVN and exceeding QCVN in terms of Pb content were all taken in Dao Thinh cinnamon farming area (Yen Bai), including the samples Đ1-ĐT5; Đ1-ĐT10 and Đ2-ĐT7. In addition, the cinnamon farming area in Vien Son commune (Yen Bai) also had a Pb content of up to 41.6 mg/kg detected in the sample D1-VS6. There was no significant difference in Pb concentrations between the two depths of soil layers (p=0.05) (Table 8).

Table 8. Statistics on average values of heavy metal concentrations in soil

Depth	Metal	Number of Samples	Variation range	Mean	QCVN 03-MT:2015/BTNMT	
			mg/kg		Agricultural soil	Forest soil
1st layer	Pb	133	**2.73-82.9**	11.62±10.45	**70**	100
	As	133	**0.36-39.8**	5.69±6.11	**15**	20
	Hg	80	0.06-0.35	0.15±0.05	**-**	-
	Cd	12	0.02-0.5	0.1±0.14	**1.5**	3
2nd layer	Pb	133	**1.16-78**	11.64±8.85	70	**100**
	As	131	**0.23-44.3**	6.52±7.11	15	**20**
	Hg	74	0.06-1.18	0.17±0.17	-	**-**
	Cd	3	0.03-0.12	0.08±0.04	1.5	**3**

Note: Variation range (VR) is indicated by minimum value - maximum value

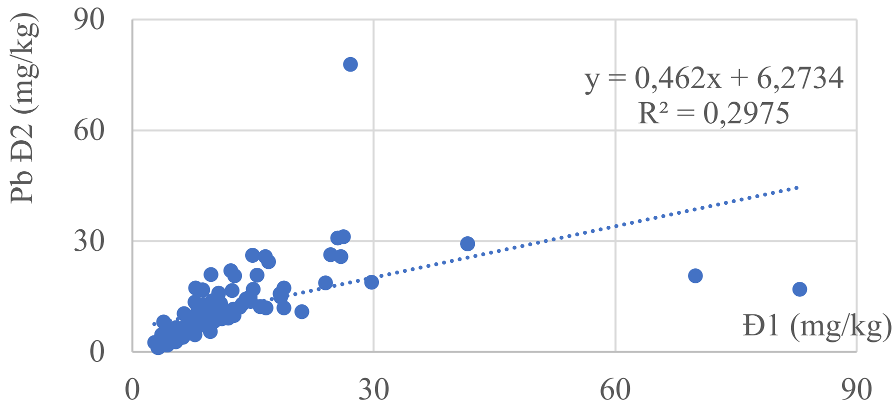
The mean value is represented by arithmetic mean ± standard deviation (SD)

The As concentration in the soil ranged from 0.4-39.8 mg/kg in the 1st layer and 0.2-44.3 mg/kg in the 2nd layer. Six samples in the 1st layer and 12 samples in the 2nd layer (accounting for 4.5% and 9.1% of the total quantifiable samples, respectively) had a As content (15 mg/kg) in soil which exceeded the QCVN. The samples from the 1st layer which exceeded the QCVN were from cinnamon forests in Ban Cai, Phu Nhuan and Nam Det (Lao Cai). The samples from the 2nd layer which exceed the QCVN were from (D1-BC2; D1-BC9; D1-BC10; D1-) PN7; D1-PN8; D1-ND7) and in the areas of Ban Cai, Phu Nhuan, Nam De (Lao Cai), Vien Son (Yen Bai) (D2-BC10; D2-PN4; D2-PN5; D2 - PN7; E2-PN8; E2-ND6; E2-ND7; E2-ND9; E2-ND11; E2-VS11; E2-VS12).

The Hg and Cd concentrations in the soil ranged from 0.06-1.18 mg/kg and 0.02-0.50 mg/kg respectively and were within the acceptable limits of QCVN. Hg in the 1st layer was lower than that in the 2nd layer, possibly due to the effects of evaporation and oxidation (Abdul. W, 2011). In contrast, Cd content did not differ significantly by depth.

Some sites with notable concentrations of Hg are Vien Son (Yen Bai) and Nam Det (Lao Cai) with Hg concentrations in the 2nd layer soil above 1 mg/kg (D2-VS8 and D2-ND8). Notable Cd concentrations were detected in some sites i.e., Phuoc Kim (Quang Nam – sampling points D1-PK4; D1-PK6) on the first layer with the concentrations >0.2 mg/kg; Liem Phu (Lao Cai) and An Luong (Yen Bai – sampling sites D2-LP10 and D2-AL8) on the 2nd layer have concentrations of approximately 0.1 mg/kg. In summary, high concentrations of Pb and As were found in some locations which exceeded the QCVN for agricultural soil conditions; the concentrations of Hg and Cd fluctuated and high concentrations were found in some locations.

In order to assess the causes of heavy metal residues in soil, the correlation of the heavy metal content between the 1st and 2nd soil layers at the sampling locations was evaluated. The analysis showed that Pb and As concentrations within the 1st and 2nd layers are closely correlated ($R > 0.25$; $n = 131$-133; $p = 0.05$) (Fig. 4). This might mean that samples which are close to the theoretical regression line had heavy metal contamination mainly caused by the inherent soil characteristics. That samples are far away the theoretical regression line means that the heavy metal contamination from soil might be caused by external factors, such as direct discharge, sedimentation, erosion, etc.



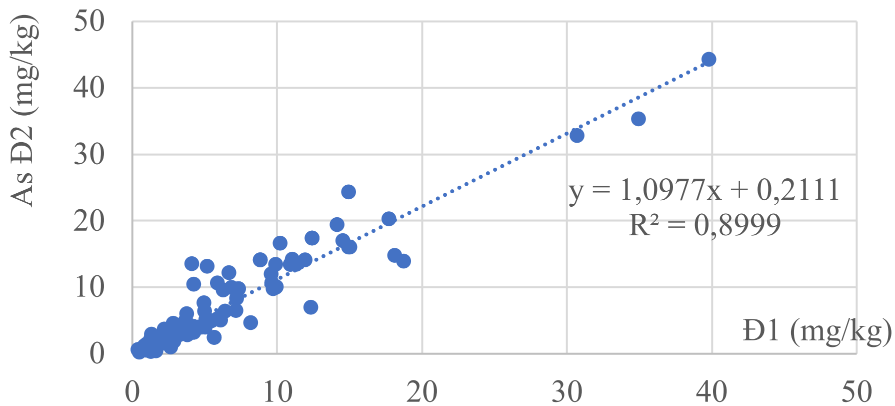


Figure 4. Correlation between the first and the second layer on the concentration of heavy metal in soil

Additionally, the analysis found that there were significant differences in heavy metal concentrations between the studied provinces ($p < 0.05$) (Table 9). The mean concentration of Pb in cinnamon farming soil was 9.7-10.3 mg/kg, 11.8-13.7 mg/kg and 17.6-24.0 mg/kg in Lao Cai, Yen Bai and Quang Nam, respectively. The mean concentration was the highest in Quang Nam, lower in Yen Bai and the lowest in Lao Cai. The mean As concentration was 7.2-8.5 mg/kg, 4.0-4.4 mg/kg and 0.6-0.8 mg/kg in Lao Cai, Yen Bai and Quang Nam respectively. In summary, the mean Pb concentration in Lao Cai was lower than Yen Bai and Quang Nam while the As concentration had an opposite tendency. These differences have a statistical significance with $p < 0.05$.

The analysis also demonstrated that there was variation in heavy metal concentrations within each province as reflected by the standard deviations in Table 9. However, no significant variation in concentrations of Hg between provinces was observed. Further, there were not a sufficient number of samples with detectable levels of Cd to determine statistical difference amongst provinces (P = 0.05) (Fig. 5).

