CHAPTER IV

VEGETABLE PRODUCTION SITUATION

This chapter describes the situation of vegetable production in the study area, which includes biophysical environment, the farmer's socio-economic characteristics, vegetable production situation and farmer's practices in vegetable farming. In addition, the chapter presents results of the accumulation of lead (Pb) and cadmium (Cd) in cultivated soil, irrigation water and vegetables in research area.

4.1 Biophysical environment

4.1.1 Location and area

Tuc Duyen is agricultural ward of Thai Nguyen city, with the total natural area of 290.28 hectares. It has 124.76 ha of agricultural land, 156.56 ha of non-agricultural land, and 8.96 ha of unused land. Land area for growing vegetables is 34.53 ha (SDTN, 2009).

Tuc Duyen ward has 23 ethenic groups mainly Kinh ethnic. It is composed of 2,229 households with the population of 7,892 people (SDTN, 2009).

4.1.2 Cultivated soil

Vegetables in Thai Nguyen city are cultivated on rich alluvial soil. The physical-chemical properties of soil are expressed as follows, pH from 4.8 to 5.6; acidic soil, humus content, N, P_2O_5, K_2O are low (Hang, 2007).

4.1.3 Climate

Tuc Duyen ward is located in the humid monsoon tropical climate in the northern of Vietnam. The climate is divided into two distinct seasons which are rainy season from May to October and dry season from November to April. Rainfall is relatively abundant, annual rainfall is averaged at 2,007 mm, with the highest rainfall recorded at 3,008 mm and the lowest rainfall of 997 mm. With an average of 198 rainy days /year, however, the distribution of rainfall is not uniform. Average annual temperature is 22^0C. The hottest month of the year is July to August, average temperature is 27.9^0C, the lowest is in December to January, average temperature is 16.4 ^{0}C (Hoa, 2008).

4.1.4 Water resources

Surface water on the ward is very diverse and has large reserves. The main water source is supplied from Cau river, canal systems and ponds in residential areas. Currently, due to rapid urbanization, the sewage system is not perfect so ponds in the ward had signs of pollutions (Hue, 2009). Through hydrogeological investigation, groundwater of the ward is very abundant with the reserves of grade (A + B), hole drilling capacity is 50,744 m^3 per day and it has an important role in providing water for Tuc Duyen precinct's needs as well as water supply for Thai Nguyen city. Through survey, there were some households using daily water from groundwater through wells where the untreated water has been contaminated with iron (Fe) (Hue, 2009).

4.2 Farmer's socio-economic characteristics

Table 4.1 shows the summarized socio-economic characteristics of the interviewed farmers.

Table 4.1 Descriptive socio-economic characteristics of the interviewed farmers

Variables	Minimum	Maximum	Mean (N=75)	Standard deviation
Age of household head (Years)	28	65	45.69	8.05
Education of HH head (Years)	3	12	7.91	1.83
Number of members in family (Number)	2	8	4.33	1.27
Total vegetable land (m^2)	100	3,500	934.81	668.71
Vegetable growing experience (Years)	9	39	21.47	8.06
Total income (Million VND/ month)	0.4	15.00	3.14	2.50
Number of times for training vegetable (times/ year)	0	5	1.28	1.10
Number of days trained for vegetable (days/ year)	0	90	13.11	27.25

Source: Survey data, 2010.

Table 4.2 showed the percentage of socio-economic characteristics of the interviewed farmers.

Table 4.2 Percentage of socio-economic characteristics of the interviewed farmers

Variables	% of respondents
Extension visit (%)	29.33
Semi-commercial production (%)	92.00
Commercial production (%)	8.00
Access information sources about clean vegetables (%)	81.00
Discussion about clean vegetables (%)	67.00
Heard about the problem of heavy metal pollution and heavy metal accumulation in vegetables	62.00

Source: Survey data, 2010.

This study investigates the socio-economic characteristics of the interviewed farmers and the target respondents were the head of the households who made decision for the vegetable farming activities.

The average age of the household head was 45.69 years old, the youngest one was 28 years while the oldest one was 65 years with a standard deviation of 8.05 (Table 4.1). Specifically, there was 4 per cent of the respondents were the age of between 20-30 years, 22.67 per cent were 31-40 years, 46.67 per cent were 41-50, 24 per cent were 51-60 years and 2.66 per cent were older than 61 years shown in Figure 4.1.

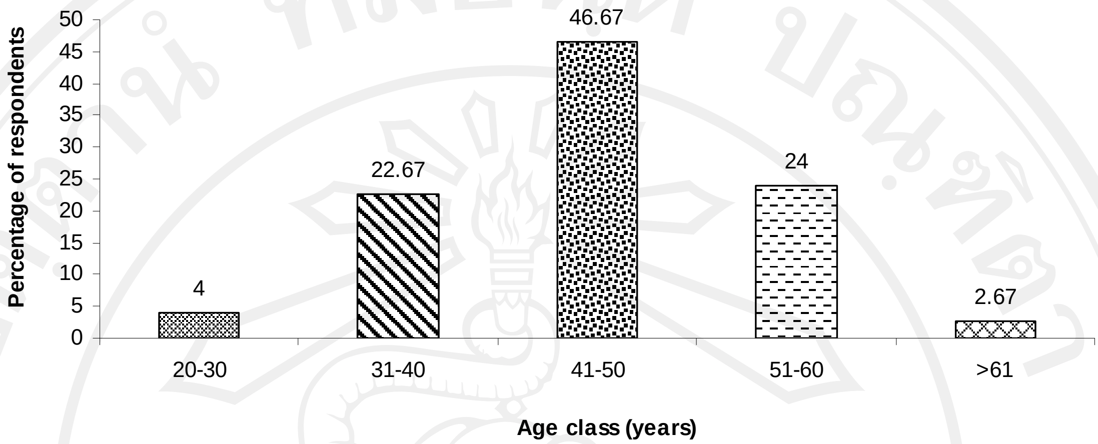

Figure 4.1 The percentage of age of the respondents in study area (n =75).

Sixty five percent head of households were female, and thirty five percent head of households were male (Figure 4.2). It was found that the head of household who made decisions and farmed was mainly women.

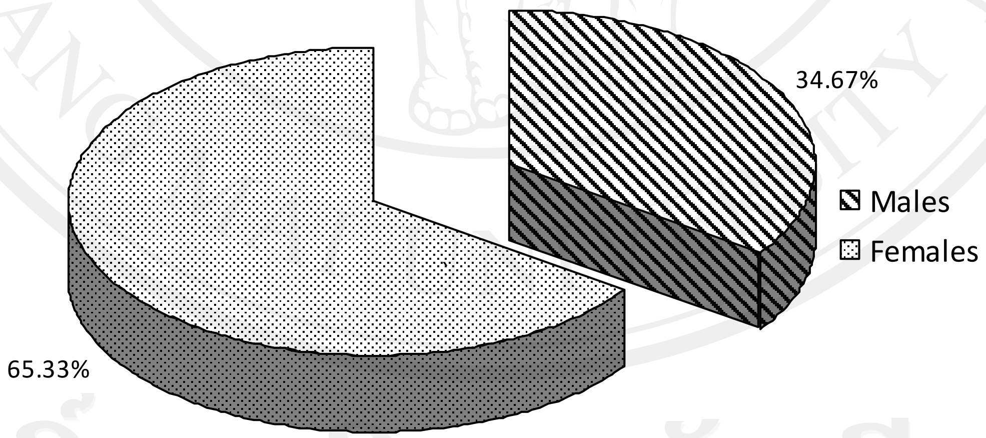

Figure 4.2 Genders of head of households.

The average numbers of years of education of the farmers was 7.91 years with a standard deviation of 1.82 (Table 4.1). Generally the education level of the farmers were medium. Seventy-five percent of the respondents have senior high school degree and 22.66 percent of the respondents had secondary education degree (Figure 4.3). Only 2.67 percent of the respondents were primary education holder. The highest educated respondents were a collage graduate with 12 years of education, which account for 9.33 percent of the total respondents. Although some respondents did not have high education but they had many skills and experience in vegetable cultivation.

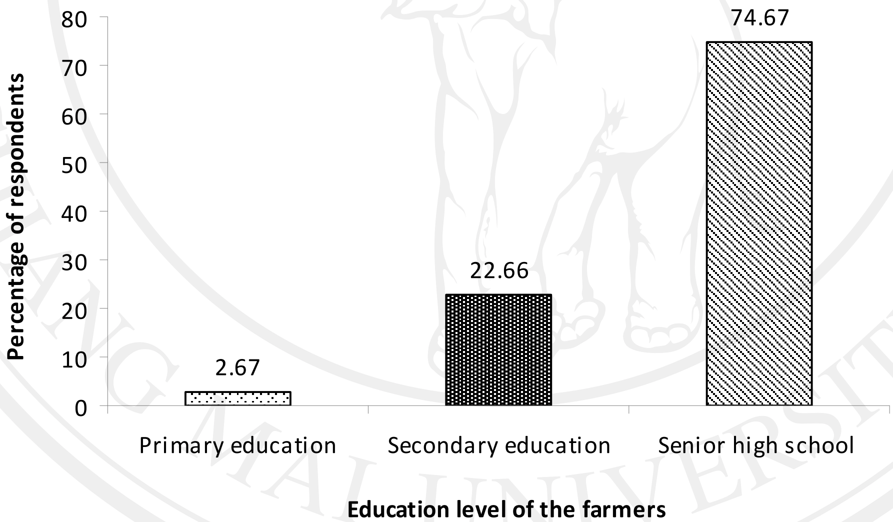

Figure 4.3 Education levels of the farmers.

The total vegetable land owned by farmers ranged from 100 meter square to 3,500 square meter, with an average of 934.81 and a standard deviation of 668.71 (Table 4.1). Fifteen percent of the total respondents owned land less than 360 square meter (360 square meter = 1 sao) and 52 percent of the farmers owned field area from 360 to 1,080 square meter (equivalent 3 sao). Most of the farmers owned medium scale fields in the study area. About 28 percent of the total respondents owned from over 1,080 to 1,800 meter square (equivalent from 3 - 5 sao) and only 5.33 percent farmers owned more than 1,800 meter square (Figure 4.4).

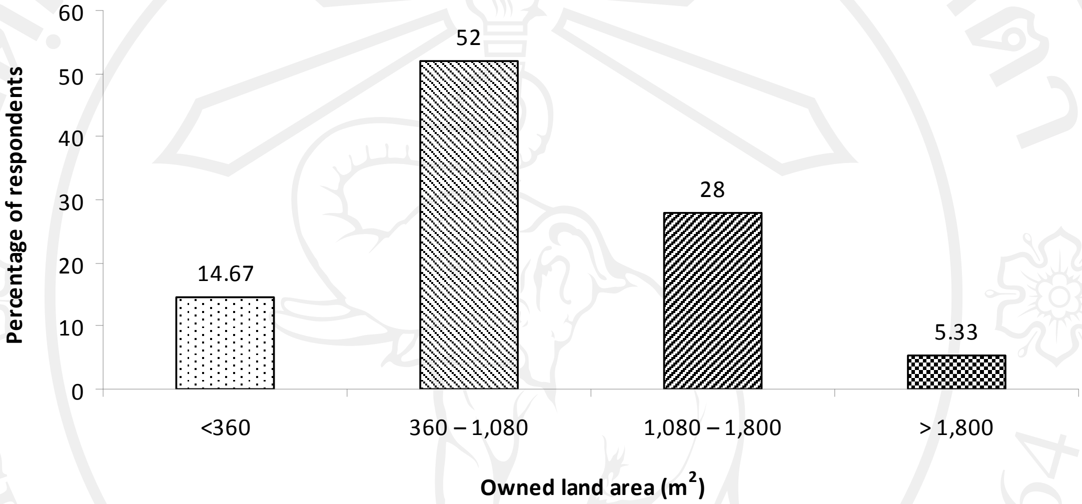

Figure 4.4 Extent of land ownership of vegatable farmers in the study area.

