CHAPTER II

LITERATURE REVIEW

2.1 Situation of vegetable production and consumption in the world

In the world, vegetables are crops which have been grown for many years. Greek and ancient Egypt people used cabbage and vegetables as a source of food. Since the year 2000, these areas became the vegetable growing countries with the average output of more than 600,000 ha yearly and also increased gradually over the years. According to Food and Agriculture Organization (FAO), area of vegetables in the world increased from 14,826,956 ha in 2000 to 18,003,909 ha in 2005 while production increased from 218,336,847 tons to 249,490,521 tons (FAO, 2006).

Vegetables which used in combination with other fruits are good foods for the health because they contain vitamins, antioxidants and natural resistance. Therefore, demands for vegetables and fruits are very big. Japanese people consume more vegetables than any other countries in the world. Each year, Japan consumes 17 million tons of vegetables, with average of 100 kg/person/year. The trend now is consuming more vegetables and wild vegetables; this will be beneficial to the health of human. In the world, average consumption of a person is 154-172 g/day (FAO, 2006).

2.2 Situation of vegetable production and consumption in Vietnam and Thai Ng

Vietnam has a long history of growing vegetables. It has favorable climatic conditions for growth, development and creation of vegetable seeds, including vegetables from tropical and temperate origin.

There are about 70 species of plants used as vegetables or processed into vegetables. Local vegetables have been grown with more than 30 species. 15 species are general vegetables and growing in Vietnam; 80% of these species are leaf eating vegetables. There are two major areas planting vegetables and fruits, which are the Red River Delta and Southern plains. The most popular vegetable that have been grown throughout the country is cabbage, and it is grown a lot in northern part of Vietnam. For farmers, vegetable crops are important for household's income (Son, *et al*., 2005).

However, vegetable production in Vietnam is mainly in small scale. In Vietnam, growing vegetables depends much on fertilizers and pesticides. Besides, production environment is affected by industrial wastes, sewage and human activities. Without environmental considerations, lack of selective applications on scientific techniques along with the lack of knowledge on process of growing fresh vegetables in farming process have made the products of green vegetables contaminated with NO_3^-, heavy metals, microbial pathogens and plant protection chemicals. The problem on vegetable pollution has been occurred in almost vegetable growing areas nationwide (Hai *et al*., 2000; Hong, 2003; Tuan *et al*., 2003).

Currently, food safety issue is a concern of all people, all branches. Vegetable is the food used daily in all families. For this reason, to ensure the consumer's health in recent years, the State, agricultural branch and localities have had a lot of policies and measures to rapidly develop safe vegetable production model. In fact, Vietnam currently has two major types of safe vegetable development model.

Firstly, it is safe vegetable development model on narrow area and has high investment in technical infrastructure. It is model of vegetable growing in net-house, greenhouse, hydroponic vegetables growing. The advantages of this model are that vegetables can be grown off-season, with high yield, avoid adverse weather conditions. This model is suitable mainly for leaf eating vegetables and high-grade vegetables. The biggest drawback of this vegetable growing model is relatively high investment. The investment for 1 ha net-house is from 250-300 million VND (12,500-15,000 USD), for greenhouse will spend fews billions VND. Due to high cost, small scale so there are only few people involved in manufacturing, quantity of clean vegetables do not satisfy the majority of consumers who have low incomes, therefore it is very difficult to expand.

Secondly, it is a safe vegetable development model on a large area at the fields by investing and transfering technology to farmers. The basic downside is that vegetables can not be grown off-season, often be effected adversely by weather, but this model has the advantages are that many farmers can apply, exploit the advantages of tropical weather, easy to expand production scale, low cost, large area and yield so meet the needs of almost all consumers. This is called as the "community clean vegetable production model" which was researched, applied and initiated from Vinh Phuc province in the period 2000 - 2003, then has been spreaded to many provinces such as Hanoi, Thai Nguyen, Hai Duong, Bac Ninh, Binh Dinh, Khanh Hoa, Da Lat, etc. This model is now proved its appropriateness and efficiency.

Although the authorities had a lot of efforts in developing the model of safe vegetables, but it only developed at modest level. According to the MARD, production of fruits and vegetables accounted for 13.2% of total agricultural output value and 16% of total cultivation in the country but safe vegetable production accounted for only about 5% and just met a small part of consumers' demand in which consist of collective kitchens, schools and businesses (Dung, 2006). It can be said that at present, the production of safe vegetables is still not popular (Huong, 2005). According to the MARD, after 3 year-results of safe vegetable project in the 6 areas of Ha Noi, Hai Phong, Ha Tay, Vinh Phuc, Bac Ninh, Hung Yen reached nearly 16,000 ha, accounted for only 8.4% in area and 7.7% in volume. Even in Hanoi, area of safe vegetables accounted for only about 44% area and in Vinh Phuc only is 17% of total vegetable acreage in the area (Tam, 2006).

There are many reasons that both consumers and state management agencies doubting the safety of vegetables, in which there are two main reasons:

The first cause: Due to farmers grew vegetables in a small-scale, they did not apply full process and techniques for growing safe fruits and vegetables. Currently, 40% of safe vegetable growing area nationawide, microorganisms, toxic chemicals, heavy metals and plant protection chemical which residue in safe vegetables still existed (Linh, 2006).

The second cause: The planning of safe vegetable production areas was not complete, safe vegetable fields were arranged alternately with the fields which did not follow process. The most inadequate issue is that there are fields growing vegetables according to proper process, but they are cultivated in the polluted areas. Currently, areas of safe vegetable production are still fragmented (small scale), very difficult for organizing production as well as inspecting and consuming products. Even Hanoi is a locality which has planning speed for safe vegetables faster than many other localities but safe vegetable areas are still scattered, mixed with areas planting rice and traditional vegetables. Most of safe vegetable areas of Hanoi were converted from land planting paddy and crops with a history of using many plant protection drugs, fertilizers, etc. Therefore, it is hard to avoid the adverse effect of the residual chemical in the environment on vegetables.