Table 9. Comparison of mean heavy metal concentrations in soil at locations

Depth	Metal	Concentration of heavy metal (mg/kg)		
		Lao Cai	Yen Bai	Quang Nam
1st layer	Pb	9.69 ± 4.99^{a}	13.72 ± 15.7^{b}	17.57 ± 5.91^{b}
	As	7.2 ± 6.7^{a}	4.02 ± 2.92^{b}	0.81 ± 0.58^{c}
	Hg	0.16 ± 0.05^{a}	0.15 ± 0.06^{a}	0.22^{a}
	Cd	0.03 ± 0.24^{a}	0.05 ± 0.02^{a}	0.26 ± 0.24^{a}
2nd layer	Pb	10.34 ± 6.23^{a}	11.84 ± 12.13^{a}	24 ± 7.32^{b}
	As	8.49 ± 7.78^{a}	4.36 ± 3.59^{b}	0.56 ± 0.2^{c}
	Hg	0.17 ± 0.18^{a}	0.17 ± 0.16^{a}	0.12^{a}
	Cd	0.1^{a}	0.07 ± 0.06^{a}	-

Note: The mean value is represented by arithmetic mean ± standard deviation (SD)

$^{a, b, c}$: Least Significant difference (LSD) at p = 0.05

The differential concentration is valid when value $^{a, b, c}$ is different

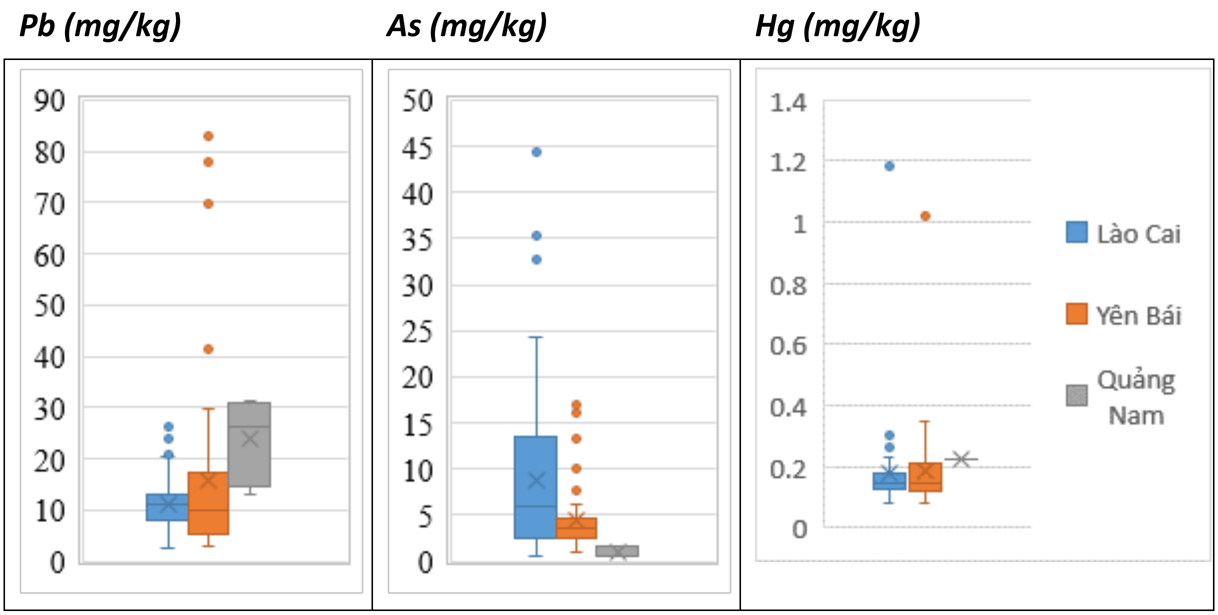


Figure 5. Comparison of heavy metal concentration in soil among provinces

In order to evaluate the potential influence from transportation and industrial zone emissions on soil heavy metal content, additional samples were collected from Tang Loong industrial zone.

The project team, in collaboration with the Lao Cai Department of Agriculture and Rural Development, took samples at Mo Sat in Chieng Ken commune, Van Ban district, Lao Cai province. The analysis results are shown in Table 10.

Table 10. Analysis results of soil samples at Chieng Ken

Unit: mg/kg

Sample	Analytical criteria			
	Pb	As	Hg	Cd
CK1 (Chiềng Ken 1)	26.5	7.26	0.33	LOD<0.03
CK2 (Chiềng Ken 2)	48.6	9.43	0.36	0.13
CK3 (Chiềng Ken 3)	47.1	11.8	0.19	0.036
QCVN 03-MT:2015/BTNMT (forest land)	100	20	-	3

QCVN 03-MT:2015/BTNMT: National technical regulation on allowable limits of some heavy metal residues of soil

As shown in Table 10, the analysis results of ore samples showed that the Pb content ranged from 26.5 to 48.6 mg/kg, As ranged from 7.26 to 11.8 mg/kg, Cd from 0.036 to 0.13 mg/kg and Hg from 0.19 to 0.36 mg/kg.

Although the above values are within QCVN (except for Hg because of no regulations are in place), however, in comparison with the analyzed values in the soil samples, the contents of Pb and As in the ore area has a larger fluctuation and higher values than those in other regions.

3.2. Status quo of heavy metal residues in cinnamon products

3.2.1. Key results from heavy metal analysis in cinnamon

Fresh cinnamon samples, including cinnamon bark (number of samples as described in chapter 2), leaves and cinnamon roots (added at some locations) were taken. Since the market share of cinnamon bark accounts for a large proportion of the surveyed products, therefore, the concentration of heavy metals in fresh cinnamon bark is seen as the reflection of the current status of heavy metal residues in cinnamon products.

With a total of 148 samples collected among provinces, the percentage of samples that are able to quantify the heavy metal contents in cinnamon bark is 100% for Pb; 28.4% for As; 18.9% for Hg and 100% for Cd. All remaining samples that were below the detection limit of the food quality analysis method were not used for this statistical analysis. The results of the mean heavy metal concentrations in cinnamon samples collected in 5 provinces are shown in the following table 11.

Table 11. Comparison of average heavy metal concentrations in fresh cinnamon samples in provinces

Criteria	**Subjects**	**concentration in Fresh samples (mg/kg)**			
		Pb	**As**	**Hg**	**Cd**
By provinces	Lao Cai	0.33±0.21 (**0.89**)	0.06±0.05 (0.24)	**0.03**±0.01 (**0.04**)	0.18±0.10 (**0.54**)
	Yen Bai	0.37±0.27 (**1.67**)	0.04±0.02 (0.09)	0.02±0.01 (**0.03**)	0.19±0.12 (**0.56**)

Criteria	Subjects	concentration in Fresh samples (mg/kg)			
		Pb	**As**	**Hg**	**Cd**
	Quang Nam	0.23±0.09 (0.35)	0.03	-	0.11±0.03 (0.16)
	Quang Ninh	0.23±0.09 (0.34)	0.05±0.01 (0.06)	-	0.21±0.06 (0.27)
	Thanh Hoa	0.35±0.19 (0.62)	0.11±0.04 (0.14)	-	0.15±0.07 (0.27)

Arithmetic mean ± Standard Deviation (Maximum value detected)

Pb concentrations in cinnamon products ranged from 0.06-1.67 mg/kg whereas As concentrations in cinnamon products ranged from 0.02-0.24 mg/kg. Hg concentrations in cinnamon samples were mostly not detected in the samples. However, Hg was detected in some samples in the Lao Cai and Yen Bai provinces. The concentration of Cd was in the range of 0.03-0.56 mg/kg.

When comparing the heavy metal concentration in cinnamon among provinces, the method of determining the least significant difference (LSD) indicates the following results: there is no difference in Pb content between samples collected in Lao Cai and Yen Bai but both provinces had significantly higher detected values than other provinces (Thanh Hoa, Quang Ninh and Quang Nam). Hg was detected only in samples collected in Lao Cai and Yen Bai provinces while it was below the measurement threshold in other provinces. All the remaining parameters such as As, Cd did not have any differentials between the surveyed provinces with $p < 0.05$ (Fig. 6).