The average household size was 4.33 members ranged from 2 to 8 members, standard deviation 1.27 (Table 4.1). The most common household size was from 3 to 5 members, which was 78.67 percent of the total sampled households.

On the average, the respondents had been engaged in vegetables production for 21.47 years (standard deviation 8.06) with a minimum 9 years and maximum 39 years (Table 4.1). Most farmers had been farming for many years and had accumulated experiences in vegetable production.

The average family income (combination of farm income and off-farm income) was 3.14 million VND[1] per month, with a standard deviation of 2.50 (Table 4.1). In which, the minimum income was 0.4 million VND and the maximum was 15 million VND per month.

Income level was assumed to have indirect influence on the awareness of the farmers about clean and safe vegetables, including heavy metal accumulation problem in vegetables, for instance the individuals with high income can buy some facilities such as newspapers, TV, radio or telephone, etc, meaning that he/she might have more opportunities of being exposed to different media of information sources.

Number of times for training of farmer's average was 1.28 ranging from 0 to 5 times with a standard deviation of 1.10 (Table 4.1). Extension visit of extension officers were 29.33 percent. Farmers in the region have many opportunitie to regularly meet with extension workers.

Number of days trained for vegetable production was averaged at 13.11 day/year, ranged from 0 to 90 days, with a standard deviation of 27.25 (Table 4.1). So farmers in this study area received good training.

Besides, 92 perecent of farmers growing vegetables for semi-commercial production and only 8.00 percent for commercial production (Table 4.2)

In addition, there were 81 percent of the respondents had access and knew the source of information about clean vegetables/ safe vegetables including issues on heavy metal accumulation in vegetables (Table 4.2). About 78 percent of respondents had access other sources of information about clean and safe vegetables newspaper, radio, television;

[1] 1US$ = 20,000 VND in May 2011

25 percent of respondents got information from the seminar, training; 14 percent of respondents known from exhibit, display, poster, and 22 percent of respondents said that they got information through conversation with their neighbors (Figure 4.5). The farmers in the study area had a high rate of obtain information about clean and safe vegetables. People in the study area also access to many sources of information.

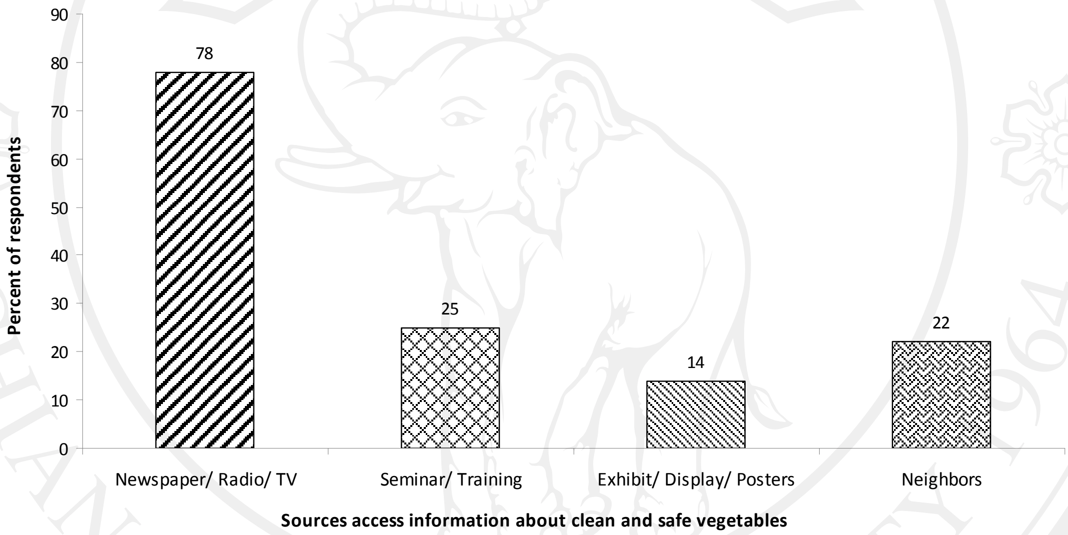

Figure 4.5 Access information sources about clean and safe vegetables.

Additionally, 67 percent of the respondents had opportunity to participate in group discussion about clean and safe vegetables, including heavy metal accumulation in vegetables (Table 4.2). About, 21 percent of the respondents talked and discussed with family members about the clean and safe vegetables, 37 percent with government officials, 24 percent with sellers of agrochemicals, 12 percent with neighbors and 29 percent with consumers (Figure 4.6). The farmers in the study area, through mass medias had awareness, vision with the problem about pollution in vegetables, particularly the effort to ensuring clean and safe vegetables.

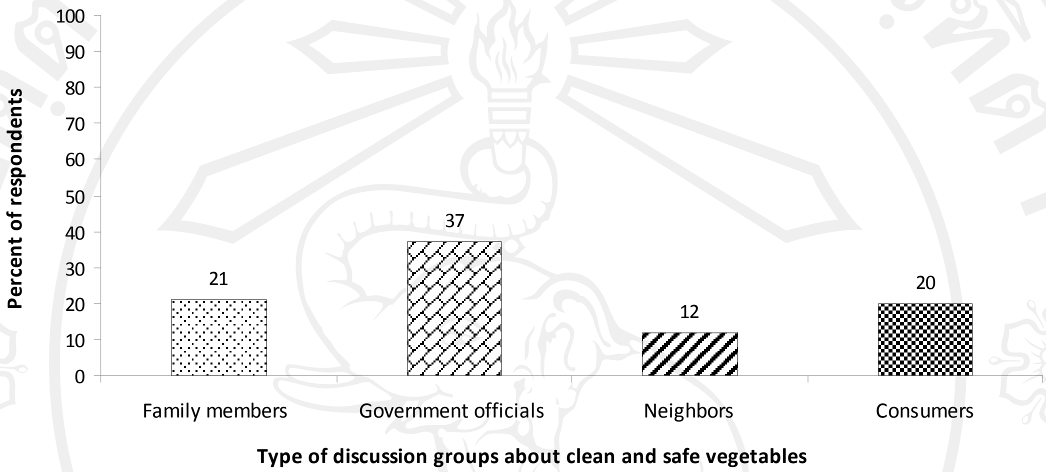

Figure 4.6 Type of discussion groups about clean and safe vegetables.

About 62 percent of the respondents had heard about the problem of heavy metal pollution and heavy metal accumulation in vegetables (Table 4.2). About, 27 percent of them learnt from newspapers, radio, television; 44 percent from the workshops, training courses and from extension staff; 12 percent from the neighbors and only 4 percent from activities of exhibitions, displays, posters and advertisements (Figure 4.7). Therefore, farmers in the study area had good understandings about the problem of heavy metal pollution, sources of heavy metals and heavy metal accumulation in cultivated soil, irrigation water and vegetables.

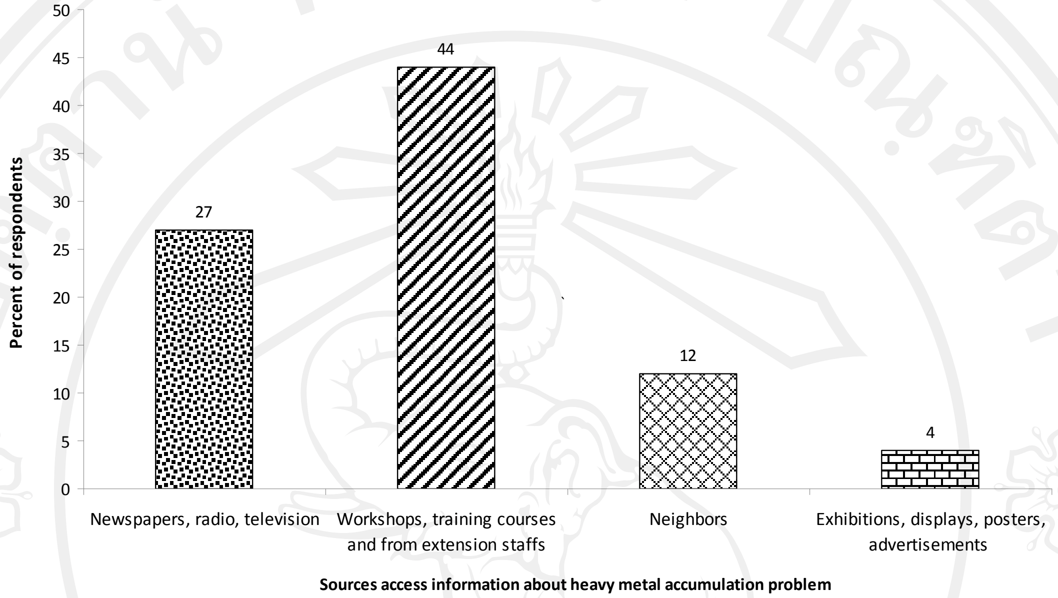

Figure 4.7 Sources understanding of farmers about the accumulation of heavy metals in vegetables.

4.3 Vegetable production status

4.3.1 Situation of using irrigation water

Surface water in the area of Tuc Duyen ward is very diverse and has large reserves. Water resource is mainly provided by Cau river through the system of ponds and canals in residential areas. Currently, due to urbanization, water source from Cau river has signs of pollution, besides sewage system has not been perfect so the ponds in the ward also has signs of pollution. Especially in the southern region of Tuc Duyen ward (Chua hamlet), water source for irrigation has been affected by waste water sources from commercial activities and residential areas around the market area of Thai Nguyen city.

Results of field survey and farmer's interviewing by using formal questionnaire showed that there were three water sources for irrigating vegetables. These included water from ponds (taken water from canal, ditch source from Cau river), well water (groundwater) and tap-water. In which, 100 percent of the respondents had used irrigation water from Cau river. Some households used other sources of water to irrigate vegetables. Specifically, 9.33 percent of respondents used well water and 10.67 percent used tap-water for vegetable irrigation.

Most households used water from public ponds to irrigate vegetables. Specifically, 77.33 percent of households used water for irrigation from public ponds and only 22.67 percent of households had own pond for their family (Figure 4.8).

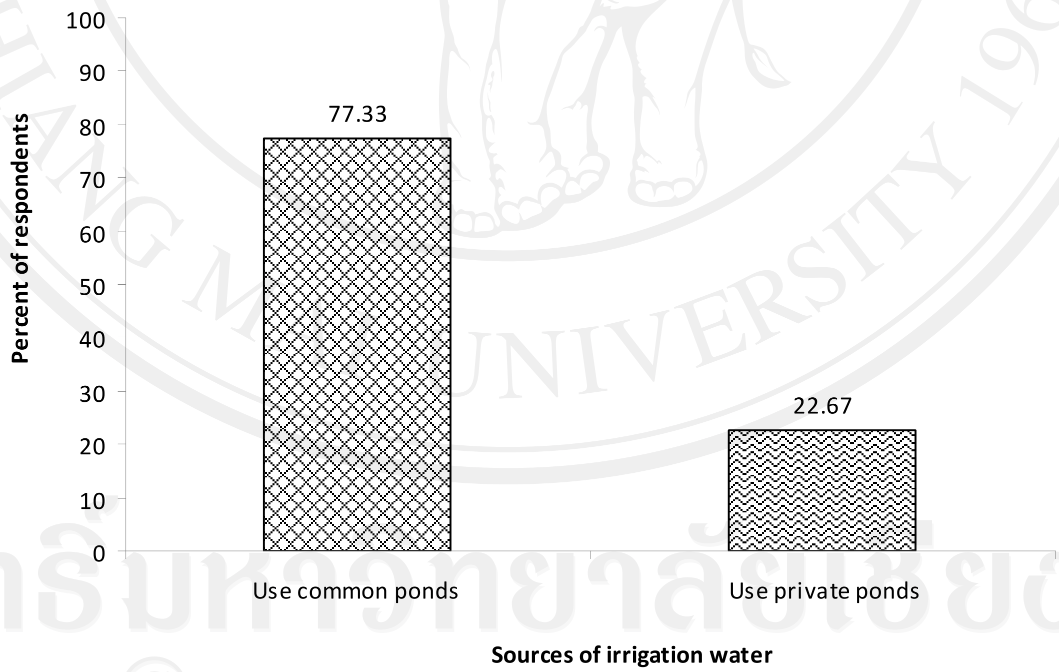

Figure 4.8 Sources of irrigation water for vegetable production in Tuc Duyen ward.