In a survey, Hanoi had 108 vegetable fields out of the total 478 fields with the area of 932 hectares, accounting for 35.3% of cultivated area, but they did not have enough conditions of soil and water to produce safe vegetables, with only 77 vegetable fields had heavy metal content in water exceeded the prescribed limits, of which 16 areas irrigated with ground water and 61 areas irrigated by surface water; 36 areas had heavy metal concentrations in soil exceeded the prescribed limits mainly copper (Cu), cadmium (Cd) and zinc (Zn) (CDMARD, 2007). The deployment of safe vegetable production model in Thai Nguyen city was also in such situation, the models were not isolated from the areas with common practice of farming and farming environment was polluted, these made consumers not trust the quality of safe vegetables so they consumed very little (TNPPD, 2009).

Thus, to be able to develop vegetable production sector towards safe and sustainable, it is necessary to have synchronous measures such as training farmers on techniques, improving awareness of community, testing quality of land, water to plan productions isolated from contaminated areas, monitoring and inspecting quality, advertising brand, etc. Besides, there must have close coordination between branches, levels and farmers, like this the deployment of safe vegetable model can reach high efficiency.

2.2.1 Jute

Jute (Corchorus capsularis L.) is a member of Tiliaceae family. This is an annual erect herbaceous plant 1-2.5 m tall (up to 4 m in cultivation). Base is often becoming woody with smooth branching near the top. The branchlets are cylindrical. The leaves are with linear-ovate stipules sized 0.5-1 cm long. The leaf stalk is 0.5-3 cm long and covered with soft short hairs at above. The 5-14 cm x 1-6 cm blade is narrowly egg-shaped to elliptical. Its base is round. The margin is with 2 lower teeth prolonged into fine pointed auricles up to 1 cm long. The apex is acuminate, smooth above and minutely papillose below. The fruit is a depressed spherical and it is 1-1.5 cm in diametre, longitudinally grooved, coarsely warty, 10-valvate and with 35-50 seeds. The seed is rhomboid to obovoid, about 2-3 mm long and dark brown (Plant Resources of South-East Asia, 2003).

Figure 2.1 Jute (Corchorus capsularis L.)

(Source: http://www.rfviet.com)

Vegetable jute is planted throughout Asia and Africa. In our country, it is grown in home gardens. Vegetable jute grows fast, just a month after sowing, its leaves and tops can be taken to eat.

Vegetable jute is cultivated mainly in spring season and harvested from summer to autumn. Growing season of vegetable jute from early March to July and harvesting season from May to September. Vegetable jute is rotated with other crops.

Vegetable soil is suitable in light meat soil, medium meat soil, sandy soil, pH from 6.0 to 6.7. Leaves or fruits of vegetable jute are also used as a tonic, sedative, diuretic in many countries. Leaves of vegetable jute are used as tonic in India, or in Malaysia, its leaves are used to cure dysentery and cough in children.

2.2.2 Basella alba

Basella alba (Basella rubra L. or B. lucida L.; B. cordifolia Lam.; B. nigra Lour) is a member of family Basellaceae.

Basella alba is a fast growing vegetable, native to tropical Asia, probably originating from India or Indonesia and extremely heat tolerant (Grubben and Denton, 2004). It is grown throughout the tropics as a perennial and in warmer temperate region as an annual crop. Its thick semi-succulent heart-shaped leaves have a mild flavour and mucilaginous texture. It is commonly known as Malabar, Ceylon, East-Indian, Surinam and Chinese spinach (Facciola, 1990).

Basella alba is a perennial vine found in the tropics where it is widely used as a leaf vegetable. Basella alba is a fast-growing, soft-stemmed vine, reaching 10 m in length. Its thick, semi-succulent, heart-shaped leaves have a mild flavour and mucilaginous texture. The stem of the cultivar Basella alba 'Rubra' is reddish-purple. Basella alba grows well under full sunlight in hot, humid climates and in areas lower than 500 m above sea level. Growth is slow in low temperatures resulting in low yields. Flowering is induced during the short-day months of November to February. It grows best in sandy loam soils rich in organic matter with pH ranging from 5.5 to 8.0 (http://en.wikipedia.org/wiki/Basella_alba Basella alba).

Figure 2.2 Basella alba (Basella rubra L.)

(Souce: http://www.botanyvn.com)

Basella is often grown as leaf vegetables, harvested yearly, often used fresh. Plant part used leaves, young stems, matured fruits, root.

In Vietnam, basella alba is the food used in daily meals. For a long time, it has also been used as a medicament.

2.2.3 Bitter melon

Bitter melon (Momordica charantia L) is a member of Cucurbitaceae. Momordica charantia, called bitter melon or bitter gourd in English, is a tropical and subtropical vine of the family Cucurbitaceae, widely grown in Asia, Africa, and the Caribbean for its edible fruit, which is among the most bitter of all fruits. There are many varieties that differ substantially in the shape and bitterness of the fruit (http://en.wikipedia.org/wiki/Bitter_melon Bitter melon).

Momordica charantia is a cucurbit vine native to Asia and now widely cultivated throughout the world for the immature fruits, and sometimes for the tender leafy shoots or the ripe fruits (Yamaguchi, 1983). The immature fruits, called bitter melon, bitter gourd or balsam pear, are harvested at developmental stages up to seed hardening. The bitter principle, for which the fruit is named, is due to the alkaloid momordicine, not to cucurbitacins as in other members of the Cucurbitaceae (Walters and Decker-Walters, 1988). The bitter melon is also important for its medicinal properties (Morton, 1967; Walters, 1989).

Figure 2.3 Bitter melon (Momordica charantia L)

(Souce: http://healthglance.blogspot.com)

This herbaceous, tendril-bearing vine grows to 5 meters. It bears simple, alternate leaves 4–12 cm across, with 3–7 deeply separated lobes. Each plant bears separate yellow male and female flowers. The fruit has a distinct warty exterior and an oblong shape. It is hollow in cross-section, with a relatively thin layer of flesh surrounding a central seed cavity filled with large flat seeds and pith. The fruit is most often eaten green, or as it is beginning to turn yellow. At this stage, the fruit's flesh is crunchy and watery in texture, similar to cucumber, chayote or green bell pepper, but bitter. The skin is tender and edible. Seeds and pith appear white in unripe fruits; they are not intensely bitter and can be removed before cooking .When the fruit is fully ripe it turns orange and mushy, and splits into segments which curl back dramatically to expose seeds covered in bright red pulp (http://en.wikipedia.org/wiki/Bitter_melon Bitter melon).