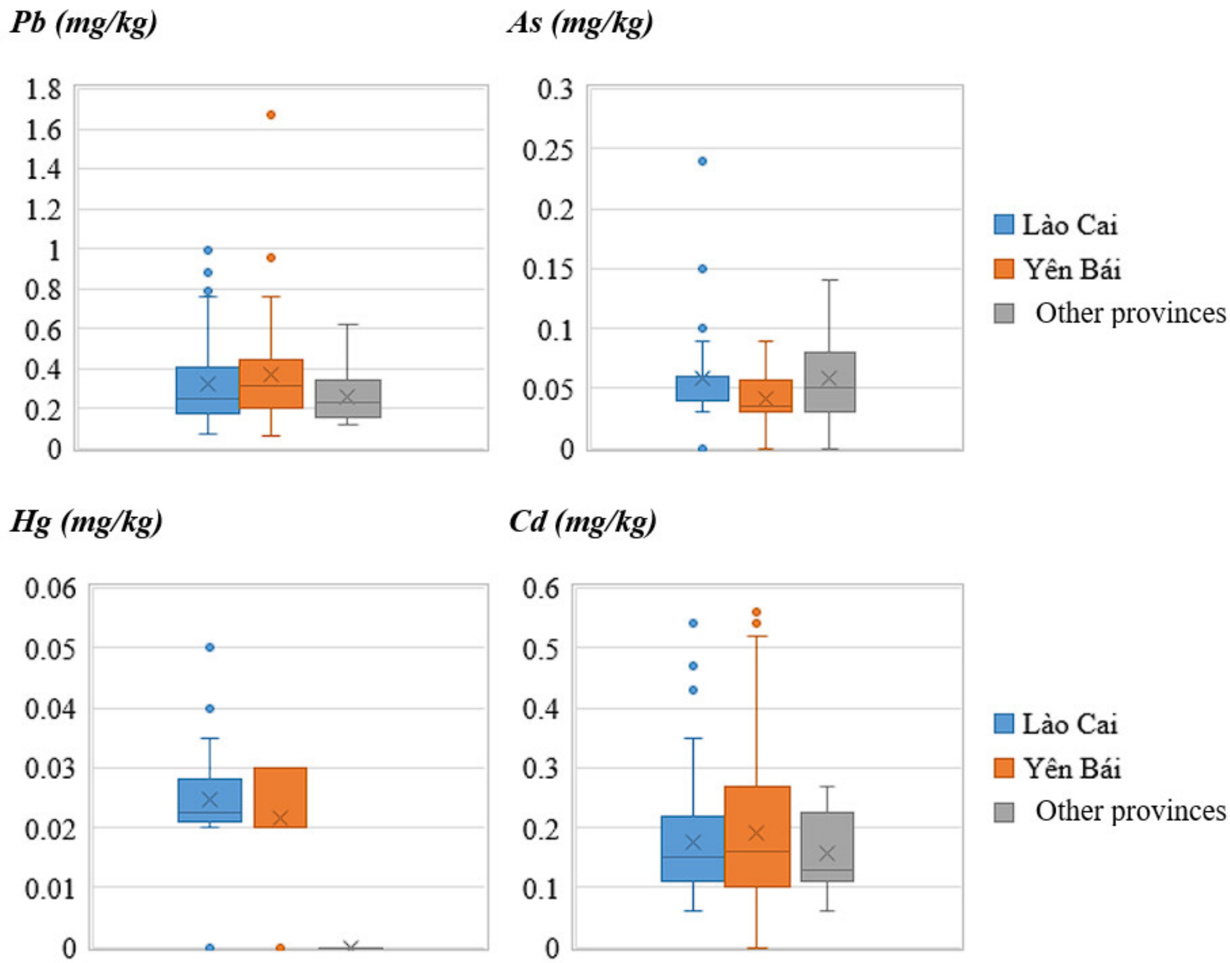


Figure 6. Comparison of heavy metal concentrations in fresh cinnamon samples among provinces

In summary, the cinnamon products in the surveyed provinces contained detectable levels of heavy metals but did not exceed the maximum allowable values of Vietnam and some existing export markets. Pb and Hg residues in cinnamon products produced in Lao Cai and Yen Bai provinces are higher than those in other provinces.

Of the finished cinnamon product samples taken in some factories, the Pb content was in the range of 0.16-3.12 mg/kg, the Cd concentration was in the range of 0.35-0.59 mg/kg, especially sample QNM1-CV has a Pb content of 3.12 mg/kg, and at the same time Cd content of 0.59 mg/kg exceeding the QCVN for some markets on the content of these metals in food (Table 12).

Table 12. Heavy metal concentrations of finished cinnamon products

Name of samples	Concentration (mg/kg)			
	Pb	**As**	**Hg**	**Cd**
QNM1-CV	**3.12**	0.07	<0.007	0.59
QNM2-BV	0.19	<0.01	<0.007	0.35
QNM3-QĐ	0.58	<0.01	<0.007	0.5
QNM4- QV	0.17	<0.01	<0.007	0.39
QNM4-QV-QC	0.16	<0.01	<0.007	0.39
QCVN 8-2:2011/BYT	**2.0**	**5.0**	**0.05**	**1.0**

In summary, all samples of fresh cinnamon and most of finished cinnamon product samples all meet QCVN (Vietnamese Standard) for the heavy metal content in food, however, some samples have Pb content exceeding QCVN and exceeding Hg and Cd MRLs of some markets.

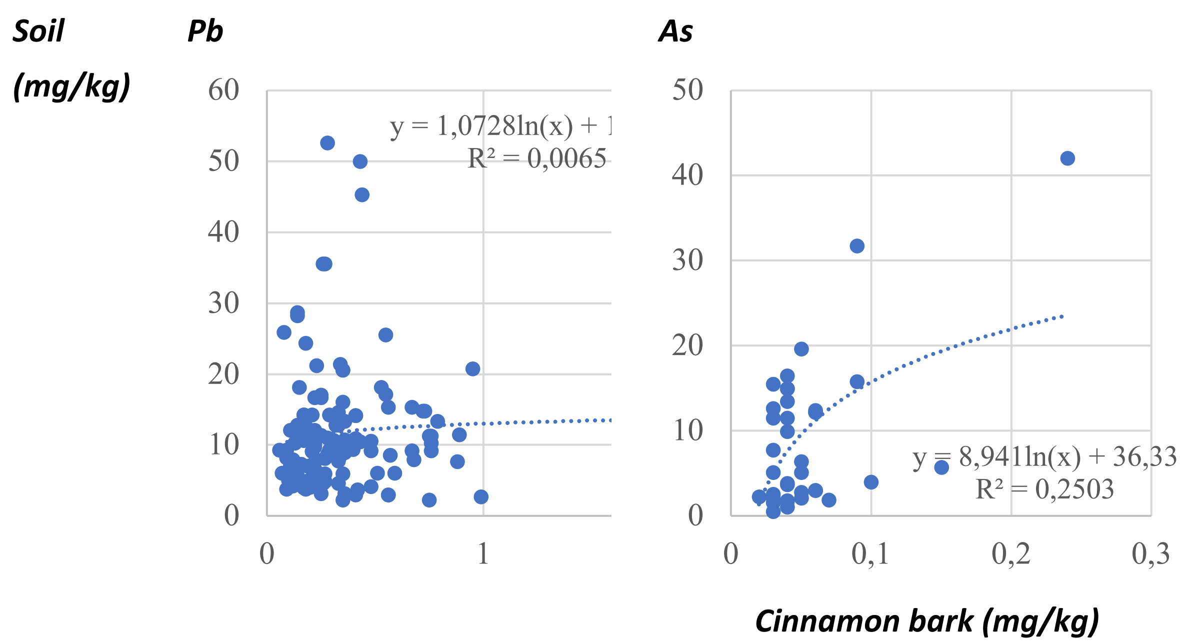
3.2.2. Factors influencing heavy metal residues in cinnamon products

a. Heavy metal accumulation from soil

Based on the current status of heavy metal concentration in soil (Paragraph 3.1.2) and in finished cinnamon products (Paragraph 3.2.1), some locations where high heavy metal contamination and pollution have been found in soil tends to have heavy metal contamination in their cinnamon barks. Therefore, the correlation between heavy metal concentration in soil and in trees was evaluated to determine how huge is the impact on heavy metal accumulation in cinnamon caused by the soil. The logarithmic correlation equation was used to represent the relationship between the metal concentration in cinnamon trees and the metal concentration in soil, the equation takes the form $y = a \ln(x) + b$ where y is the concentration in soil, x is the concentration in the tree, a and b are the regression coefficients. The correlation coefficient (r) and the regression coefficient

(R^2) were used to describe the strength of this correlation. The correlation graphs are presented in figure 7 and table 13.

The results show that there is not a statistically significant correlation among the concentrations of Pb, and Hg in soil and in trees. Correlation coefficients of 0.050 and 0.072 were calculated, respectively for Pb and Hg. However, with additional samples, a correlation may be observed. There was a minor correlation between soil and cinnamon concentrations for As (R=0.585). Meanwhile, the correlation between Cd in tree and in soil is negatively correlated with the correlation coefficient of -0.249 corresponding to the number of 14 samples.



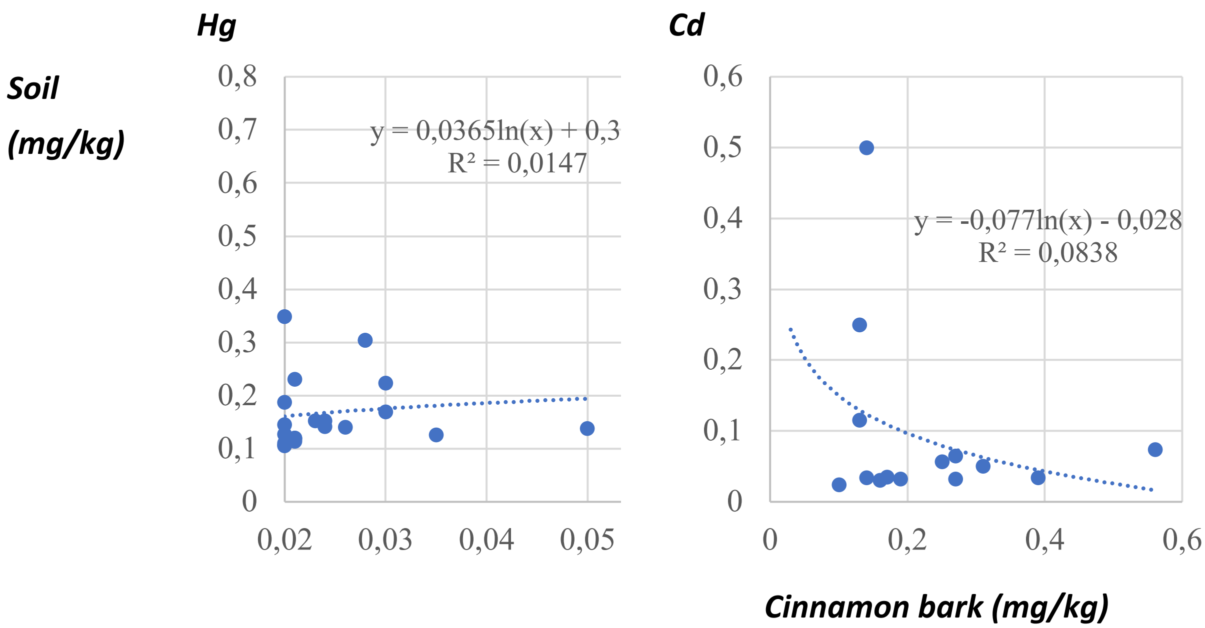


Figure 7. Correlation of heavy metal concentrations in soil and cinnamon products