Through the questionnaire on the frequency of watering vegetables, on the average farmers irrigate their vegetable 1.2 times per day, with a standard deviation of 0.54. Specifically, 17.33 percent of the respondents waterred 2 times per day, 54.67 percent said that they waterred once per day, 28 percent of those watered every two days (Figure 4.9). In addition, farmers used irrigation water tanks (Vietnamese name called as "O doa" barrel) with a capacity of 15-20 liters to water their vegetables. Through the survey, the average amount of irrigation water was 1.91 liters per square meter per day with a ranged from 1.05 to 3.00 liters/meter, with a standard deviation of 0.43. Farmers in the study area have used a large amount of water to irrigate vegetables during cultivation process. This farming operation is related to the addition of substances into the environment of cultivated soil.

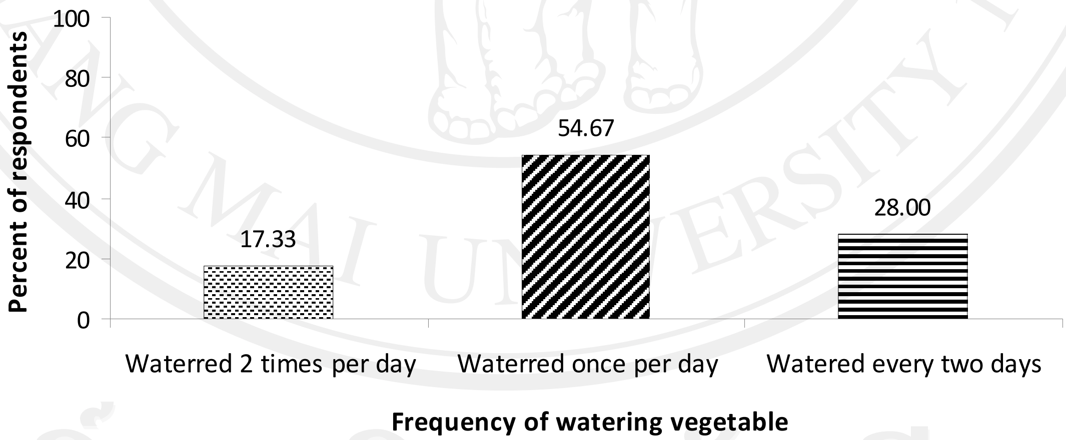

Figure 4.9 Frequency of watering vegetables per day in Tuc Duyen ward.

4.3.2 Situation of using pesticides and fertilizer

Tuc Duyen ward is a long-standing area of planting vegetables in Thai Nguyen city. Farmers have tradition and experiences of vegetable production. They have been participated in many training courses about vegetable cultivation, methods of using pesticides and fertilizers, and participated in training classes about IPM (Integrated Pest Management) and GAP (Good Agriculture Practices). About 77 percent of farmers participated in training courses while the remaining 23 percent did not participate. Farmers used only pesticides and fertilizers that were allowed by the government or ones which government officials recommended to use.

Through observation and interviewing farmers by using a formal questionnaire, the farmers did not use “external” fertilizers such as prohibited fertilizers, fertilizers with unknown label etc. Cover of pesticides' packaging was specified with labeling and components of chemical substances. Households growing selected vegetables did not use inorganic fertilizers, pesticides containing Pb and Cd. Pb and Cd. Inorganic fertilizers, pesticides containing Pb, Cd and its compounds have been banned since 2002 under the decision of the Ministry of Agriculture and Rural Development.

Generally, the amount of fertilizers which applied low rate of fertilizer for vegetables in Tuc Duyen ward, depending on production condition and economic condition of each household. Most farmers fertilized based on their experiences even though many farmers have been through training. Inorganic fertilizers were mainly synthetic fertilizers such as "Buffalo" manure, “Ranh river" manure, etc. Percentage of respondent using liming was 30.67 percent. In three important types of chemical fertilizers (nitrogen, phosphorus, potassium), growers only noticed nitrogen fertilizer, followed by phosphorus fertilizer, majority households did not use potassium. Specifically, percentages of respondents using nitrogen, phosphorus, potassium fertilizer are 87 percent, 60 percent and 8 percent respectively. This was also warned by Hang (2007), when the author carried out an investigation in the area in 2004. In addition, the application of substances containing heavy metals into soil in recent years, including the use of phosphate and fertilizers which containing phosphorus, with the risk of containing high Cd level, had been warned (HMMVA, 2010).

Animal manure was used very little in vegetable production in the study area. Some households used fresh animal manure water or compost to fertilize their vegetables. The animal manures are mainly chicken and pig manures (Survey, 2010). This is the risk of affecting the quality of vegetables and infecting humans through food chain. In addition, the application of substances containing heavy metals into soil in recent years, including the using fresh animal manure (chicken manure and pig manure) with the risk of containing high Pb, Cd level have been warned (HMMVA, 2010). In addition, a study of Hong (2003) concluded that using heavy metals contaminated water and fertilizers to irrigate vegetables, heavy metals will be accumulated in crops. Cd concentration in soil is directly proportional with the concentration of Cd in irrigation water.

In addition, to prevent pest damage on the vegetables, the vegetable growers applied plant protection chemical especially for bitter melon. The vegetable growers used various types of pesticides at a high rate. The average times of spraying pesticides for jute was 2.6 times per crop, basella alba was 2.4 times per crop, with bitter melon, farmers sprayed every 5-10 days. On the average, in one crop of bitter melon, farmers sprayed 18.76 times (Figure 4.10). The main reason is that farmers believe in the prevention of the pests and better price for bitter melon.

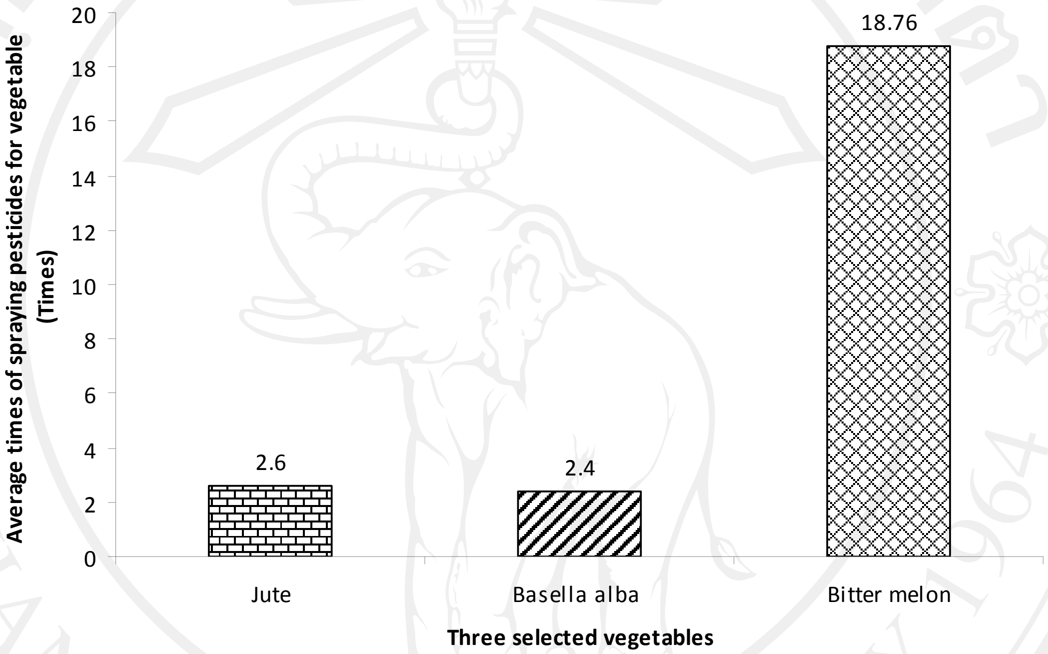

Figure 4.10 Average number of spraying pesticides for vegetables.

4.4 The accumulation of lead (Pb) and cadmium (Cd) in cultivated soil, irrigation water and three selected vegetables

Location of 75 selected vegetable growing fields separated by three types of vegetables namely jute, basella alba and bitter melon was showed in Figure 4.11.

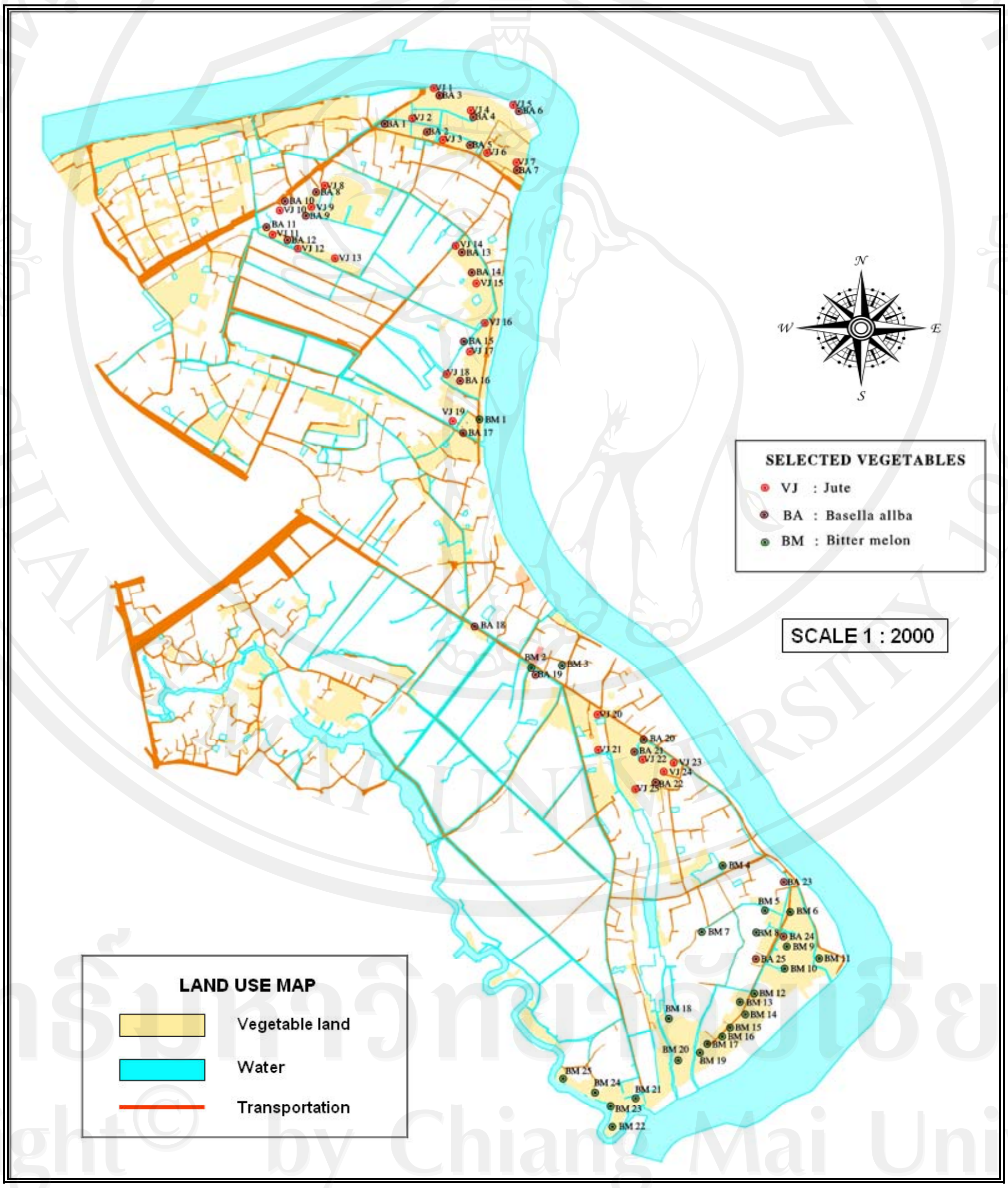

Figure 4.11 Locations of research vegetables growing fields.