Bitter melon originated in Africa, now widely grown in all parts of the tropics and subtropics. Due to the wide ecological amplitude, so in the tropics bitter melon can be grown yearly, easily susceptible to flooding conditions. Bitter melon can be grown on many soils, but its growth is most conveniently in nutritious and well drained soil. In the world, bitter melon is grown in many Asian countries, Latin America. In Viet Nam, bitter melon is grown in every region.

Bitter melon is easy to grow in any land. It prefers moist, light, fewer pests and diseases. Because fruits of bitter melon have funny shiny shape, so it is grown as an ornamental, for shade and to get fruits in the family. Bitter melon can be grown on a large area to have goods prodving to market of food product, medicines and cosmetics.

In Vietnam, bitter melon can be grown yearly but is best planted in October - November of the calendar (in this time, it has the longest production cycle). Bitter melon is seeded from early March to September, harvested from May - December. However, if planted late, its productivity will be decreased, pest and disease will increase.

2.3. Current status of heavy metals (Pb, Cd) pollution in soil and water in vegetable land

2.3.1 Lead (Pb)

2.3.1.1 Distribution and existence form of lead (Pb) in the environment

- **In soil**

Lead (Pb) is a naturally occurring bluish-gray metal found in small amounts in the earth's crust. It is seldom found in its elemental form; however, it is part of several ores including its own (galena, PbS). It is very soft, highly malleable, ductile, and relatively poor conductor of electricity. Lead is the most abundant heavy metal in the earth's crust. It occurs at an average concentration of 12.5 mg/kg in igneous rock, 7 mg/kg in sandstones, and 20 mg/kg in shells. The decay of uranium and thorium through geologic times has produced about one-third of the lead in the earth's crust. About 10% of lead is found in out bodies but an average concentration of 17 mg/kg is also found in uncontaminated soils (Moor, 1986).

Lead can be found naturally in parts of the environment, but much of it comes from human activities including burning fossil fuel, mining, and manufacturing. Currently, lead is found in ore with zinc, silver, and copper and it is extracted together with these metals. The main lead mineral is galena (PbS) and there are also deposits of cerrussite and anglesite ($PbSO_4$) which are mined. Galena (PbS) is mined in Australia, which produces 19% of the world's new lead, followed by the USA, China, Peru, and Canada. World's production of new lead is 6 million tons a year, and workable reserves total are estimated at 85 million tons, which is less than 15 years' supply (Lenntech, 2001).

Pb is relatively common metal in many natural minerals. It is a heavy metal element which has less flexibility, time to decompose in land from 800 to 6,000 years. According to many authors, lead content in soil is average of 15-25 ppm (mg/kg).

Several factors may influence the content and distribution of heavy metals in soil. Some of these factors are parent material, organic matter, particle size distribution, drainage, pH, type of vegetation, amount of vegetation, and aerosol deposition (Lee *et al*., 1997).

Heavy metals including Pb tend to accumulate in the clay fraction of the soil profile (Boon and Soltanpour, 1992; Lee *et al*., 1997; Li and Wu, 1999). Strong ionic bonds are formed between the cation and the clay particle. Acidic conditions will cause desorption of these cations into solution making them available for uptake by plants. Desorption to the soil solution also increase cation mobility through the profile (John and VanLaerhoven 1972; Cataldo *et al*., 1981; Chen *et al*., 1997; Peles *et al*., 1998; Li and Wu 1999).

In soil, Pb is usually in the form of stable complexes with anions (CO_3^{2-}, Cl^-, SO_3^{2-}, PO_4^{3-}). In neutral or alkaline environment, Pb will form $PbCO_3$ or $Pb_3(PO_4)_2$ with small impact on crops. According to some authors, with carbonate chemical reaction in neutral soil, Pb contamination will be limited. The increase of acidity may increase the solubility of Pb and the decrease of acidity usually increases the accumulation of Pb due to precipitation. Lead is exchanged with a small proportion (<5%) in comparison with Pb in soil. Lead can also combine with organic compounds to form volatile substances such as $(CH_3)_4Pb$. In soil, Lead is highly toxic, it restricts the activities of microorganisms and stably exist as complexes with organic matter (Hai, 2008).

Pb in soil can replace K^+ ions in the adsorbed complexes which have organic or clay minerals origin. Pb adsorption capacity increases to the pH at which forming precipitation of $Pb(OH)_2$, the solubility of Pb in soil increased due to acidification in acidic soil.

Lead (Pb) is especially accumulated in surface horizon of soil because its low water solubility within an environmentally relevant pH range results in very low mobility. Pb behavior in soil is similar to Cd behavior in soil. However, Khan and Frankland (1983) showed that Pb was less mobile in soil than Cd. Very little of either Pb or Cd was leached through the soil profile. In fact, more Pb and Cd were removed from the soil by plants than was leached through the profile (Khan and Frankland 1983).

- **In water**

In water, Pb exists in 3 forms which are soluble Pb, suspended Pb and colloidal complexes. In water environment, the features of lead compounds are determined mainly by its solubility. Solubility of lead depends on the pH, when pH increases, its solubility will reduce and it depends on other factors such as ion concentrations of water and redox conditions. Normally, pH = 6 in water, then Pb exists in the form of inorganic form, less in the form of colloid. In surface water which is used for agricultural production if the pH = 7, Pb is colloidal. Due to adverse forces of organic matters, colloidal complexes of Pb will be in the form of $Pb(CH_3)_3^{2+}$; $Pb(CH_3)_4$ and $Pb(CH_3)_2^{2+}$ and usually deposited in the bottom sludge, Pb in natural water mainly exists in the form of chemotherapy 2 (Hang, 2007)

2.3.1.2 Emission source of lead (Pb) in soil and water environment

- **In soil**

There are two main emission sources of heavy metals (such as Pb and Cd) in soil which are from weathered rocks in soil formation processes and human activities). In which, sources of heavy metal pollution in soil are mainly due to human activities. The source from weathered rocks in soil formation processes depends on mother-rock. The heavy metal content in rock is often very low, so if do not have the cumulative process due to erosion etc is less likely to have high levels of heavy metals in natural land. Apart from rock weathering process, there are many sources from human activities bringing metals into, including: Mining and smelting, industrial activities, deposited from atmosphere (Witter, 1994), agricultural activities (Ubavie *et al*., 1994; Manh, 2000).