With the assumption that the metal residue in trees is directly proportional to the concentration in soil, the t-test of the correlation gives the following results: the concentrations of heavy metals in the tree to concentrations in the soil were not significantly correlated. Pb in tree is not significantly correlated with Pb in soil at p = 0.0.5 (Z = 1.724 < 1.978); As and Hg in soil and in plants are correlated at p = 0.05 (equivalent to Z = 6.289 and 3.087 compared to t = 2.030 and 2.086 respectively), but do not meet the threshold for statistical significance; while the correlation of Cd in soil and in tree is not significant at p = 0.05 (with Z = 1.160 < 2.179). The correlation coefficient may be low due to the influence of many other external factors such as meteorology, water source, farming practice, tree age, etc. In summary, no statistically significant correlation exists between the concentrations of Pb, As, Hg, CD in the soil and in cinnamon products.

Table 13. T-test of the correlation of heavy metal concentrations between soil and cinnamon products

Metals Statistical indicators	Pb	As	Hg	Cd
Number of samples	134	37	22	14

Correlation equation (y=)	1.073ln(x) + 13.003	8.941ln(x) + 36.33	0.036ln(x) + 0.303	-0.077ln(x) - 0.028
Correlation coefficients (R)	**0.050**	**0.585**	**0.072**	**-0.249**
Testing value (Z)	1.724	6.289	3.087	1.160
t -test (p = 0,1)	**1.656**	1.690	1.725	1.782
t - test (p = 0,05)	1.978	**2.030**	**2.086**	2.179

Note: number of samples = pairs of samples that can quantify both cinnamon and soil

The Least Significant Difference (LSD) at p =0.1 and 0.05, n-2 with Z ≥ t

b. Bio – accumulation factor (BCF) of heavy metals in trees

Based on the relation between soil-tree and the position of heavy metal accumulation in the different parts of the cinnamon tree, the Bioaccumulation factor (BAF) of heavy metals on cinnamon bark is determined.

Table 14. Bioaccumulation factor (BAF) of heavy metals in trees

Metal	**Cinnamon**		**Fern**	
	Average	**VR**	**Average**	**VR**
Pb	0.038±0.034	0.003-0.363	0.532±0.231	0.228-0.715
As	0.01±0.01	0-0.05	0.091±0.044	0.031-0.129
Hg	0.16±0.066	0.057-0.362	0.182	-
Cd	4.809±3.113	0.28-11.47	-	-

Source:Team of consultants (2022)

Note: a. Variation range (VR) represented by minimum -÷ maximum
b. The mean of average represented by arithmetic mean ± standard deviation (SD)
c. BCF = Concentration of heavy metals in tree/Concentration of heavy metals in soil

The results (Table 14) showed that the bioaccumulation factor of As in cinnamon was 0.01. The bioaccumulation factors of Pb, Hg, and Cd were 0.038, 0.16, and 4.809, respectively. This is due to the fact that cinnamon bark accumulates only 1% - 16% compared to the soil absorption of metals As, Pb, Hg but the Cd accumulation in cinnamon bark is nearly 5 times -11 times higher than the soil absorption of Cd. This result is similar to the tendency assessed on the metal distribution in different parts of the trees. The comparison of cinnamon trees and ferns (representing the vegetation cover) at the same surveyed site shows that ferns absorb Pb and As more strongly than cinnamon trees, absorb Hg as high as cinnamon trees do but do not absorb Cd. Although the comparison is only relative (due to the comparison between the whole tree and its different parts; and the comparison between perennial and short-day trees), this result is consistent with many other studies on the tendency of heavy metal accumulation in trees and warning of the risk of Cd contamination, causing a concern over the quality of products made of cinnamon bark.

c. The heavy metal accumulation in various parts of cinnamon trees (shared by Son ha spice flavoring co, ltd)

Cinnamon trees grown in soil contaminated with heavy metals will absorb such heavy metals into their tissues through many different ways. Son Ha Spice flavoring co, ltd has shared a small study that was conducted with 15 samples collected in the communes of Lao Cai and Yen Bai provinces to examine the distribution of heavy metals amongst the bark, leaves, and roots of cinnamon trees. The results of the study are presented in (Table 15):

Table 15. Comparison of the mean heavy metal concentrations in different parts of cinnamon

Criteria	**Subjects**	**Fresh sample concentrations (mg/kg)**			
		Pb	**As**	**Hg**	**Cd**
Different parts of the tree	**Bark**	0.33±0.23 (1.67)	0.06±0.04 (0.24)	0.03±0.01 (0.04)	0.18±0.10 (0.56)
	Leaf	2.98±1.77 (6.62)	0.31±0.21 (0.67)	0.06±0.03 (0.11)	0.15±0.07 (0.27)
	Root	2.39±2.64 (10.6)	0.21±0.21 (0.69)	0.03±0.01 (0.04)	0.12±0.09 (0.35)

(Source: SON HA SPICE FLAVORINGS CO, LTD*)*

Note: Results are expressed as arithmetic mean ± standard deviation (maximum value)

QCVN 8-2:2011/BYT: National technical regulation on permissible limits of heavy metal pollution in food (spices)

Additional samples which were used for analyzing heavy metal concentrations in cinnamon roots indicated the mean detection values of 2.39; 0.21; 0.03 and 0.21 mg/kg of Pb, As, Hg and Cd respectively. Additional samples which were used for analyzing heavy metal concentrations in cinnamon leaves had the mean detection values of 2.98; 0.31; 0.06; 0.15 mg/kg of Pb, As, Hg and Cd respectively (Fig. 8).

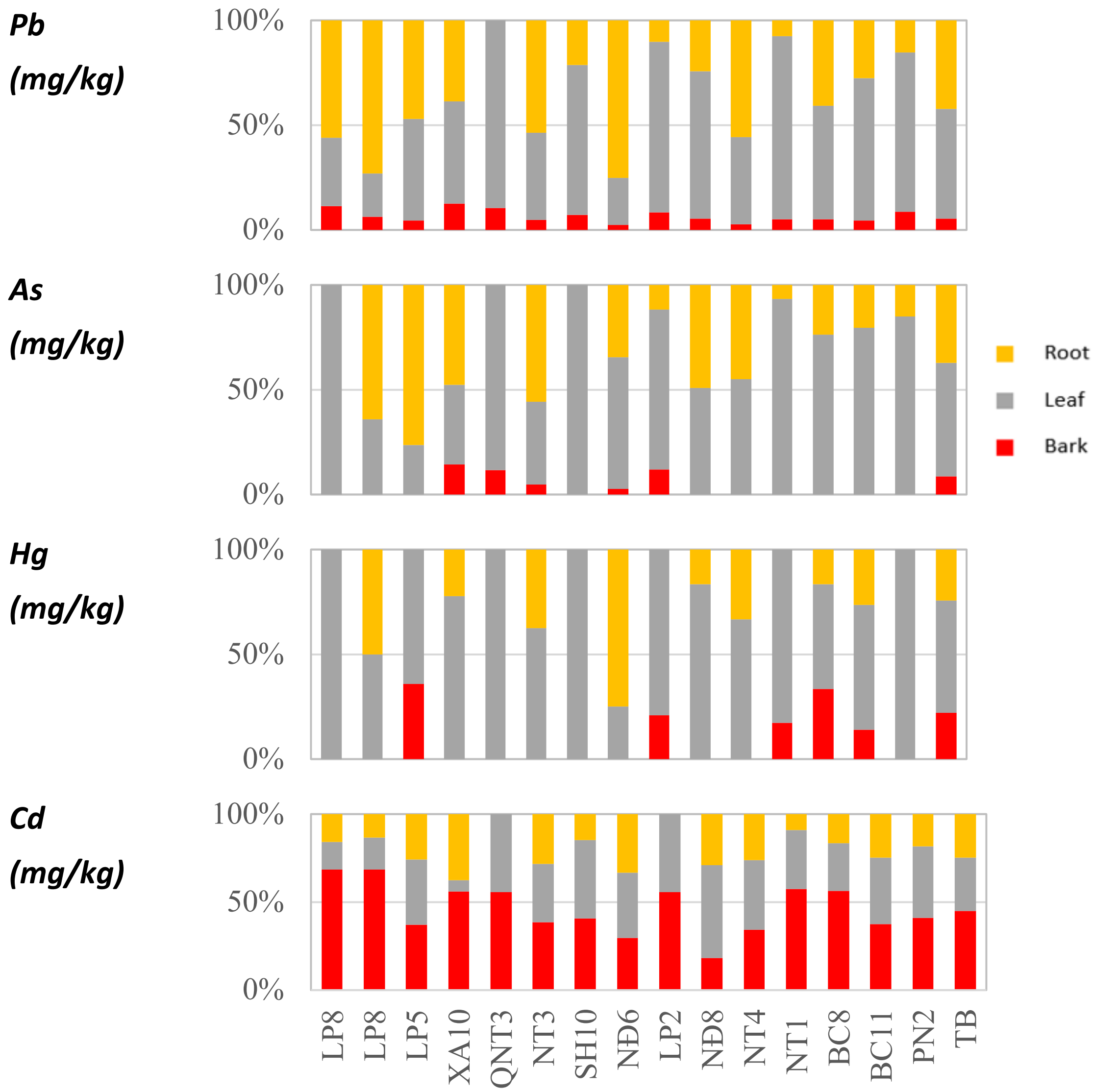


Figure 8. Distribution of heavy metals on different parts of cinnamon

Thus, Pb and As concentrations in cinnamon leaves and roots were much higher than the mean detection value of heavy metal concentrations in cinnamon bark, accounting for 42-