4.4.1 Lead (Pb) content

4.4.1.1 In irrigation water

Results from the laboratory analysis of Pb content showed that average content of Pb in irrigation water samples was 0.031 mg/liter which ranged from 0.013 to 0.124 mg/liter. The standard deviation was about 0.021 mg/liter (Table 4.3). Three out of the total 75 water samples had Pb concentration greater than the permitted standard of Vietnam and the World FAO/WHO (0.1 mg/liter) accounting for 4 percent (Figure 4.12). About 72 samples of the total 75 irrigation water samples had Pb concentration less than the permitted standard, accounting for 96 percent of total samples. Compared with permissible standard which is 0.01 mg/liter, we can conclude that Pb content in irrigation water samples for selected vegetables in the research area is still in the permissible limit.

Table 4.3 Accumulation of Pb in irrigation water, cultivated soil and three selected vegetables Tuc Duyen ward

Sources	Pb content in samples (n=75)			
	Minimum	Mean	Maximum	Standard deviation
Irrigation water (mg/litre)	0.013	0.031	0.124	0.021
Cultivated soil (mg/kg)	21.20	65.50	142.37	21.41
Vegetables (mg/kg)	0.23	1.56	4.06	0.81

However, there were 5 irrigation water samples of 5 bitter melon fields in the southern region of Tuc Duyen ward (Chua hamnet) have Pb content increased suddenly and exceeded the permitted standard (average of 0.105 mg/liter). As results of the irrigation water source there was polluted by waste water source discharged from commercial and residential area in Thai Nguyen city's market area.

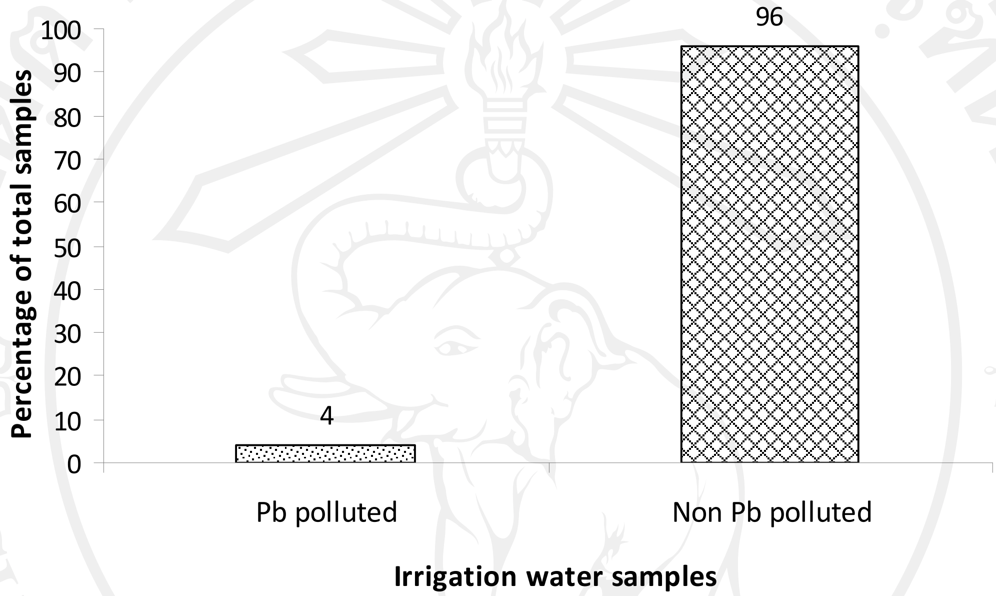

Figure 4.12 Lead (Pb) content in irrigation water samples.

Comparing the content of Pb in irrigation water with different type of vegetables showed that Pb content in irrigation water for the three research vegetables were similar and still within Pb permitted standard of FAO/WHO (0.1 mg/liter) (Figure 4.13). There were no major variations among Pb content in irrigation water for vegetables in the study area.

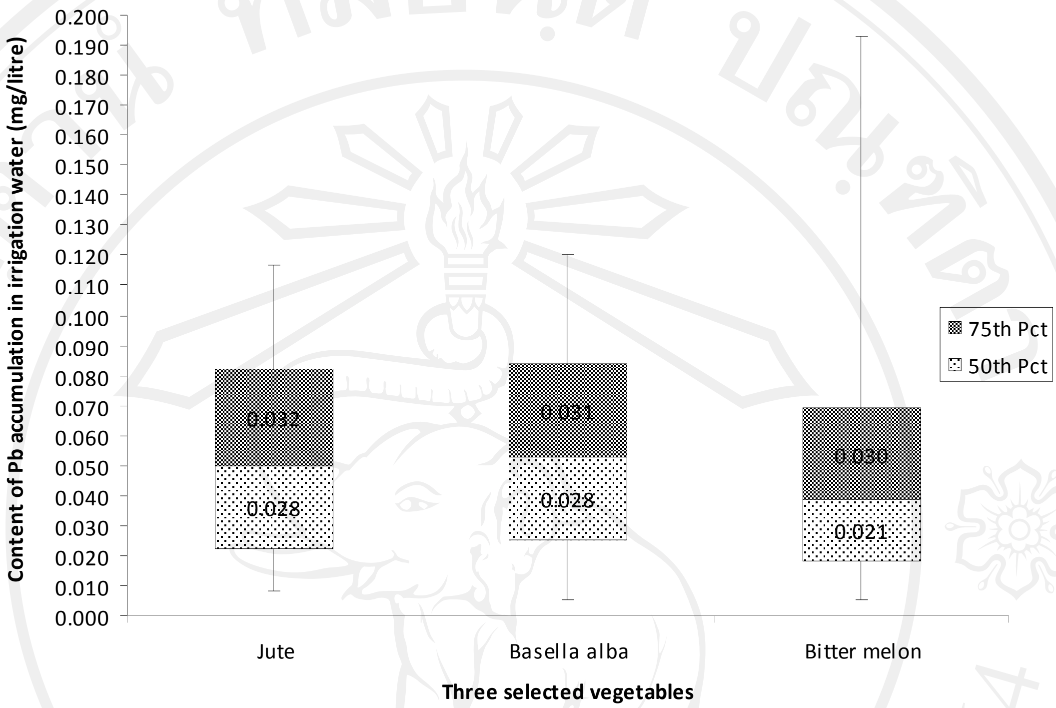

Figure 4.13 Accumulation lead (Pb) in irrigation water of three selected vegetables.

Due to the time collecting data was observed in rainy season, therefore results of Pb content in water is low. In fact, Pb content in irrigation water in Tuc Duyen ward which mainly from Cau river is very variable depending on each time of the year, rainfall amount and waste sources discharge at the upstream (Hang, 2007;EMCTP, 2009).

Many researches have shown that wastewater from commercial activities and residential areas often contain many toxic substances including heavy metals (Wang *et al.*, 2011). Besides, one of cause of heavy metal pollution in water in the area is the process of discharging industrial wastewater and hazardous wastewater which were not treated or not treated as required into water environment (Hang, 2007). In addition, many results of researches have shown that wastewater from commercial activities and residential areas often contain many toxic substances including heavy metals (Wang *et al*., 2011).

4.4.1.2 In cultivated soil

Results from the laboratory analysis of Pb in cultivated soil showed that average level of Pb in soil samples was 65.50 mg/kg which ranges from 21.20 mg/kg to 142.37 mg/kg. The standard deviation was about 21.41 mg/kg (Table 4.3). In particular, 29 out of the total 75 soil samples (about 38.67 percent of total samples) exceeded the permitted standard of Vietnam (70 mg/kg). Remaining 46 out of the total 75 (about 61.33 percent of total samples) was under permissible standard (Pb content less than 70 mg/kg) (Figure 4.14).

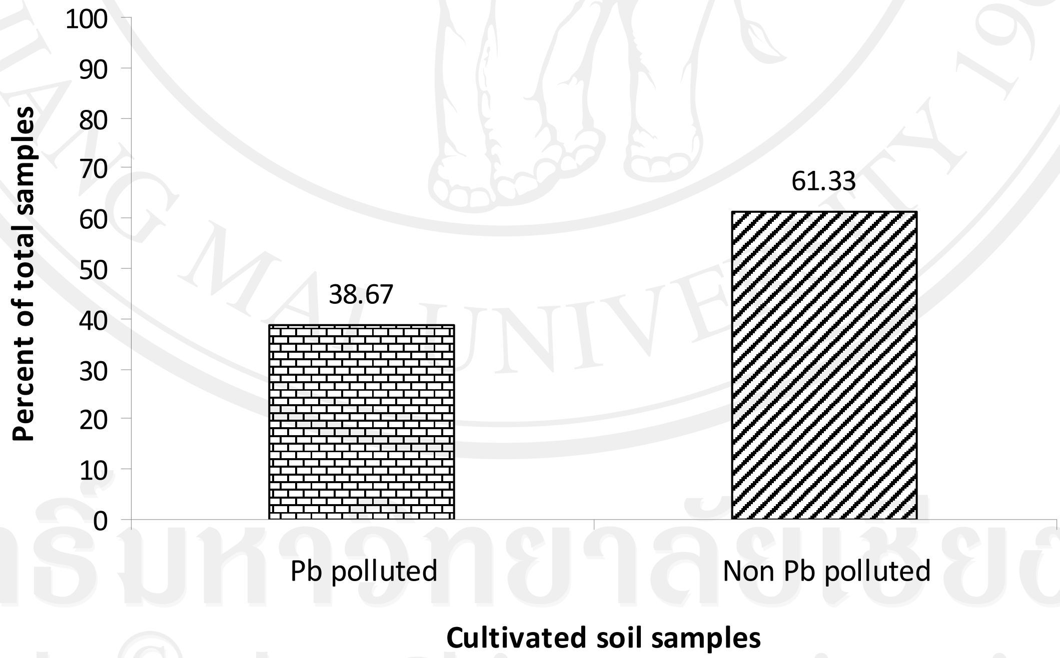

Figure 4.14 Lead (Pb) content in cultivated soil.

Spatial distribution of Pb accumulation in cultivated soil in Tuc Duyen ward was showed on Figure 4.15.