Pb has many industrial and commercial uses. It is used in the production of ammunition, as solder, in ceramic glass, and the production of batteries (ATSDR 1999b). Other sources of Pb in the environment include automobile exhaust, industrial wastewater, wastewater sludge, and pesticides (Balba *et al*., 1991).

There are different sources of metal contamination in mining areas, including grinding, concentrating ores and tailings disposal (Wang *et al.*, 2004; Adriano, 1986). Inappropriate treatment of these tailings and acid mine drainage could pollute the agricultural fields surrounding the mining areas (Willians *et al.*, 2009).

Agricultural use of pesticides was another source of heavy metals in arable soils from non-point source contamination. Although pesticides containing Cd, Hg and Pb had been prohibited in 2002, there were still other trace elements containing pesticides in existence, especially copper (Cu) and zinc (Zn). It was estimated that a total input of 5000 tons of Cu and 1200 tons of Zn were applied as agrochemical products to agricultural land in China annually (Luo *et al.*, 2009; Wu, 2005).

- **In water**

The phenomenon of heavy metal contamination in water often occurs near industrial areas, big cities and mining areas. Heavy metal pollution expresses in high concentrations of heavy metals in water. In some cases, there occurs the death of a series of fish and aquatic organisms. (Wang *et al.*, 2011)

The main cause of heavy metal pollution in water is the process of discharging industrial wastewater and hazardous wastewater which were not treated or treated as required into water environment (Hang, 2007). Water pollution by heavy metals has negatively impact to living environment of animals and humans. Heavy metals are accumulated from the food chain and they penetrate into human body. Contaminated surface water will spread contaminants into groundwater, into land and other relevant environmental components. To limit water pollution, it is necessary to strengthen measures to treat industrial wastewater, manage better livestocks in the environment which is at risk of pollution such as fish, planting vegetables by wastewater sources.

Emission sources of lead (Pb) in water from paper industry, petrochemical industry, dying and bleaching industry, fertilizer production and using, oil processing industry, steel production industry, derrous metal industry, industry of automotive and aircraft production (Boyer, 1984; Dean *et al.*, 1972). Besides, according to Win *et al*., (2003), the lead (Pb) contamination is due to the waste sources of printing industry, batteries, metal casting, and transport.

2.3.1.3 Factors affecting the accumulation of Pb in soil, vegetables and water

In general, vegetables are contaminated with heavy metals derived from factors such as application of fertilizer, sewage sludge, or irrigation with waste water (Devkota, *et al*., 2000; Frost *et al*., 2000; Mangwayana *et al*., 1995). Also, the uptake and bioaccumulation of heavy metals in vegetables are influenced by factors such as climate, atmospheric depositions, concentrations of heavy metals in soils, nature of the soil on which vegetables are grown, and the degree of maturity of the plants at the time of harvest (Lake *et al*., 1984; Scott *et al*., 1996; Voutsa *et al*., 1996).

Concentration of heavy metals accumulation in plants depends on the ability to assimilate heavy metals of the plants, on pH of environment, amount of heavy metals in soil and irrigation water as well as plant species and different types of heavy metals, on organic matter in soil, ion exchange capacity, and clay composition. Concentration of heavy metals in plants also depends on the type of their compounds in soil and irrigation water.

One of the most important factor to control the solubility of heavy metals are acidic, with pH greater than 5.5, free Pb^{2+} concentration is small (Wang *et al*., 2006).

According to the research by Robert (1974), Pb accumulation is highest in leaf eating vegetables (lettuce), in the areas which are heavily contaminated, Pb content in lettuce can be up to 0.15% and when having the presence of Pb in nutrient solutions, bulb-plants can absorb Pb most powerful and this absorption will increase in accordance with the concentration of Pb in soil and planting time.

Heavy metals are present in products of fresh vegetables, fruits and vegetables processed through many different paths. There are many reasons but the main causes such as process of cultivation and heavy metals entering the fruits and vegetables, vegetables grown on polluted land and water.

According to research of Manh (2000), vegetables grown in contaminated soil, water, such as mining area of pyrite, copper, zinc; waste areas after coal mining; areas containing waste after many years of industrial production; solid waste landfill or vegetables irrigated by polluted water such as municipal sewage, industrial waste water are contaminated with heavy metals in products. Especially the cases of using waste sludge, manures processed by urban waste to plant vegetables were reseached by many authors. They observed that it increased the amount of heavy metals in products (Dao, 1999; Manh, 2000).

Processing, packaging, storage also increase the levels of heavy metals in vegetable products, particularly for fruits and vegetables have a large amount of organic acids, salt and sour vegetables, etc. Heavy metals are put into through the wash water, equipment or ceramic glaze that contains high monoaxit lead, tin-plated soldering iron box, etc.

In addition to, Pb contamination in Vietnam is becoming more serious due to sources of leaded gasoline is used more and more to run the engine. Pb content is up to 0.4 g/liter of fuel, when burning, it will be spreaded into the atmosphere and deposited to the ground or water. The closer to traffic roads, the higher content of lead in soil is. The majority of Pb in soil is below the surface 50 cm and mainly located in the topsoil.

Factors influencing the bioavailability of metals and their occurrences in crops were found as soil pH, cation exchange capacity, organic matter content, soil texture, and interaction among the target elements. It is concluded that total metal concentrations in soils are the main controls on their contents in plants. Soil pH was also an important factor. A stepwise linear multiple regression analysis was also conducted to identify the dominant factors influencing metal uptake by plants. Metal concentrations in plants were also estimated by computer-aided statistical methods (Jung, 2008).

2.3.1.4 Lead (Pb) effects on plant and human

- **On plant**

Decreased growth and yield have been observed in plants grown in Pb contaminated soils. Balba *et al*. (1991) showed a significant decrease in plant biomass yield with increasing Pb treatments that varied with soil type. The highest adverse effects were on those plants grown in soils with high clay content. Khan and Frankland (1983) also showed decreased plant growth and yield in soils with Pb contamination.