52% (for Pb) and 37-54% (for As) respectively. While the Cd content in cinnamon bark is higher than the rest of other parts (accounting for 45%); Hg content is usually highest in leaves and is similar in other parts of the tree (54% vs 22-24%). The percentage is relative due to the fact that the mass of the different parts of the tree is different but also it somewhat determines the tendency of the heavy metal concentration on the cinnamon trees.

In summary, As, Pb and Hg metals are concentrated in the roots and leaves of cinnamon while Cd tends to be concentrated in the bark. Then, out of the four heavy metal parameters considered, Cd is the parameter with a higher level of risk than the rest due to the high concentration on the cinnamon bark.

Son Ha company also shared its independent study of fresh cinnamon leaf samples, and cinnamon bark samples taken from the tops, branches, stems and roots of cinnamon harvested from sourcing areas in Lao Cai and Yen Bai provinces.Cinnamon samples were evaluated separately in combination with scraping of the outer cuticles of the collected cinnamon bark. The results of the mean heavy metal concentration in the samples obtained are as follows (Table 16):

Pb concentration of cinnamon bark after peeling off the outer cuticles (hereinafter referred to as peeling) decreased from 0.778-1,539 mg/kg to 0.035-0.093 mg/kg. The As concentration after peeling decreased from 0.024-0.036 mg/kg to 0.012-0.013 mg/kg. Hg concentration decreased from 0.034-0.037 mg/kg to 0.011-0.012 mg/kg; Cd concentration decreased from 0.310-0.373 to 0.279-0.353 mg/kg. After peeling, the concentrations of all metals decreased, in which the efficiency of removing Pb, As, Hg and Cd reached about 92.3-97.4%, 28.6-63.9%, 64.7-67.7% and 5.3-13.62% respectively. This may show that heavy metals especially Pb, Hg and As are concentrated in quite large amount in the outer cuticles of cinnamon bark. Thus, the efficiency of the peeling solution prior to the processing stage was highest for Pb; quite high for Hg, moderate and unstable for As, and quite low for Cd.

Table 16. Comparison of heavy metal concentrations in different parts of cinnamon by removing the outer epidermis

TRT	Part	Pb	As	Hg	Cd

Control (mg/kg)	Leaf	0.674	0.032	0.033	0.051
	Branch bark	1.539	0.050	0.032	0.310
	Top bark	1.208	0.036	0.034	0.316
	Body	0.778	0.028	0.037	0.323
	Root	0.488	0.024	0.034	0.373
Peeling practice (mg/kg)	Top bark	0.093	0.013	0.012	0.287
	Body	<0.02	<0.01	0.012	0.279
	Root	0.035	0.012	0.011	0.353
Peeling Efficiency (%)	Top bark	92.30	63.89	64.71	9.18
	Body	97.43	28.57	67.57	13.62
	Root	92.83	50.00	67.65	5.36

Therefore, removing outer cuticles before processing may lower heavy metal content for those cinnamon products that are at a higher risk of heavy metal uptake (e.g., adjacent to the mines).

3.3. Potential solutions to increase the competitiveness of cinnamon products

With aims to define the causes of heavy metal exposures in cinnamon, the findings of interviews and field surveys indicated that there is potential for the following factors to influence heavy metal concentrations in cinnamon: soil, metabolism and accumulation mechanisms, raw materials, seedlings, irrigation water, and air. Therefore, in order to reduce heavy metal residues in cinnamon products,improve the competitiveness of the products, and increase Vietnam's market share in high-end markets such as the EU, Japan, Korea it is highly recommended that additional research should be conducted on how to control heavy metal concentrations in cinnamon products (National Sustainability Curriculum for Cinnamon, VNForest).

3.3.1. Short-term recommendations (immediate recommendations)

- Policies:

- It is recommended to comply with the technical guidance under the Decision No. 14/QD-BNN-TCLN dated January 1, 2022 of the Ministry of Agriculture and Rural Development, promulgating technical instructions on seeding, planting, tending, nurturing, harvesting, and semi-processing and preservation of cinnamon products (*Cinamomum cassia BL*).

- Technique

- Removal of the outermost layer of cinnamon bark appears to reduce heavy metal uptake in cinnamon products. Further research should be conducted to better determine how this technique may be used to reduce heavy metals in finished cinnamon products.
- It is advised to classify cinnamon and develop standards to strictly control heavy metals in different types of cinnamon bark products (roots, stems, tops, branches, etc.). Additionally, thinning and pruning (as opposed to harvesting the entire tree) should be evaluated as a strategy for mitigating heavy metal content.
- Enterprises are advised to classify cinnamon by its origin of sourcing with a special attention being paid to cinnamon sourcing areas where cinnamon trees are growing on the soil of the ore mines since such areas will have a higher risk of heavy metal contamination. Lao Cai province needs particular attention since this

province has many types of mines. An in-depth study on mapping and zoning cinnamon sourcing areas should be completed to promote the compliance with high-end market requirements.

- Vegetation cover on the ground may minimize the risk of heavy metal accumulation. This research evaluated the potential for using ferns as a vegetation cover to reduce uptake by the cinnamon tree. Additional research on this mitigation strategy should be conducted.
- It is recommended to control the planning of cinnamon forest development such that trees are not planted where mines and ores are or have been recently active.

3.3.2. Long-term focused solutions

- **Land planning and management for cinnamon production:**

  - It is recommended to review and adjust land use planning such that future cinnamon production is developed in regions with lower heavy metal concentrations in the soil to promote compliance with global regulatory standards.

- Branding and trade promotion:

- Cinnamon growing needs to clearly identify the main export market so that support policies for businesses and cinnamon growers can be developed.

- **Planning:**

- It is recommended to integrate the assessment of heavy metals in soil into the soil degradation assessment program, into the province's periodical environmental monitoring program, especially in mineral-rich areas with aims to mapping and zoning the quality of soil, thereby the planning for agricultural production in general and cinnamon production in particular shall be made in accordance with the current status and quality of soil;
- It is recommended to develop a planning for agricultural production areas, which is seen as a priority in the province's land use planning scheme. It is also important to mainstream this planning into the land use planning and the environmental protection plan to identify new planting areas suitable for sustainable cinnamon development; it is advised not to plan the cinnamon growing area on both active

and inactive mine areas and also stop people from growing cinnamon trees on such lands.

- **Science and technology**

- It is recommended to have in-depth and systematic research on the heavy metal accumulation and different forms of heavy metals in cinnamon products in order to define optimal solutions to minimizing the exposure to heavy metals, for instance, in-depth research on indigenous plants which have a high ability to absorb heavy metals and on intercropping patterns where some types of low light-demanding plants with a high ability to absorb heavy metals are to be intercropped with cinnamon trees.
- It is recommended to conduct research on scientific and technological techniques to improve the characteristic in soil to reduce the dynamics of heavy metals in the soil, thereby minimizing the cinnamon tree's heavy metal absorption and accumulation in cinnamon products.

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

Concentrations of Pb and As in soil are varied by geographical locations. The average soil Pb concentration of Lao Cai was lower than that of Yen Bai and Quang Nam, while the As concentration had the opposite tendency. Though heavy metal concentrations in the air samples tested were low and complied with the QCVN for ambient atmosphere, concentrations of Pb and As exceeded the QCVN for agricultural land environment in some of the samples tested and concentrations of Hg and Cd in soil samples fluctuate strongly.

All samples of fresh cinnamon bark products and most finished cinnamon products met the QCVN standard after being processed, but some of the samples exceeded other global regulatory limits. Based on data shared by a Vietnamese cinnamon company, As, Pb and Hg are mainly accumulated in roots and leaves of cinnamon trees while Cd tends to be accumulated in cinnamon bark (two times higher than other parts of the tree). Additionally, the concentration of heavy metals (Pb, As, Hg) was shown in this company data to be mainly accumulated in the outermost layer of cinnamon bark. The research suggests that the removal of the outer cuticle before processing, and avoiding parts of the tree such as leaves, branches and top bark may result in a reduction in heavy metal content.