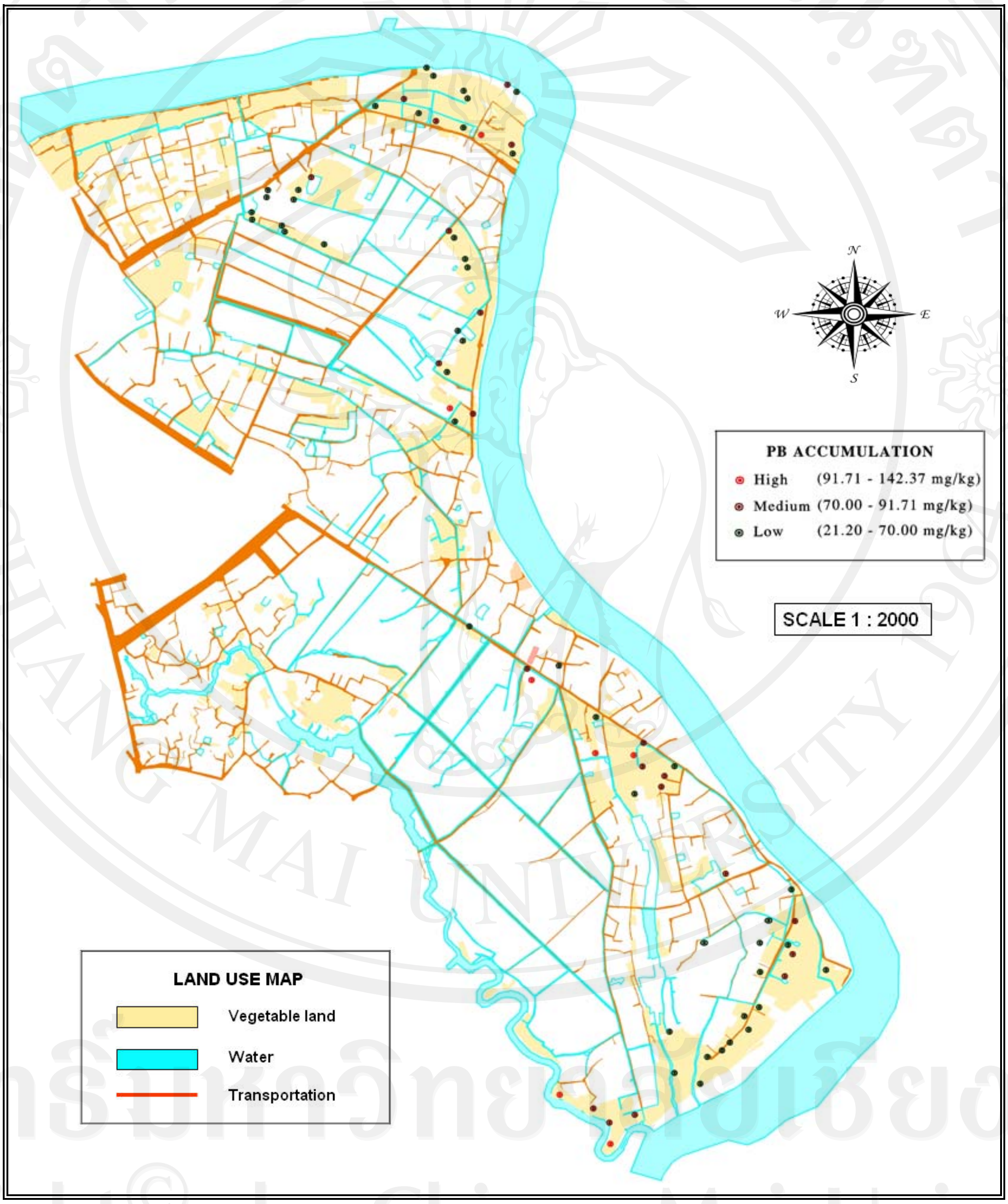

Figure 4.15 Spatial distribution of Pb accumulation in cultivated soil in Tuc Duyen ward.

Figure 4.15 showed the southern half region of Tuc Duyen ward had 17 out of the total 29 polluted soil samples (about 58.62 percent of total samples) and the higher half region of Tuc Duyen ward had 12 out of the total 29 polluted soil samples (about 41.38 percent of total samples). Therefore, the southern half region of Tuc Duyen ward has a higher Pb accumulation than the northern half region. In addition, there were 5 soil samples of 5 bitter melon fields in southern region of Tuc Duyen ward (chua Hamlet) (average 91.90 mg/kg) tended to be higher than Pb content in soil for planting for three selected vegetables in other remain areas (average 63.67 mg/kg) due to irrigation water source in southern region of Tuc Duyen ward (Chua hamlet) planting bitter melon had been contaminated by waste water discharged from commercial and residential area in Thai Nguyen city's market area (Survey, 2010).

Compared with permitted standard which is 70 mg/kg (according to standard of Vietnam and the FAO/WHO), we can conclude that the Pb content in soil samples were still in the permitted standard. However, Pb content in cultivated soil was close to the threshold content (average content of Pb is 65.49 mg/kg) so the problem of Lead (Pb) pollution in cultivated soils in the study area needs to be studied.

Comparing the content of Pb in soil with different type of vegetables showed that Pb content in soil for planting jute (75 percentile is 86.60 mg/kg) is the highest, followed by Pb bitter melon (75 percentile is 72.21 mg/kg) and lastly basella alba (75 percentile is 63.28 mg/kg) (Figure 4.16). This showed that jute and bitter melon had high Pb contaminated sign and Pb contaminated in basella alba was still lower than threshold content of permissible standard.

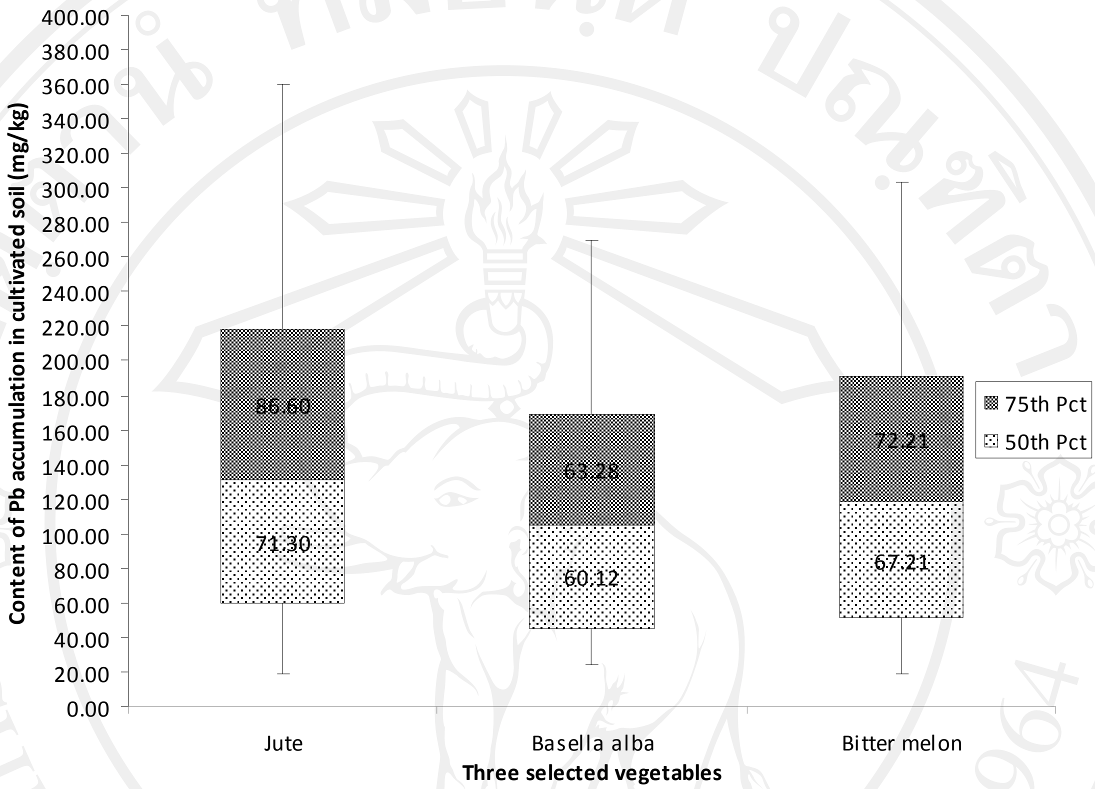

Figure 4.16 Accumulation of lead (Pb) in cultivated soil of three selected vegetables.

Aside source metal from rock weathering process, Pb was absorbed into soil through human activities such as irrigation water source effected by industrial wastewater, commercial and residential wastewater (Ubavie *et al*., 1994; Balba *et al*., 1991; Manh, 2000; Hang, 2007).

4.4.1.3 In vegetables

Results from the laboratory analysis of Pb in vegetables showed that average Pb content in three kinds of selected vegetables is 1.56 mg/kg which ranges from 0.23 mg/kg to 4.06 mg/kg and a standard deviation of 0.81 mg/kg (Table 4.3). Compared with allowed standard of the world FAO (0.5 mg/kg dry), it can concluded that Pb content in vegetables samples of three selected vegetables in Tuc Duyen ward was crossed the permissible limits. Particularly, Pb content in vegetables samples is about 3.1 times compared to allowed standard. Therefore, Pb content in vegetable samples of three research vegetables was polluted at a high level.

Specifically, 65 out of the total 75 vegetable samples, about 89.33 percent of total samples, exceeded the permitted standard FAO (Pb content allow in vegetables is 0.5 mg/kg). The remaining 8 samples out of the total 75 of vegetable samples, about 10.67 percent of total samples, is below permitted standards (0.5 mg/kg) (Figure 4.17).

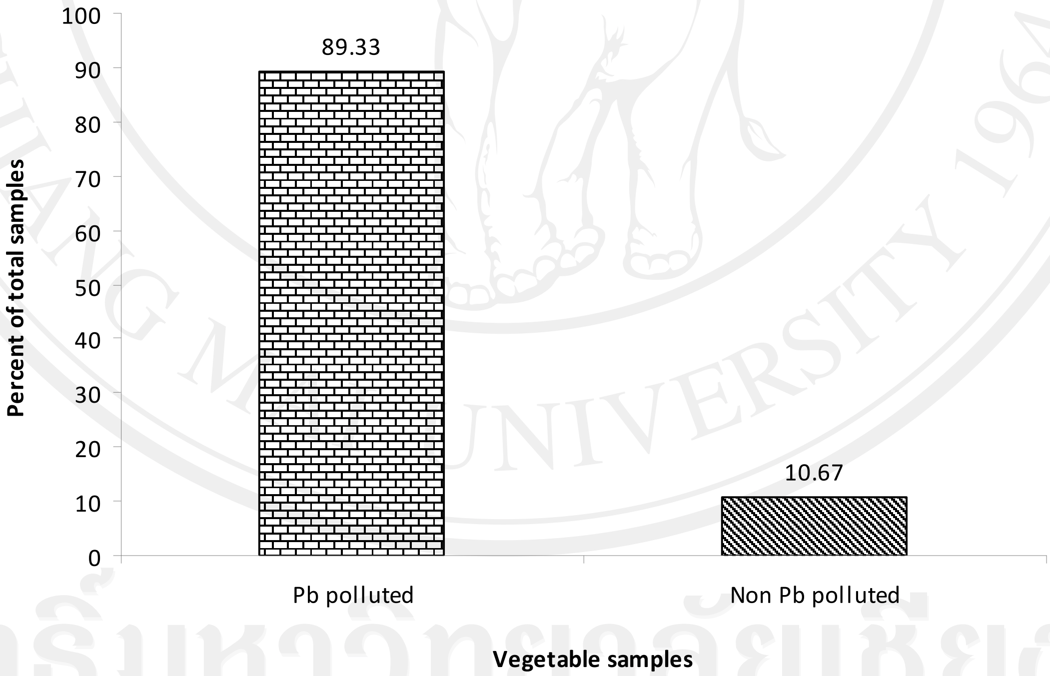

Figure 4.17 Lead (Pb) content in three selected vegetables.