Lead can be harmful to plants, although plants usually show ability to accumulate large amounts of lead without visible changes in their appearance or yield. In many plants, lead accumulation can exceed several hundreds times the threshold of maximum level permissible in human (Wierzbicka, 1995). The introduction of lead into the food chain may affect human health, and thus studies concerning lead accumulation in vegetables have become important (Coutate, 1992).

- **On human**

The contamination of vegetables with heavy metals poses a critical threat to society and environment as regards to the increasing concern of food safety issues, potential health risks, and detrimental effects upon soil ecosystems (Mclaughlin et al., 1999). Ingestion of vegetables grown in soils containing elevated metal concentration has been suggested as possible risk to the health of humans and wildlife (Flemming e*t al*., 1977; Xu *et al*., 1985).

Heavy metals such as Hg, Cd, Pb, As, Sb, Cr, Cu, Zn, Mn, etc are often not involved or less involved in biochemical processes of living organisms and they are often accumulated in the organism. So, these are toxic elements for living organisms.

Lead has been on intense focus of environmental health research for many decades. Studies in humans were greatly assisted by the development of methods (such as graphite furnace atomic absorption spectroscopy) for the accurate and reliable measurement of lead in blood. The general body of literature on lead toxicity indicates that depending on the dose lead exposure in children and adults can cause a wide spectrum of health problems ranging from convulsions, coma, renal failure, and death at the high end to subtle effects on metabolism and intelligence at the low end of exposures (ATSDR, 1999). Neurological problems, especially in children, are the principal concern for chronic lead exposure, along with other health-endangering effects, such as blood enzyme changes, anemia and hyperactivity (Curtis *et al*., 2002; Barkirdere *et al*., 2008).

Lead (Pb) is an element not necessary for the organism, Pb can penetrate into human body through food, drinking water, inhalation or through skin, but lead mainly goes into the human body by food and drinking, it is accumulated in bones, less cause toxicity except high doses, more dangerous matter is its long-term accumulation in the body even at low doses. Showing symptoms of lead poisoning include fatigue, loss of appetite, headache, its effects on the central nervous system and peripheral system. An important biochemical effect of Pb is intervening into red blood, it interfers the process of creating intermediate compounds in the process of forming hemoglobin. When the concentration of Pb in blood reach 0.3 ppm, it is toxic and when its concentration > 0.8 ppm, it will lose hemoglobin and cause anemia, renal dysfunction (Thanh, 2002).

Lead (Pb) is a highly toxic element for human health. Lead is harmful to the central nervous system, peripheral nervous system, effects to enzyme systems containing active hydrogen groups. People affected by lead poisoning will lead to disorders of hematopoietic part (bone marrow). Depending on the extent of contamination, people will have abdominal pain, arthralgia, nephritis, hypertension, cerebral stroke, severe intoxication which can cause death. The distinct characteristic is that after entering the body, lead cannot be rejected but it accumulates over time and then poisoning. Lead enters the human body through drinking water, air and lead-contaminated food. Lead accumulates in bone will cause metabolism by inhibiting the metabolism of vitamin D. According to WHO, the maximum allowed standard of lead concentration in drinking water is: 0.05 mg/ml.

2.3.1.5 Management of lead (Pb) in Vietnam's agricultural

Except from alluvial soil in Mekong Delta plain and Red river plain, soil in Vietnam has low pH, low organic carbon content, less clay and lack of nitrogen (N), phosphorus (P), calcium (Ca) and magnesium (Mg). To maintain or increase agricultural production (agricultural productivity), farmers need to put more nutrients into soil such as additional chemical fertilizers, manure types. Otherwise crop yields will decline sharply to a low level of productivity. The fact proved that the nutrients put into the soil can be contaminated by metals that have negative impact on productivity and quality of agricultural products.

Before the phenomenon of soil, water environmental pollution are taking place seriously as now, scientists have conducted studies to protect the vital resources of the earth. Currently, there are many methods to reduce pollution such as precipitation methods, sedimentation, adsorption, ion exchange, extraction. In recent time, the issue on treatment of heavy metals in soil and water environment has been reveived much concern by scientists in the world, however, in Vietnam they are only the initial studies.

According to results of research (Tau *et al*., 1998) which surveyed 5 major land groups nationwide showed that: Alluvial soil in Red River delta has the highest Pb and Zn content, most of soils have a high rate of flexible heavy metals content compared to others.

Results of the survey (Maqsud, 1998) from 8/1995 to 8/1997 at some canals in Ho Chi Minh City showed that: Most of the canals in Ho Chi Minh City were polluted with very high content of heavy metals, compared with the allowed standard, Cd is higher 16 times, Zn 90 times, Pb 700 times. Concentrations of heavy metals in sediment are also at an alarming rate, As is higher 11.7 times than Vietnamese Standard; Cd is 36 times and 61 times of Pb.

After period of time for researching and tracking the phenomenon of heavy metal contamination as well as changes in their concentration levels in 16 ponds and lakes in Hanoi city, compared with No 5942-1995 Vietnamese Standard for Class A with surface water, all Hanoi's lakes were contaminated with heavy metals, especially As, Pb and Hg were contaminated to 90% samples tested (Tau *et al*., 2000).

Currently, in reducing heavy metal pollution, scientists are aiming cheaper methods and more friendly to the environment, it is a method of treating pollution by plants (Phytoremediation) - it is also one of the important feasible solutions for the treatment of land and water contaminated heavy metals. This is an important area of biotechnology applications in environmental protection work.

The scientists successfully tested the method of handling both heavy metals in soil and water by plants (Antiochia *et al*., 2007; Channey *et al*., 1995, Duc *et al*., 2005, Blaylock *et al*.,; Dushenkov. *et al*.; Tu *et al*., 2004). This is a relatively new direction in handling contamination in soil and water. In Vietnam, some authors also proposed measures to clean up heavy metal pollution in soil by using a number of plants able to accumulate toxic metals at high level such as chrysanthemum (Tau et al., 2005). Dog-tail seaseed and water lentil are able to reduce Pb, Zn, Fe and Cu in Bay Mau lake, Hanoi. Pineapple guava and cucumber plants (Herterostrema villosum) are capable of absorbing high levels of Pb and Cd, ferns may clean up water contaminated with As (Tu *et al*., 2004).