2. Limitations

The research was carried out in a short time with limited funding, some issues has not yet been resolved, which requires further study, including:

- The research shows that the detection value of heavy metals in the mining areas is higher than in other areas. Therefore, the expansion of cinnamon sourcing areas in Lao Cai where many ore mines are scatteredly distributed throughout the province will potentially cause heavy metal contamination in cinnamon products in the future. Within the scope of this research, it is not possible to define the “hotspots” of the cinnamon sourcing areas.
- The research does not include the development of suitable farming models to minimize the transmission of heavy metals from the soil into the trees. Therefore,

in the future, if possible, it is necessary to build practical farming models in the area to provide specific technical guidance.

- The technique of removing the outer cuticle before processing shows that it will greatly reduce the content of heavy metals in the products. However, more research is needed on which cinnamon products should be peeled and how thick the outer cuticles are peeled to ensure quality as well as economic efficiency.

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ANNEX 1. SOME PHOTOS OF THE RESEARCH MISSION

Identifying locations to collect samples

Taking samples of fresh cinnamon, air and soil samples

Conducting inventories and collecting semi-processed cinnamon samples

Segment of planting and tending cinnamon in Yen Bai province

Segment of harvesting, transporting and semi-processing cinnamon in Lao Cai

ANNEX 2. PRIMARY RAW DATA ON RESEARCH FINDINGS

Sample code	Detection value in cinnamon (mg/kg)				Detection value in the 1st soil layer (mg/kg)				Detection value in the 2nd soil layer (mg/kg)			
	Q-Pb	**Q-As**	**Q-Hg**	**Q-Cd**	**Đ1-Pb**	**Đ1-As**	**Đ1-Hg**	**Đ1-Cd**	**Đ2-Pb**	**Đ2-As**	**Đ2-Hg**	**Đ2-Cd**
BC1	0.55		0.026	0.31	24.6	1.49	0.11		26.4	0.69	0.17	
BC10	0.25			0.11	10.8	17.7			11.9	20.3		
BC11	0.41		0.021	0.26	15.9	5.65			12.3	2.5	0.12	
BC11	0.41		0.021	0.26	15.9	5.65			12.3	2.5	0.12	
BC12	0.88			0.14	9.63	11.9	0.151		5.63	14.1	0.137	
BC2	0.57	0.04	0.02	0.22	8.78	18.1	0.15		8.25	14.8	0.224	
BC3	0.27			0.13	8.88	3.75	0.282		7.25	6.04	0.159	
BC4	0.79		0.022	0.35	10.7	6.84			16	9.94		
BC5	0.32		0.023	0.31	8.67	0.93			16.8	1.37	0.152	
BC5-QC	0.33		0.024	0.32	8.67	0.93			16.8	1.37	0.152	
BC6	0.17			0.14	11.9	1.58	0.186	0.034	9.26	1.19		
BC7	0.68	0.04		0.18	7.97	1.58			7.89	1.78		
BC8	0.41		0.04	0.54	9.89	2.22			11.8	2.01		

Sample code	Detection value in cinnamon (mg/kg)				Detection value in the 1st soil layer (mg/kg)				Detection value in the 2nd soil layer (mg/kg)			
	Q-Pb	**Q-As**	**Q-Hg**	**Q-Cd**	**Đ1-Pb**	**Đ1-As**	**Đ1-Hg**	**Đ1-Cd**	**Đ2-Pb**	**Đ2-As**	**Đ2-Hg**	**Đ2-Cd**
BC9	0.25		0.024	0.25	18.4	18.7			14.9	13.9	0.142	
LP1	0.09		0.021	0.12	8.18	1.89			10.4	2.49	0.117	
LP10	0.12		0.05	0.27	7.22	4.2		0.034	8.54	10.5	0.138	0.095
LP11	0.17			0.15	4.68	2.21			3.11	1.7		
LP12	0.48	0.1		0.11	10.5	3.92						
LP2	0.35	0.07	0.021	0.1	6.81	2.63	0.231		4.99	1		
LP3	0.07			0.13	5.39	4.76	0.117		6.64	3.99	0.125	
LP4	0.27		0.035	0.2	5.63	3.95	0.126		4.04	3.33		
LP5	0.13		0.028	0.1	9.37	4.2	0.304		11.2	3.25		
LP5	0.13		0.028	0.1	9.37	4.2	0.304		11.2	3.25		
LP6	0.12			0.14	7.6	5.01			7.86	4.04		
LP7	0.1			0.21	4.74	3.66			5.22	5		
LP8	0.21			0.26	9.01	2.47	0.132		9.11	2.74	0.157	
LP8-QC	0.21			0.26	9.01	2.47	0.132		9.11	2.74	0.157	
LP9	0.28			0.18	9.95	6.26			12	9.57		
NĐ1	0.67		0.02	0.29	18.8	2.77	0.124		11.9	2.19	0.13	

Sample code	Detection value in cinnamon (mg/kg)				Detection value in the 1st soil layer (mg/kg)				Detection value in the 2nd soil layer (mg/kg)			
	Q-Pb	Q-As	Q-Hg	Q-Cd	Đ1-Pb	Đ1-As	Đ1-Hg	Đ1-Cd	Đ2-Pb	Đ2-As	Đ2-Hg	Đ2-Cd
NĐ1	0.89	0.06		0.21	11.9	2.19	0.13		10.9	3.75	0.148	
NĐ10	0.2	0.04		0.06	12.3	9.86			10.7	10	0.15	
NĐ11	0.16	0.04		0.12	8.81	10.2	0.136		12.9	16.6	0.117	
NĐ12	0.09			0.09	7.59	9.88	0.135		8.74	13.4	0.159	
NĐ2	0.17			0.08	16.6	4.08	0.141		11.9	13.5		
NĐ3	0.48			0.12	8.57	8.17	0.176		9.81	4.67	0.15	
NĐ4	0.36			0.07	13.6	5.85			13	10.6	0.12	
NĐ5	0.15			0.15	10.2	9.59	0.157		13	10.6	0.12	
NĐ6	0.14			0.14	10.2	9.59	0.157		13	10.6	0.12	
NĐ6	0.35	0.03		0.17	10.2	14.9			9.66	16		
NĐ7	0.4			0.16	7.71	34.9	0.141	0.03	13.6	35.3	0.12	
NĐ8	0.26			0.07	5.63	12.3	0.176		3.44	6.98	1.18	
NĐ9	0.33			0.17	7.81	14.1			7.7	19.4		
NL1	0.15			0.07	15.5	1.27	0.101		20.8	2.3	0.208	
NL2	0.34	0.05		0.16	24	6.4			18.7	6.39		
NL3	0.23			0.17	10.9	6.64	0.167	0.035	12.1	12.2		

Sample code	Detection value in cinnamon (mg/kg)				Detection value in the 1st soil layer (mg/kg)				Detection value in the 2nd soil layer (mg/kg)			
	Q-Pb	**Q-As**	**Q-Hg**	**Q-Cd**	**Đ1-Pb**	**Đ1-As**	**Đ1-Hg**	**Đ1-Cd**	**Đ2-Pb**	**Đ2-As**	**Đ2-Hg**	**Đ2-Cd**
NL4	0.25			0.11	18.3	9.7			15.8	9.79	0.128	
NL5	0.17	0.03		0.07	10.1	8.79	0.111		12.9	14.1		
NL5-QC	0.18	0.04		0.07	10.1	8.79	0.111		12.9	14.1		
NL6	0.21			0.13	14.2	7.14			14.2	6.46	0.082	
NT1	0.22		0.021	0.19	12.7	4.49	0.114		20.6	4.03		
NT10	0.22			0.1	8.45	3.67			11	2.99		
NT11	0.19			0.11	9.76	3.13			12.7	2.95		
NT12	0.76	0.15		0.14	10.4	4.97			12	6.38		
NT2	0.22	0.04		0.28	11.1	4.02	0.203		9.06	3.59		
NT3	0.23	0.06		0.15	6.68	10.9			5.11	13.4		
NT3-QC	0.23	0.06		0.15	6.68	10.9			5.11	13.4		
NT4	0.22			0.13	7.08	9.55	0.112		8.06	12		
NT5	0.12			0.14	3.63	7.29	0.137		4.73	9.82		
NT5-QC	0.11			0.15	3.63	7.29	0.137		4.73	9.82		
NT6	0.11			0.06	6.74	0.81	0.106		7.44	1.17		
NT7	0.16			0.08	7.52	0.62			7.1	0.8	0.143	