From there, we found that the rate of vegetable samples was contaminated with Pb with high rates. In fact, the issue of Pb metal pollution in vegetables in the city of Thai Nguyen province in general and in particular Tuc Duyen ward had been warned in research Hang (2007), Hoa (2008) when they conducted survey research and analysis of vegetable samples in the area. This is a problem often occurred in vegetable growing areas near industrial zones, mining and mineral exploitation, and residential areas (Maqsud, 1998; Dao, 1999).

Spatial distribution of Pb accumulation in three selected vegetables in Tuc Duyen ward was showed in Figure 4.18.

Figure 4.18 showed that Pb content in selected vegetables samples of vegetable growing fields near Cau river higher than other area which far the Cau river. However, there were 5 bitter melon samples in southern region of Tuc Duyen ward (chua Hamlet) (average 2.80 mg/kg) tended to be higher than Pb content in three selected vegetables in other remain areas (average 1.47 mg/kg) due to irrigation water source in southern region of Tuc Duyen ward (Chua hamlet) planting bitter melon had been contaminated by waste water discharged from commercial and residential area in Thai Nguyen city's market area (Survey, 2010).

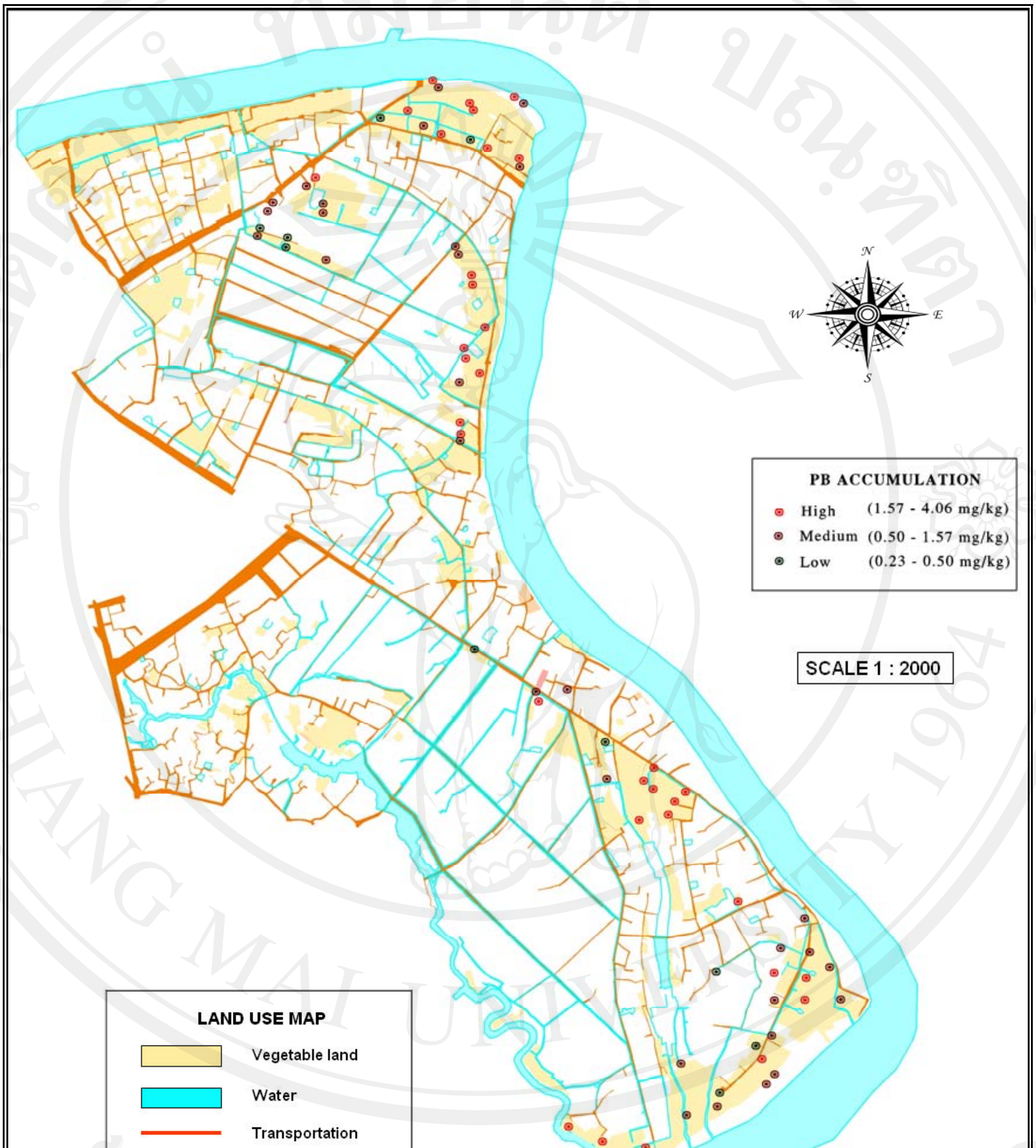

Figure 4.18 Spatial distribution of Pb accumulation in vegetables in Tuc Duyen ward.

Comparing the content of Pb in vegetables found that jute had the highest Pb content (75 percentile is 2.27 mg/kg), followed by in bitter melon (75 percentile is 1.92 mg/kg) and the lastly in basella alba (75 percentile is 1.61 mg/kg) (Figure 4.19).

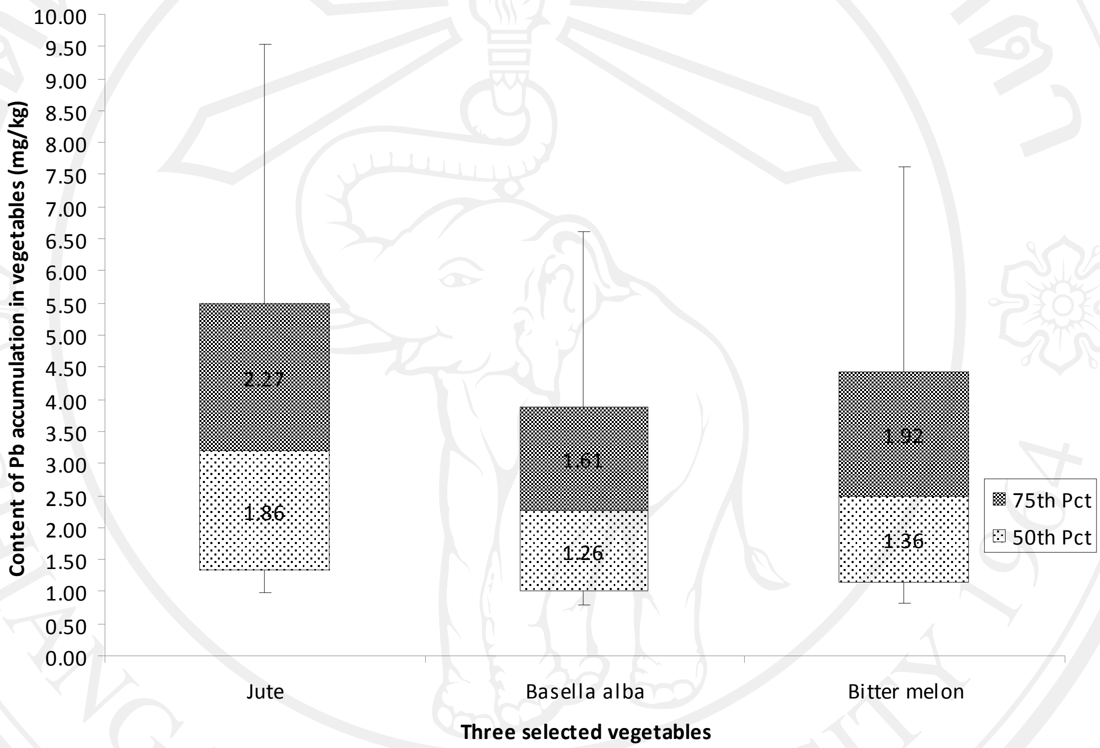

Figure 4.19 Accumulation of lead (Pb) in three selected vegetables.

Through the Figure 4.16 and Figure 4.19, correlated with the accumulation of Pb in three selected vegetables, we found a favorable/corresponding correlation between Pb accumulation in cultivated soils for plating three selected vegetables and Pb accumulation in selected vegetables. This means that if Pb content in cultivated soil for planting jute is the highest so Pb content in jute is also the highest and vice versa. This result corresponding with research results of Bride *et al*. (2002), the presence of metals in soil is strongly correlated with their absorption into the plants, particularly absorption of the plants also has a linear relationship with the addition of Pb in soil (Bride *et al*., 2002). Besides, according to research results of Kachenko *et al*. (2004), the soil metal concentrations appear to influence the uptake of Pb, Cd in vegetables. Specifically, there is a significant correlation which was observed between soluble lead (Pb) from soil and lead (Pb) in some kinds of vegetables such as tomatoes, carrots. Otherwise, the significant correlation is the same for Cd concentrations.

According to research results, plants uptake metals at different level depending on the species and varieties (HMMVA, 2010). Each plant is capable absorbing of heavy metal differently, and portions of vegetables were also accumulated an amount of heavy metals differently (Phuong, 2005). In addition, many researchers had shown that some vegetables are capable of accumulating high levels of metals from the soil (Garcia *et al*. 1981; Khan and Frankland 1983).

4.4.2 Cadmium (Cd) content

4.4.2.1 In irrigation water

Results from the laboratory analysis of Cd content showed that average content of Cd in irrigation water samples is 0.005 mg/liter which ranges from 0.003 to 0.009 mg/liter. The standard deviation is about 0.001 mg/liter (Table 4.4). About 100 percent of total samples had Cd concentration in water is less than the permitted standard of Vietnam and the World FAO/WHO (0.01 mg/liter). Compared with permissible standard FAO, we can conclude that Cd content in irrigation water samples for selected vegetables in the study area is still in the permissible limit.

Table 4.4 Accumulation of Cd in irrigation water, cultivated soil and three selected vegetables in Tuc Duyen ward

Sources	Cd content in samples (n=75)			
	Minimum	Mean	Maximum	Standard deviation
Irrigation water (mg/litre)	0.003	0.005	0.009	0.001
Cultivated soil (mg/kg)	0.32	1.07	2.54	0.58
Vegetables (mg/kg)	0.02	0.13	0.28	0.06

However, although irrigation water source for bitter melon fields in southern region of Tuc Duyen ward (Chua hamlet) was polluted by waste water discharged from commercial and residential area in Thai Nguyen city's market area but Cd content in irrigation water samples were still within the permitted standard (average of 0.005 mg/litre) and tended to be similar as Cd content in irrigation water samples of other remain area. Therefore, waste water from the Thai Nguyen market area at the time of analysis is not infected with Cd accumulation.

Comparing the content of Pb in irrigation water with different type of vegetables showed that Pb content in irrigation water for three vegetables was tended to be little variable. In which the concentration of Cd in irrigation water for basella alba and bitter melon did not have major variations (75 percentile is 0.005 mg/litre) (Figure 4.20). Cd content in irrigation water for jute was higher than that in other two vegetables a bit (75 percentile is 0.006 mg/litre). However, the average concentration of Cd in irrigation water for all three types of vegetables is relatively similar.