The problem of heavy metal pollution generally has challenged environment of Vietnam, normal type of pollution found in urban of Vietnam is surface water pollution, dust pollution, heavy metal pollution and toxic substance pollution such as lead (Pb), Cadimi (Cd), mercury (Hg), arsenic (As), etc (Thuan, 2006).

2.3.2 Cadmium (Cd)

2.3.2.1 Distribution and existence form of cadmium (Cd) in the environment

- **In soil**

Although cadmium is a naturally occurring element, it is rarely found as a pure metal in nature. It is generally associated with oxygen, chlorides, sulfates, and sulfides. Cadmium is often a byproduct of the extraction of Pb, Zn, and Cu from their respective ores (ATSDR 1999a). Carbonaceous shale, coal, and other fossil fuels are also sources of Cd. Volcanism is the largest natural source of Cd (ATSDR 1999a). Anthropogenic sources of Cd in the soil and groundwater include the use of commercially available fertilizers and the disposal of sewage sludges as soil amendments (Baker *et al.*, 1979; Garcia *et al.*, 1979; Kosla 1986; Peles *et al.*, 1998; Gallardo-Lara *et al.*, 1999).

Cadmium can accumulate in high concentrations in soils. Cadmium is recalcitrant in the soil profile, particularly in the surface horizons (John *et al.*, 1972; Khan and Frankland 1983). Most soil profiles have an A horizon, which is primarily topsoil composed of decaying organic matter such as leaves and grass, and a B horizon, which is composed of smaller clay-sized particles. In general, heavy metal concentrations are higher in the B horizons than in the A horizons (Lee *et al.*, 1997). Heavy metals tend to accumulate in the clay fraction of most soil profiles (Boon *et al.*, 1992; Lee *et al.*, 1997).

Cd is a metal which locate deep inside the earth, exists in the form of Cd^{2+}. In oxidising conditions, Cd are usually in the form of solid compounds such as CdO. $CdCO_3$, $Cd_3(PO_4)_2$. In reducing conditions (Eh ≤ - 0.2 V), Cd often exists in the form of CdS, in addition, Cd can exist at the form of complex such as $CdCl^+$, $CdHNO_3^+$; $CdHCl^-$; $CdCl_4^-$; $Cd(OH)_4^-$. In acidic soil, Cd exists more flexibly (Cd^{2+}), but if the soil contains more Fe, Al, Mn, organic matter, Cd will be combined then it will lead to reduce the mobility of Cd. In neutral or alkaline soil by liming, Cd is precipitated in the form of $CdCO_3$. Normally, Cd exists in soil in the form of adsorption and exchange, accounting for 20-40%, of carbonate compound is 20%, of hydroxide and oxide is 20%, the linking of organic compounds accounts for a small percentage (Hang, 2007).

- **In water**

In water, Cd exists mainly in the form of chemotherapy 2 and is is easily hydrolysed in alkaline environment. Aside from the form of inorganic compounds, it is associated with organic compounds, especially humic acids to form complexes and these complexes have good adsorption capacity on the sedimented particles, accounting for 60-75% of the total concentration in the water.

2.3.2.2 Emission source of cadmium (Cd) in soil and water environment

- **In soil**

The two major sources of Cd in soils are natural occurrence derived from parent materials and anthropic activities (WHO, 1992). Numerous human activities such as mining, waste disposal, vehicle exhausts and phosphate fertilizer application, etc have resulted in the release of significant quantities of Cd to the environment (WHO, 1992; Manta *et al*., 2002; Komarnicki, 2005). Cadmium in soil is easily accumulated by plants through the root system, compared with other toxic metals (Thuvander *et al*., 1998). Hence, the soil-plant human transfer of Cd has been considered as a major pathway of human exposure to soil Cd (Cui *et al*., 2004).

Heavy metals input to arable soils through fertilizers courses increasing concern for their potential risk to environmental health. Lu *et al.* (1992) reported that the phosphate fertilizers were generally the major source of trace metals among all inorganic fertilizers, and much attention had also been paid to the concentration of Cd in phosphate fertilizers.

- **In water**

The industrial effluents often contain many heavy metals such as Cd. In industrial areas, many agricultural fields are inundated by mixed industrial effluent or irrigated with treated industrial waster water.

Emission sources cadmium (Cd) in water from petrochemical industry, dying and bleaching industry, fertilizer production and using, oil processing industry, steel production industry, ferrous metal industry, industry of automotive and aircraft production (Boyer, 1984; Dean *et al*., 1972).

Specifically, cadmium (Cd) discharge into the environment from many waste sources such as: Waste water from painting plants, plastic decomposition and combustion, tire decomposition, battery technology, technology of fertilizer production and amount of fertilizers used, especially phosphate.

2.3.2.3 Factors affecting the accumulation of Cd in soil, vegetables and water

Accumulation of heavy metals in soil is necessary to be considered, but their flexibility in soil need to be paid more attention. Actually, heavy metals in soil or water always occur the exchange process with the surface of adhesive soil. The mobility of heavy metals depends on many factors such as: pH environment, redox, concentration of complexing substances capable of dissolving heavy metals (Ejaz ul Islam *et al*., 2007), anions which coexist in the environment (Cl-, SO_4^{2-}, NO^{3-}) (Danielle Oliver *et al*., 2003). The mobility of heavy metal ions increases when pH of soil is low and decreases when pH of is high, in alkaline environment (pH of soil is about 9 - 12), heavy metals will be precipitated as hydroxides or carbonates.

Boon *et al*. (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. This results in the immobilization of heavy metals, and there is very little leaching through the soil profile (Khan and Frankland, 1983). Immobilization can increase the Cd concentration of the soil and ultimately lead to the increased toxicity of the contaminated soil. Higher soil Cd concentrations can result in higher levels of uptake by plants (John *et al*., 1972). However, specific 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).