Sample code	Detection value in cinnamon (mg/kg)				Detection value in the 1st soil layer (mg/kg)				Detection value in the 2nd soil layer (mg/kg)			
	Q-Pb	Q-As	Q-Hg	Q-Cd	Đ1-Pb	Đ1-As	Đ1-Hg	Đ1-Cd	Đ2-Pb	Đ2-As	Đ2-Hg	Đ2-Cd
NT8	0.14			0.09	9.87	0.95			13.9	0.5		
NT9	0.11			0.06	12.5	0.56			11.6		0.13	
PN1	0.75	0.04		0.34	12.6	1.12			9.83	0.97	0.145	
PN2	0.76			0.27	8.03	1.26	0.176		12.5	0.34	0.12	
PN3	0.75	0.03		0.21	3.2	11	0.11		1.16	14.2	0.121	
PN4	0.99	0.05		0.17	2.73	14.9			2.54	24.3	0.1	
PN5	0.28	0.04		0.43	7.69	12.4	0.187		9.64	17.4		
PN5-QC	0.28	0.04		0.47	7.69	12.4	0.187		9.64	17.4		
PN6	0.19			0.11	6.97	2.18	0.116		6.98	2.21	0.142	
PN7	0.34	0.24		0.23	6.43	39.8			10.4	44.3		
PN8	0.42	0.09		0.1	3.82	30.7	0.131		3.45	32.8	0.317	
PN9	0.51	0.04		0.14	5.46	1.86	0.111		6.55	1.62		
SH10	0.22			0.11	10.8	1.55			11.4	1.87	0.265	
SH11	0.43	0.05		0.19	9.09	1.28	0.122		11.8	2.89	0.127	
SH12	0.59	0.03		0.22	3.85	1.77	0.222		8.24	2.4	0.15	
PK 6	0.14			0.13	25.5	1.5		0.25	30.9	0.8		

Sample code	Detection value in cinnamon (mg/kg)				Detection value in the 1st soil layer (mg/kg)				Detection value in the 2nd soil layer (mg/kg)			
	Q-Pb	**Q-As**	**Q-Hg**	**Q-Cd**	**Đ1-Pb**	**Đ1-As**	**Đ1-Hg**	**Đ1-Cd**	**Đ2-Pb**	**Đ2-As**	**Đ2-Hg**	**Đ2-Cd**
PK1	0.22			0.06	10.9	0.47			13.2	0.23		
PK2	0.17			0.08	14.1				14.4			
PK3	0.35	0.03		0.16	14.9	0.36			26.2	0.64		
PK3-QC	0.35			0.12	14.9	0.36			26.2	0.64		
PK4	0.23			0.14	16.5	0.59		0.5	25.9	0.62		
PK5	0.14			0.1	26.2	1.59	0.221	0.024	31.2	0.4	0.116	
QA1	0.17			0.24								
QA1-QC	0.18			0.26								
QA2	0.32			0.12								
QA3	0.33	0.05		0.25								
QA3-QC	0.34	0.05		0.27								
QA4	0.2			0.21								
QA5	0.12			0.2								
QA6	0.15	0.06		0.13								
TT1	0.5	0.08		0.11								
TT2	0.62	0.14		0.11								

Sample code	Detection value in cinnamon (mg/kg)				Detection value in the 1st soil layer (mg/kg)				Detection value in the 2nd soil layer (mg/kg)			
	Q-Pb	Q-As	Q-Hg	Q-Cd	Đ1-Pb	Đ1-As	Đ1-Hg	Đ1-Cd	Đ2-Pb	Đ2-As	Đ2-Hg	Đ2-Cd
XL3	0.23			0.11								
XL4	0.24			0.27								
XL5	0.12			0.09								
XL6	0.37			0.13								
AL1	0.11			0.17	4.91	3.75	0.237		4.52	4.57	0.177	
AL10	0.23	0.05	0.02	0.17	5.52	2.44			5.13	3.06		
AL11	0.14		0.03	0.25	6.09	2.56		0.056	5.28	2.59	0.223	
AL12	0.14	0.06	0.03	0.05	13.3	11.3			12.2	13.4		
AL2	0.25		0.02	0.09	5.41	2.56	0.11		3.93	2.61		
AL3	0.09		0.02	0.09	3.71	1.85			3.87	1.56		
AL4	0.08	0.05		0.09	25.9	5.1	0.156		25.9	5.1	0.156	
AL5	0.2		0.02	0.1	5.29	2.86	0.348		3.7	2.72		
AL6	0.18		0.03	0.19	3.86	0.99			3.69	0.86		0.032
AL7	0.11		0.02	0.08	6.7	9.9	0.105		5.68	10.1		
AL8	0.17		0.02	0.13	4.85	3.24	0.122		4.88	4	0.167	0.115
AL9	0.06		0.02	0.15	10.1	5.87			8.4	5.21	0.106	

Sample code	Detection value in cinnamon (mg/kg)				Detection value in the 1st soil layer (mg/kg)				Detection value in the 2nd soil layer (mg/kg)			
	Q-Pb	Q-As	Q-Hg	Q-Cd	Đ1-Pb	Đ1-As	Đ1-Hg	Đ1-Cd	Đ2-Pb	Đ2-As	Đ2-Hg	Đ2-Cd
ĐT1	0.73			0.07	14.6	1.902	0.12		15	1.641	0.1	
ĐT1	0.76			0.27	9.5	3.785	0.11		8.9	3.94	0.12	
ĐT10	0.43			0.09	82.9	6.079	0.12		17	5.06	0.074	
ĐT11	0.35			0.11	21	0.993	0.12		11	1.492	0.18	
ĐT12	0.56			0.22	9.7	2.197	0.096		21	2.44	0.12	
ĐT2	1.67	0.02		0.14	15	2.489	0.18		17	1.949	0.33	
ĐT3	0.67			0.1	8.4	2.028	0.08		10	2.714	0.08	
ĐT4	0.36	0.03		0.11	9.4	7.184	0.056		12	8.296	0.095	
ĐT5	0.44			0.11	69.9	3.882	0.084		20.6	3.026	0.067	
ĐT6	0.72			0.07	14.6	1.902	0.12		15	1.641	0.1	
ĐT7	0.28			0.17	27.1	2.535	0.084		78	2.144	0.063	
ĐT8	0.18			0.07	29.7	2.096	0.17		19	1.544	0.062	
ĐT9	0.31			0.1		4.911	0.11		10.6	7.681	0.14	
VS1	0.48			0.13	4.92	2.83	0.219		3.28	1.87		
VS10	0.36			0.54	4.29	2.87			1.95	3.23		
VS11	0.53	0.09		0.24	18.8	14.5	0.126		17.4	17		

Sample code	Detection value in cinnamon (mg/kg)				Detection value in the 1st soil layer (mg/kg)				Detection value in the 2nd soil layer (mg/kg)			
	Q-Pb	Q-As	Q-Hg	Q-Cd	Đ1-Pb	Đ1-As	Đ1-Hg	Đ1-Cd	Đ2-Pb	Đ2-As	Đ2-Hg	Đ2-Cd
VS12	0.29			0.29	14.7	15	0.13		13.7	16	0.11	
VS2	0.22			0.08	6.64	3.96			6	3.72		
VS3	0.23			0.03	7.71	3.67			4.71	3.75		
VS4	0.27	0.04		0.12	6.24	2.82	0.142		5.63	4.54		
VS5	0.41			0.27	11.1	2.15	0.168	0.032	9.67	2.26	0.139	
VS6	0.26			0.14	41.6	3.88	0.12		29.4	4.34	0.144	
VS6-QC	0.27			0.12	41.6	3.88			29.4	4.34		
VS7	0.36			0.36	8.4	3.11	0.247		9.45	3.06	0.142	
VS8	0.2	0.03		0.19	6.2	5.04	0.127		3.99	5.14	1.02	
VS9	0.29			0.31	8.13	5.13	0.141	0.05	10.3	13.2	0.101	
XA1	0.18			0.22	7.83	3.62			17.3	4.57		
XA10	0.41	0.03		0.52	3.58	2.34	0.109		2.25	2.66	0.117	
XA11	0.35	0.03		0.56	3.12	1.49		0.074	1.25	1.6		
XA12	0.4			0.32	10.1	5.47	0.193		8.57	4.95	0.144	
XA2	0.55			0.39	12.2	2.2	0.126	0.034	22.1	2.08		
XA3	0.4			0.32	10.5	4			10.7	3.54	0.128	

Sample code	Detection value in cinnamon (mg/kg)				Detection value in the 1st soil layer (mg/kg)				Detection value in the 2nd soil layer (mg/kg)			
	Q-Pb	**Q-As**	**Q-Hg**	**Q-Cd**	**Đ1-Pb**	**Đ1-As**	**Đ1-Hg**	**Đ1-Cd**	**Đ2-Pb**	**Đ2-As**	**Đ2-Hg**	**Đ2-Cd**
XA4	0.33			0.31	12.4	3.86	0.168		16.7	3.15	0.116	
XA5	0.95	0.06		0.27	16.9	3.18	0.157		24.5	2.8	0.105	
XA6	0.56			0.16	3.75	3.45	0.157		2.11	3.55	0.281	
XA6-QC	0.56			0.16	3.75	3.45	0.157		2.11	3.55	0.281	
XA7	0.25		0.03	0.25	4.3	3.79	0.206		1.92	2.86	0.132	
XA8	0.2			0.14	5.33	2.51	0.238		2.71	2.53	0.279	
XA9	0.33			0.22	4.59	2.51	0.123		4.6	2.51	0.148	