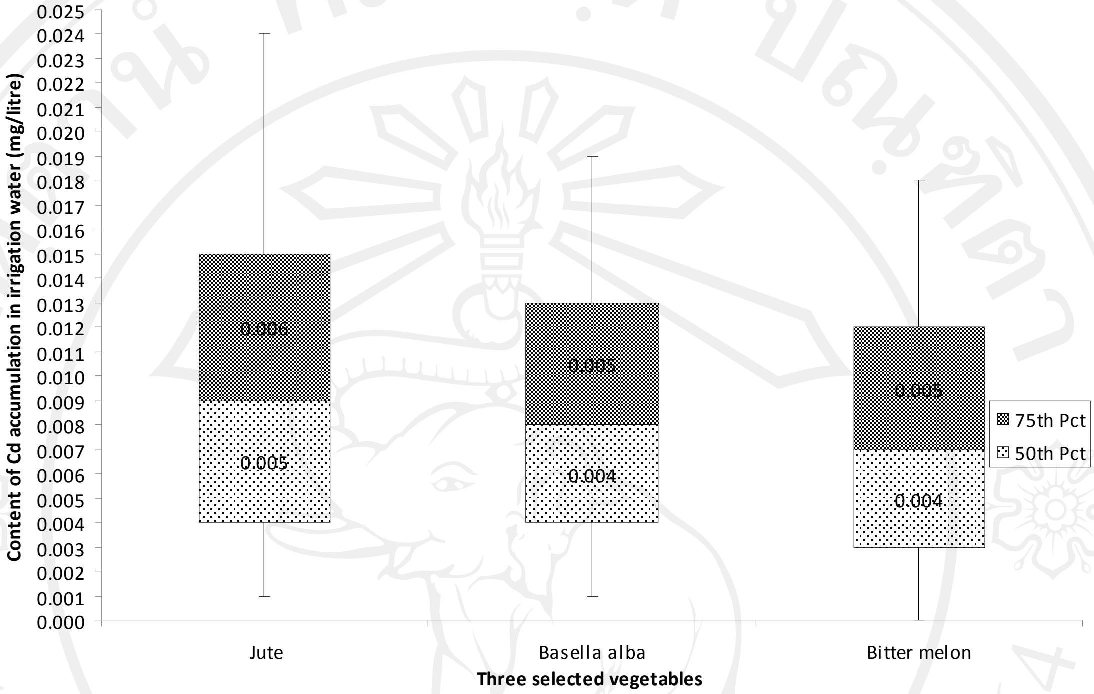

Figure 4.20 Accumulation of Cd in irrigation water of three selected vegetables.

Due to the time collecting data was observed in rainy season, therefore results of Cd content in water is low. In fact, Cd content in irrigation water in Tuc Duyen ward which mainly from Cau river is very variable depending on each time of the year, rainfall amount and waste sources discharge at the upstream (Hang, 2007; Environmental Monitoring Center of Thai Nguyen province, 2009).

Many researches showed that wastewater from commercial activities and residential areas often contain many toxic substances including heavy metals (Wang *et al.*, 2011). Besides, one of cause of heavy metal pollution in water in the area is the process of discharging industrial wastewater and hazardous wastewater which were not treated or not treated as required into water environment (Hang, 2007). In addition, many results of researches have shown that wastewater from commercial activities and residential areas often contain many toxic substances including heavy metals (Wang *et al*., 2011).

4.4.2.2 In cultivated soil

Results from the laboratory analysis of Cd in soil showed that average level of Cd in soil samples was 1.07 mg/kg which ranged 0.32 mg/kg to 2.54 mg/kg. The standard deviation was about 0.58 mg/kg (Table 4.4). In particular, 6 soil samples out of the total 75 total samples (about 8 percent of total samples) exceeded the permitted standard of Vietnam and the FAO/WHO (2 mg/kg). Remaining 69 soil samples out of the total 75 total samples (about 92 percent of total samples) was under permissible standard (Figure 4.21). Most of the vegetable soil samples, Cd concentrations in soil were below the permitted standard. Compared with permitted standard which is 2 mg/kg, we can conclude that the Cd content in cultivated soil samples of three selected vegetables in the study area were still in the permitted standard, however, vegetables in this area had signs of Cd contamination. However, the issue of Cd accumulation in vegetables in the city of Thai Nguyen province in general and in particular Tuc Duyen ward had been warned due to flexibility of Cd in acidic soil environment (Hang, 2007). Therefore, the Cd accumulation in cultivated soil in the research area needs to be studied.

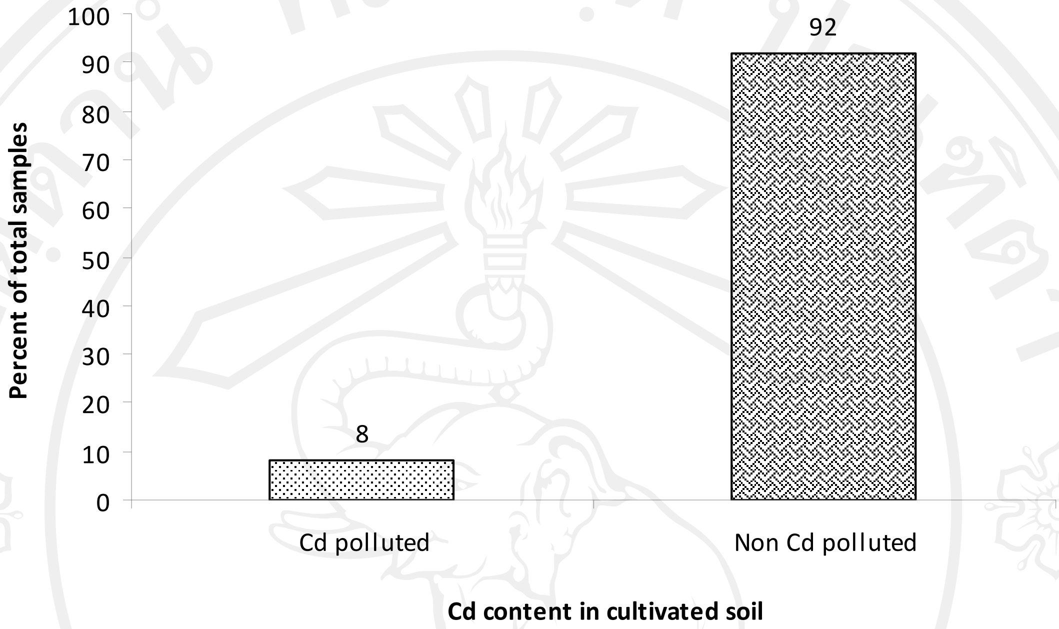

Figure 4.21 Cadmium (Cd) content in cultivated soil.

Comparing the content of Cd in soil with different type of vegetables showed that Cd content in soil for planting basella alba (75 percentile is 1.86 mg/kg) is the highest, followed by Cd content in soil for planting jute (75 percentile is 1.20 mg/kg), and lastly Cd content in soil for planting bitter melon (75 percentile is 0.89 mg/kg) (Figure 4.22). This showed that cultivated soil of three selected vegetables contain lower than threshold Cd concentration of the permissible standard of 2 mg/kg.

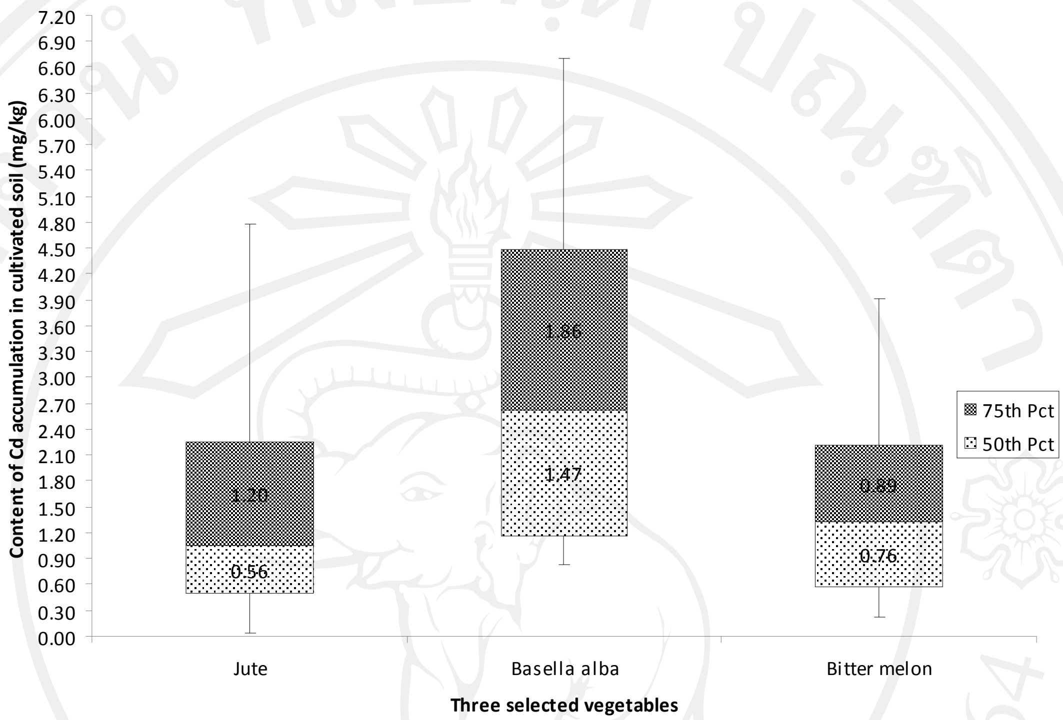

Figure 4.22 Accumulation of Cd in cultivated soil of three selected vegetables.

However, in fact, the issue of Cd accumulation in vegetables in the city of Thai Nguyen province in general and in particular Tuc Duyen ward had been warned in Hang (2007) and Hoa (2008) when they conducted survey research and analysis of vegetable samples in the area. This is a problem often occurred in vegetable growing areas near industrial zones, mining and mineral exploitation, and residential areas (Maqsud, 1998; Dao, 1999).

Research results of Hang (2007) showed that cultivated soil in Thai Nguyen city in general and cultivated soil at Tuc Duyen ward in particular has low pH from 4.8-5.6. Cultivated soil is acidic soil, and in this condition heavy metals (especially Cd) are very solubility. The effect of soil pH on mobility of heavy metals is a wellresearched topic (Cataldo *et al*., 1981; Chen *et al*., 1997; Peles *et al*., 1998; Li and Wu, 1999). Therefore, although Cd content in soil was not at the level of pollution but due to high solubility level of Cd, it can also be a cause for Cd accumulation in the research vegetables. Therefore, if cultivated soil of fields are necessary to lime, in order to limit the mobility of Cd, they must be noted to lime not only to soil but also to other sources such as irrigation water, organic fertilizers when putting substances containing heavy metals into soil during cultivation. This result is similar to the results of Islam *et al*., (2007) showed that the mobility of heavy metals depends on many factors such as pH environment factors etc. Specificially, the mobility of heavy metal ions increases when pH of soil is low. Solubility levels of Cd will increase when acidic of the environment is also raised, starting from the threshold of pH of 4-4.5, decrease 0.2 pH units then the Cd concentration will increase 3-5 times (Wang *et al*., 2006).

In addition, cultivated soils in Tuc Duyen ward are alluvial soils with a high clay content. Boon and Soltanpour (1992) concluded that the concentration of heavy metals in soil is dependant on clay content because clay-sized particles have a large number of ionic binding sites due to the higher amount of surface area. Some soil properties can have a significant effect on the amount of heavy metal assimilated by the plant (John and VanLaerhoven, 1972; Peles *et al*., 1998).

4.4.2.3 In vegetables

Results from the laboratory analysis of Cd in vegetables showed that average level of average of Cd content in three kinds of selected vegetables was 0.13

mg/kg, which ranged from 0.02 mg/kg to 0.28 mg/kg. The standard deviation was 0.06 mg/kg (Table 4.4). Compared with allowed standard which is 0.03 mg/kg, it can concluded that Cd content in vegetables samples in research area was crossed the permissible limit with high level of accumulation (Cd average content in vegetable samples was equivalently 4.37 times compared to allowed standard.).