Acidity affects the ability of soluble heavy metals in soil. Soil pH significantly influences heavy metal concentrations in both soil and plant tissues. The effect of soil pH on mobility of heavy metals is a well-researched topic (Cataldo *et* *al*., 1981; Chen *et al*., 1997; Peles *et al*., 1998; Li and Wu, 1999). As the soil pH decreases, metals are desorbed from organic and clay particles, enter the soil solution and, become more mobile (Li and Wu, 1999). When the pH is higher (pH >7), metals remain adsorbed and what metals in solution precipitate out in the form of salts (Chen *et al*., 1997). Variability in pH also affects the amount of Cd assimilated by the plant. John and VanLaerhoven (1972) showed that higher pH resulted in lower Cd uptake. Peles *et al*. (1998) concluded that the addition of lime to contaminated soils (essentially increasing the pH) decreased the uptake of heavy metals. In unlimed soils, Ambrosia trifida accumulated 13.6 µg Cd g-1 of tissue and in limed soils Ambrosia trifida accumulated 2.5 µg Cd g-1 of tissue.

Flexible levels of Cd will increase when acidity of the environment is also raised, starting from the threshold of pH = 4 - 4.5, decrease 0.2 pH units then the Cd concentration will increase 3-5 times (Wang *et al*., 2006). Generally, most heavy metals are less flexible when pH> 6.5 (Oliver *et al*., 2003).

Mainly due to threats on high levels of heavy metals in food chain, thus, in the world there had many studies on heavy metal accumulation into plants. According to Garcia (1994), Cd concentration in nutrient solution is at low level (5 - 10ppm Cd), the growth of lettuce increased but with high Cd level in nutrient solutions (> 10ppm), the growth of lettuce reduced. Singh *et al*. (1998) studied the uptake of Cd in Jill beans on the ground under the influence of waste water. They showed the level of Cd in plants is proportional to the level of cadmium contamination in sludge and waste water. Similarly in soil, uptake of plants also had linear relations with the addition of Cd to soil (Van Lune *et al*., 1997), organic matter, soil texture, soil type (Bride *et al*., 2002). In general, the presence of heavy metals in the environment is closely related with their absorption in plants.

According to On *et al*. (2004), Cd concentration in soil is correlated linearly with the time of using phosphate, especially when phosphate is used on alkaline soil, salinity soil and soil under dyke system.

Heavy metals in water and soil have a relationship with each other. If using contaminated irrigation water for land, it will lead to soil contamination. When soil is highly polluted Cd, it can also be caused by using irrigation water with high concentration of Cd (Folkes, 2001).

Heavy metals from soil enter plants primarily through the root system. In general, plant root is the most important site for uptaking chemicals from soil (Bell, 1992). Cd uptake in plants is mainly concentrated on the roots, in addition, Cd is also absorbed on the leaves, but the amount of Cd is mainly absorbed on the roots (Cieslinski, 1996; Ejaz ul Islam *et al*., 2007).

In the study on effects of fertilizers and irrigation water to heavy metal accumulation in soil (Hong, 2003), it concluded that: If using heavy metal contaminated water to irrigate vegetables, heavy metals will be accumulated through crops. Cd concentration in soil through cases is directly proportional with the concentration of Cd in water.

According to the study of Chien *et al*. (1996) Cd accumulation in plants depends on the amount of phosphorus fertilizer and the amount of cadmium in phosphate fertilizer.

Cadmium tends to be very mobile in soil systems and therefore very available to plants. Cd^{2+} is the main species in soil solution. Accumulation of cadmium in food crops at soil concentrations that are not phytotoxic is a significant concern. Plant species differ widely in their tendency to accumulate cadmium. Absorption/desorption of cadmium is about 10-fold more rapid than that of lead (Pb) (Curtis *et al*., 2002; Fritioff *et al*., 2007).

2.3.2.4 Cadmium (Cd) effects on plant and human

- **On plant**

Khan and Frankland (1983) reported that extremely high concentrations (180 µg g-1) of Cd in soil adversely affected plant development. In their research, radish plants were grown on soils contaminated with Cd and Pb. Within 3 weeks of planting, all plants that were grown in soil contaminated with 1000 µg Cd g-1 were dead. The concentrations of Cd in the soil that produced a 50% inhibition in growth were higher at the seedling stage than at the edible stage. John *et al*. (1972) also showed that plant size and yield were reduced when 50 mg Cd (dosed as $CdCl_2$) was added to 500g of soil. In both studies, chlorosis of the leaves was reported. Khan and Frankland (1983) suggested additive effects from the application of Cd and Pb at the same time. They document a considerable reduction in growth when Cd was added at 50 µg g^{-1} and Pb was added at 1000 µg g^{-1} (Khan and Frankland, 1983).

- **On human**

Cadmium (Cd) contamination of agricultural soil is of worldwide concern due to the food safety issues and potential health risks (Dudka *et al*., 1996; McLaughlin *et al*., 1999; Dorris *et al*., 2002; Tsadilas *et al*., 2005). Cadmium can accumulate gradually in the human body, where it may lead to a number of adverse health effects, such as nephrotoxicity and osteotoxicity (WHO, 1992). Chronic cadmium exposures result in kidney damage, bone deformities, and cardiovascular problems (Curtis *et al*., 2002; Fritioff *et al*., 2007).

Cd enters into the body by different ways, it is accumulated mainly in the kidney and has long biological half-cancel from 20 - 30 years. Consequences of replacing Zn by Cd cause metabolic changes leading to anemia, bone marrow disorders, hypertension and cancer. Usually, excess Cd will bind to protein and transported to accumulate in kidney at about 1%, 99% will be excreted from kidney. Besides, Cd contamination will initially be kidney failure, bone marrow failure and affects the nerves. Also Cd toxicity can lead to birth defects and fetal death in immature stages. Cadmium can cause cancer for people exposed to it at low levels but for a long period, especially breast cancer (Thanh, 2002). According to the regulations of World Health Organization (WHO), Cd is accepted in the body at maximum of 100 mg/day or 1 mg/kg body weight.

Low-level chronic exposure to Cd can cause adverse health effects including gastrointestinal, hematological, musculoskeletal, renal, neurological, and reproductive effects. The main target organ for Cd following chronic oral exposure is the kidney (ATSDR, 1999a). Because cadmium tends to accumulate in the kidneys, the EPA has based the RfD for cadmium on the concentration of the metal in the human renal cortex (EPA 1994a). The highest Cd level in the renal cortex that does not cause significant proteinuria is 200µg Cd/g (EPA, 1994a; ATSDR, 1999a).