***Remarks*: The location where samples were taken are coded in the following Table:**

Province	**Communes (district)**	**Sample symbol**
Lao Cai	Ban Cai (Bac Ha)	BC
	Nam Luc (Bac Ha)	NL
	Nam Det (Bac Ha)	ND
	Son Ha (Bao Thang)	SH
	Phu Nhuan (Bao Thang)	PN
	Tang Loong (Bao Thang)	TL
	Liem Phu (Van Ban)	LP
	Nam Tha (Van Ban)	NT
Yen Bai	Dao Thinh (Tran Yen)	ĐT
	An Luong (Van Tran)	AL
	Vien Son (Van Yen)	VS
	Xuan Ai (Tran Yen)	XA
Quang Ninh	Quang An (Dam Ha)	QA
Quang Nam	Phuoc Kim (Phuoc Loc)	PK
Thanh Hoa	Thuong Xuan town	TT
	Xuan Loc (Thuong Xuan)	XL

Đ1: the 1st soil layer

Đ2: the 2nd soil layer

Q: Cinnamon sample

Sample symbol – QC: control samples

ANNEX 3. OVERVIEW OF CINNAMON GROWING AND HARVESTING PRACTICES

a. Seedling production:

- Soil preparation for nursery: Tilling is done one month in advance to create loose, aerated and dried soil to kill weeds and pathogens. 4 to 5 kg of rotting manure or microbial organic fertilizer are added into the soil. Soil beds of 1-meter width and 12-15 cm height with trenches of 50-60 cm width among these beds are made.

- Pod and substrate preparation: plastic bags are cut at the two bottom corners or small holes are made at the bottom for adequate drainage. Soil is mixed with crushed and sieved sawdust, coconut husk, organic and inorganic fertilizers. Then this subtrate is put into the pods.

- Seeding: the holes of 0.5 - 1 cm depth are made by using a stick. Cracked seeds are sown into the pods and covered with a fine layer of soil.

-Seedling tending: a trellis of black nylon net is made with a minimum height of 1,8 m to ensure the minimum shade of 50%. The seedlings are watered 1-2 times per day (depending on weather conditions), and weeds should be removed manually. During the growing period, the seedlings are fertilized 3-4 times with organic fertilizer. Fertilization is stopped 3 months prior to plantation so that the trees can become stronger.

In Yen Bai province, 47% of the interviewed households reported that they often bought seeds for self-growing while the others bought seedlings from external sources.

In Lao Cai province, 100% of interviewed farmers said that they bought seedlings from local nurseries. Though Vietnam has regulations on the certification of cinnamon nurseries, the number of certified nurseries is still very limited. Most of them currently operate without registration. When buying seedlings, farmers often do not pay attention to the certification. They only care about it when participating in the programs and projects that request the compliance with seedling quality requirements.

b. Cinnamon tending process

For dense cinnamon forests, after 3 to 5 years of planting, cinnamon trees should be pruned and thinned to produce cinnamon crumbs. Furthermore, the leaves can be used for distillation of essential oils. If being well tended, the low-lying cinnamon forest can be harvested earlier and bring in high profit. In the first 2-3 years after planting, cassava are often intercropped in cinnamon forests, creating shade for cinnamon and increasing income for farmers. However, this intercropping model has not been popular yet.

+ Fertilizer application: Depending on the financial conditions of each household and the quality of soil, inorganic fertilizer might be used 1-2 times (according to 65% of the surveyed households), or 2 to 4 times (as per 34% of surveyed households) in the first year.

+ Pruning: While Yen Bai has the advantage of essential oil processing factories, majority of them apply manual processing. The planting density in Yen Bai is much higher than in Lao Cai, therefore, after the third year of planting, trees have been pruned in some locations to generate income for farmers and create space for tree growth.

+ Pest management: Common pests and diseases to cinnamon trees include root rot on cinnamon seedlings, leaf wilt disease, red hair scurry (Haematicus paseoe), cinnamon aphid, stink bugs, and stem borer. For cinnamon forests infected with pests and diseases, it is recommended to use drugs that have obtained market authorization. In the first 5 years, farmers often cut the grass, clear the fields periodically (as per 47% of the interviewed households) up to 4 times per year, and spray pesticides directly on the diseased plants (according to 28% of the interviewed households), prune and replant additional trees to replace dead ones (62%).

Some households have been participating in the organic farming program and complying with the requirements set forth by the companies. These requirements are typically organic agricultural standards. For these households, problems are reported to the plant technician for further instructions on how to prevent and control diseases. However, those do not participate in organic farming may choose to use chemicals and herbicides. Participating in the supply chain of factories helps farmers feel confident about how to deal with their production output, in addition to higher selling price and timely advice from the company's technical staff. This is a good approach but the level of sustainability depends significantly on the companies, in which the guarantee of stable purchase price plays a decisive role.

In-depth studies on the toxicity of heavy metals to the ecosystem show that agricultural inputs always contain a very small amount of heavy metal residues.

c. Harvesting and transportation processes

For cinnamon forests with density from 2,000 to 2,500 trees/ha, there are two methods of harvesting:

(i) Selective harvesting: trees are harvested with predetermined diameter in the harvesting season:

+ First-time harvesting is applied in the 10th to 12th year, leaving the remaining density of 1,500 to 1,800 trees/ha.

+ Second-time harvesting is applied in the 14th and 15th year, leaving the remaining density of 1,000 to 1,300 trees/ha.

+ From the 20th year onwards, the remaining density is 600 to 900 trees/ha.

+ Trees that can be harvested are those meeting business objectives and ensuring an even distribution of trees for further nurturing.

(ii) Primary harvesting is applied to all trees over 15 years old.

Due to the climate conditions and ecological characteristics of cinnamon, there are two main harvesting seasons in Vietnam, particularly the spring when the weather is less rainy, warm and sunny, which is suitable for cinnamon bark harvesting and processing. In the autumn, heavy rainfalls often happen and the weather is cloudy, making the bark moldy and rotten. However, findings from the surveyed localities show that the cinnamon bark harvested in autumn has higher essential oil content. In the spring, if being harvested in the right timing, cinnamon bark is easily peeled off the trunk, and not broken.

- Tree-cutting technique: trees cutting-down must ensure that the other remaining trees are not affected.

- Bark-peeling technique: the bark can be peelef off from the trunk with a knife, following the determined specifications of 40 - 60 cm. When doing so, it is necessary to be gentle so that the inner surface of the cinnamon stick is not scratched, the two ends are not cracked, and there are no holes left. After that, the cinnamon stick should be cleaned and kept dry.

- Finally, the barks are stacked tightly together and transported out of the forest.

Figure 9. Cinnamon harvesting in Yen Bai province

(Photo credit: Lê Mai Nhất - Team Pber)

Figure 10. Cinnamon harvesting in Quang Ninh province

(Source: Department of Agriculture & Rural Development of Quang Ninh province)

After being harvested, depending on the terrain, people can carry cinnamon bark on their shoulders or transport them on motorbike from the hill to the main road and load them on the truck to be transported to the collection point. Some of the interviewed households said that they dried cinnamon barks on the hill to reduce transportation cost (because the weight will be reduced) as the hills were far away from their houses. The wood and the trunk are also transported in the same way. Thus, the heavy metals can be absorbed into cinnamon product in this stage if the cinnamon clings to the soil. However, the level of impact is not significant as the product is washed or scrubbed prior to processing.

d. Pre-processing/processing

+ Cinnamon bark: Cinnamon bark is collected in different specifications, depending on customers’ requirements and processing andclassifying procedures. Subject to the thickness of the cinnamon bark, it can be processed into various products.

Figure 11. People are producing cinnamon at their households (Khoi Ngoa village, Liem Phu commune, Van Ban district, Lao Cai province)

(Photo credit: Tiến Dũng)

Some households use cinnamon from their farms or buy cinnamon from other people to make handmade products such as flute cinnamon, and cinnamon crumbs. The processing is as follows: a knife is used to scrape off the bark, and create the mold. Then the bark is dried to shape the finished product. The sun drying process depends significantly on the weather, leading to inconsistent shapes and bad color of the products. In many cases, due to lack of sunlight or improper preservation, cinnamon will get moldy. Some households said that they used sulfur to preserve products.

Through assessing the cinnamon production process of Vinasamex company, and SHS company, the consultant team found out that these factories DO NOT USE ADDITIVES in their processing. Specifically, raw materials are washed directly with water only or the outside layer of bark is scraped off to make it thinner. Then they are cut into appropriate shapes and put into steam-run drying machine to generate raw products. Raw products are packaged for storage. The storage area is also designed in a way to ensure proper humidiy. Therefore, sulfur and other chemicals are not used to prevent mold.