Specifically, according to table of analyze results showed that 73 samples out of the total 75 vegetable samples (about 97.33 percent of total samples) exceeded the permitted standard of Vietnam and the World FAO/WHO (0.03 mg/kg). Only 2 samples out of the total 75 vegetable samples (about 2.67 percent of total samples) were below permitted standard (Figure 4.23).

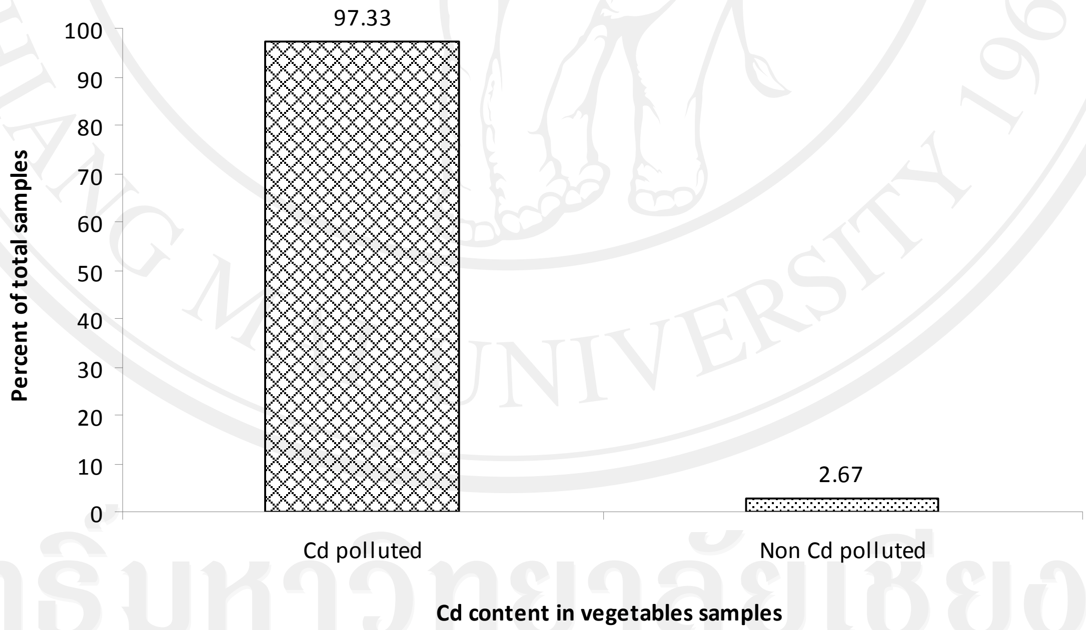

Figure 4.23 Cd content in three selected vegetables.

Preciously, Cd accumulation issue in vegetables have been warned of the many scientific studies at the nation level (Tuyen, 1995; Phuong, 2005; Dao, 1999) and at Thai Nguyen city also as well as Tuc Duyen ward in particular (Hang, 2007; Hoa, 2008).

Spatial distribution of Cd accumulation in three selected vegetables in Tuc Duyen ward was showed in Figure 4.24. Non Cd polluted samples had tended to be in the southern part of Cau river and high Cd polluted samples had tended to be near irrigation water sources such as Cau river and waste water source discharged from commercial and residential area in Thai Nguyen city's market etc. In addtion, 71 samples out of the total 75 vegetable samples (about 94.67 percent of total samples) with high Cd accumulation level arranged from 0.05 - 0.28 mg/kg, and 4 samples out of the total 75 vegetable samples (about 5.33 percent of total samples) with medium Cd accumulation level arranges from 0.03 - 0.05 mg/kg. Only 2 samples out of the total 75 vegetable samples (about 2.67 percent of total samples) were below permitted standard.

Comparing the content of Cd in vegetables revealed that Cd content in jute is the highest (75 percentile is 0.21 mg/kg), followed by Cd content in basella alba (75 percentile is 0.18 mg/kg) and finally in bitter melon (75 percentile is 0.13 mg/kg) (Figure 4.25).

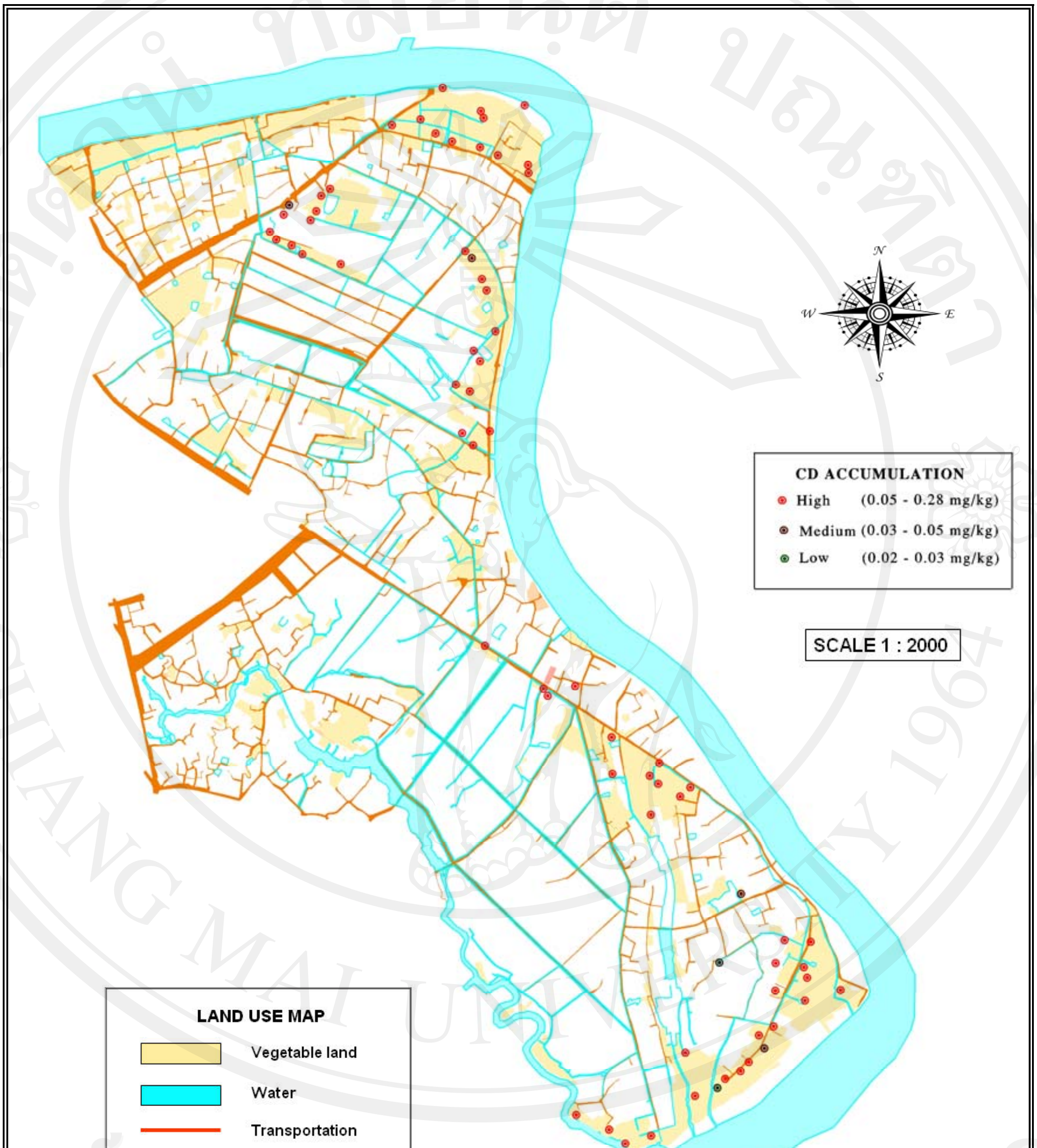

Figure 4.24 Spatial distribution of Cd accumulation in vegetables in Tuc Duyen ward.

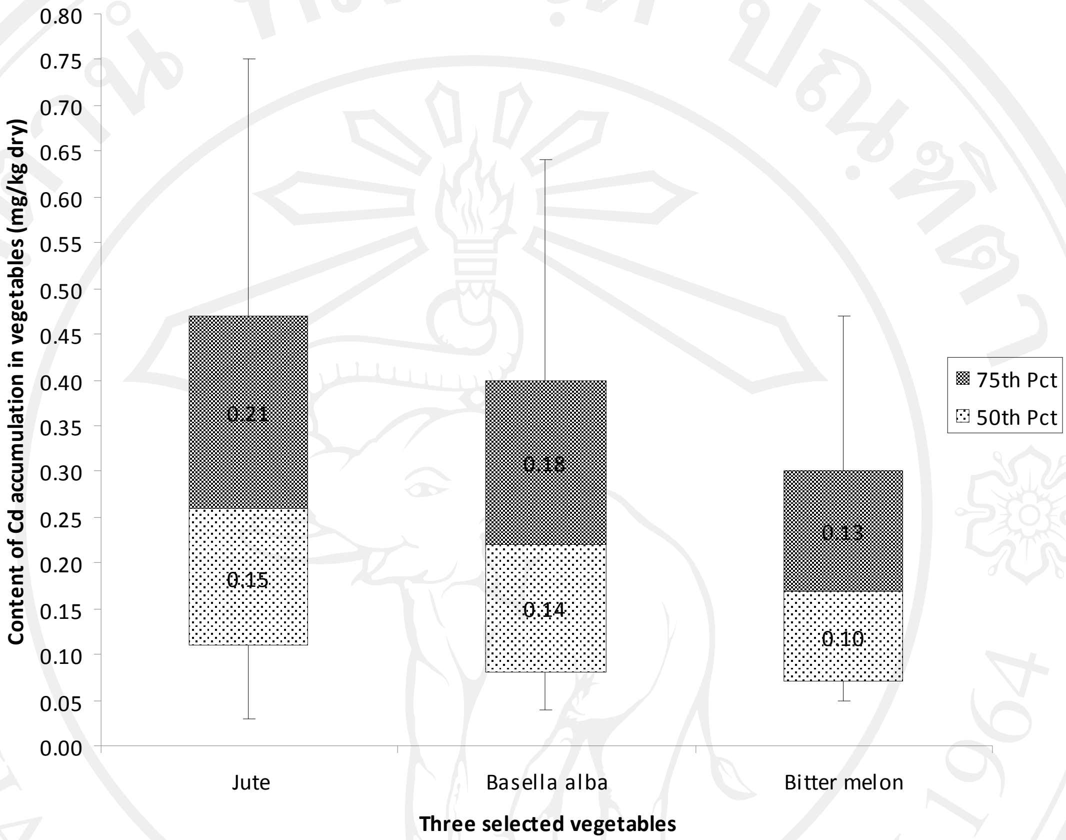

Figure 4.25 The accumulation of cadmium (Cd) in three selected vegetables.

According to results of many researches, the same as Pb accumulation in vegetables, plants uptake metal as Cd at different level depending on the species and varieties (HMMVA, 2010). Cadmium (Cd) tends to be very mobile in soil systems and therefore very available to plants. Each plant is capable of heavy metal absorption different and portions of vegetables are also accumulated an amount of heavy metals differently (Phuong, 2005). This was confirmed with Cd, specificially plant species differ widely in their tendency to accumulate cadmium (Curtis *et al*., 2002; Fritioff and Greger, 2007). In addition, absorption of Cd is about 10-fold more rapid than that of lead (Pb) (Curtis *et al*., 2002; Fritioff and Greger, 2007).