For people, Cd in the environment is not much toxic, the main risk to human health from Cd is its chronic accumulation in the kidney. It can cause dysfunction if it focuses in the kidney to 200mg/kg body weight. Food is the main road which Cd gets into the body, Cd is a harmful heavy metal to the body via food and drinking water (MARD, 2001). Cd is easily moved from land to vegetables and hang in there, when entering the body, excess cadmium will destroy kidneys. Many studies showed that Cd causes osteoporosis; fractures; cancer rate is also quite high in people using vegetables contaminated Cd.

2.3.2.5 Management of cadmium (Cd) in Vietnam's agricultural

In Vietnam, the research on heavy metals pollution is still new, but some results showed that a variety of areas which were using urban waste, sewage sludge, waste water or areas next to factories, they all had impact to quality of plants. Tuyen *et al*. (1995) when studied heavy metal residues in agricultural products in the area of Ho Chi Minh City stated that correlation coefficient between heavy metals in water and in spinach is 0.95 for Zn, 0.73 for Pb and 0.94 for Cd. Correlation coefficient between heavy metals in soil and cabbages grown on those areas is 0.98 for Zn, 0.12 for Pb and 0.99 for Cd.

In Vietnam, the source of Cd contamination is mainly caused by industrial waste, mining, electroplating, plastic pipe, painting, etc. According to Ha (2002), when studying the concentration of Cd in soil in areas where influenced by waste water, industrial waste or from traditional villages such as aluminum, copper mound, cast which have a high Cd content.

Besides, using phosphate fertilizer for a long-term will be the crucial factor which decides Cd concentration in soil. According to estimates of the EEC countries, Cd content which is put into soil annually through phosphate fertilizer is 5g/ha (Manh, 2000).

When analyzing the content of Cd in paddy soil samples and mud samples of Van Mon district, Yen Phong, Bac Ninh province, it showed that: The amount of Cd was 1mg/kg of land, there are individual samples with 3.1mg/kg, about 1.1 times higher than Vietnamese Standard, while the amount of Cd in mud samples was 5 times higher than Vietnamese Standard (Ha, 2002).

The use of municipal wastewater to irrigate vegetables will cause the accumulation of heavy metals such as Pb, Cd etc in vegetable products and level of toxic substances in water vegetable products is high than vegetable products in dried water (Le, 2004; Oanh, 2004).

According to research by Cheang Hong (2004), heavy metal content (Pb, Cd) in water was strongly correlated with their quantity in green vegetables; this relationship was more evident in later crops.

The problem of heavy metal pollution in soil and water at concentrated industrial zones and big cities in Vietnam today is an alarming fact. Scientists have also launched many measures to limit pollution, but they are just experiment researches. Currently, there was not any useful technilogical to handle heavy metal pollution in soil and water.

2.4 Factor analysis and multiple regression analysis in heavy metal contamination

2.4.1 Factors analysis

Factor analysis is an interdependence technique, whose primary purpose is to define the underlying structure among the variables in the analysis (Hair *et al.*, 2006). Factor analysis is a technique where a complex data set is simplified by creating one or more new factors each representing a group of interrelated variables within the data set (Davies, 1997; Morselli *et al.*, 2002; Garc´ıa-D´ıaz and M´endez-Romero, 2003).

In environmental science, factor analysis (FA) is a useful statistics tool that can identify origins of heavy metals in soils (Facchinelli *et al*., 2001; Loska *et al*., 2003; Boruvka *et al*., 2005; Martin *et al*., 2006).

According to the Mico *el al*., (2006), the principal component analysis - PCA (Factor analyse) was used to group variables of heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn) contents to analyze relationships between heavy metals contents and soil properties (soil organic matter, clay content, and carbonates) by using correlation matrix and cluster analysis.

Besides, principal component analysis (PCA) has been widely used to assist the interpretation of environmental data (e.g., Tuncer *et al*., 1993; Einax and Soldt, 1999) and to distinguish between natural and anthropogenic inputs (e.g., Garcı´a *et al*., 1996; Facchinelli *et al*., 2001; Lucho-Constantino *et al*., 2005).

2.4.2 Multiple regression analysis

Multiple regression analysis is a statistical technique that can be used to analyze the relationship between a single dependent (criterion) variable and several independent (predictor) variables. The objective of multiple regression analysis is to use the independent variables whose values are known to predict the single dependent value selected by the researcher (Hair *et al.*, 2006).

According to research of Kumaresan and Riyazuddin (2008), factor analysis and linear regression model (LRM) was used to analyse metal speciation and physico-chemical characters of groundwater samples to describe interrelationship between different variables and also tracing the sources of pollution of groundwater of north Chennai, India. Specifically, the trace metal speciation was grouped in separate factor groups and linear regression model (LRM) with correlation analysis was applied to check its validity for prediction of speciation and to apply LRM for rapid monitoring of water.

According to research of Cambra *et al*. (1999), multiple linear regression was used to analysis risk of a farm area near a lead (Pb) and cadmium (Cd) contaminated industrial site. In which, the relation between lead (Pb) and cadmium (Cd) content in soil and plant samples was assessed by multiple linear regressions.

Besides, multiple linear regressions also was used in research of Chumbley (1982) on cadmium and lead content of vegetable crops grown on land with a history of sewage sludge application.

On the basis of published data from metal contaminated soils in the field and some measured data, Efroymson *et al*. (2001) compared single uptake factor, single variable regression model and multiple regression model with soil pH, and recommended the single-variable regression models of log-transformed concentrations in plants versus log-transformed concentrations in soil for estimating the uptake of the inorganic contaminants in soils by plants.

Using multiple regression analysis method in line with procedures used in before research studies in evaluating environment (Kannan, 2002; Thuy *et al*., 2003), multiple regression models was constructed to determine factors affecting cadmium (Cd) and lead (Pb) accumulation in vegetable production systems in Tuc Duyen ward, Thai Nguyen city, Vietnam. Specicially, this study is conducted four multiple regression models to determine factors (independent variables) affecting the accumulation of cadmium (Cd) and lead (Pb) in soils and selected research vegetables. Therefore, determine the influence of each of factors to the accumulation of cadmium (Cd) and lead (Pb) in soil and the vegetables.