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THE POSSIBILITY OF HEAVY METAL ACCUMULATION IN TO LICH RIVER WATER, IRRIGATION WATER, CULTIVATION LAND AND VEGETABLE PRODUCTS IN BANG B HAMLET, THANH TRI DISTRICT, HA NOI, VIET NAM

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ABSTRACT

Hanoi is the capital city of Vietnam, with a high population density, and a concentration of industrial, manufacturing and processing facilities. To Lich river has a length of 14 km, receiving sewage from other rivers and the end streams are used to pump for irrigation of vegetables, supplying for people in Hanoi. The analysis results of heavy metal content (Pb, Cd, Zn, Cu, Hg, Cr_{TS}, As) at 2 different times for samples of surface water in To Lich river, irrigation water, vegetable land and vegetable products (especially water vegetables) in Bang B hamlet, Thanh Tri district, Hanoi, Vietnam show that most of the samples have content of heavy metals in April 2003 much lower than in April, 2019: surface water 1.42-48.6 times lower, vegetable water 1.36-64 times lower, cultivation land 2.26-37 times lower and vegetables 3.02-38.1 times lower. The ability to store heavy metals in a cycle from surface water, irrigation water, soil and vegetables is related to the distant, position, different kinds of vegetable, content and time, affecting the quality of vegetable products and public health.

KEY WORDS: Deposits, Heavy metal, Water, Soil, Vegetable.

INTRODUCTION

The capital of Hanoi, Vietnam is a place with a high population density of 3802 people/km^2, with many industrial production establishments, hospitals, schools, hotels, restaurants and manufacturing facilities. Hanoi's waste water is mainly domestic waste water and industrial waste water containing many hazardous components, partly untreated and partially treated but substandard (especially in some old industrial parks with outdated machinery systems, restaurants, small-scale spontaneous production facilities and from people's daily life) before being discharged into the city's common drainage system. Among 9 industrial parks in Hanoi, there are 5 concentrated industrial parks directly discharging sewage affecting the water environment of to Lich river basin: Minh Khai - Vinh Tuy, Thuong Dinh - Nguyen Trai, Truong Dinh - Duoi Ca , Phap Van - Van Dien, Cau Buou. Waste water from separate sewer lines with small size and hydraulic slope, unreasonable structure, high amount of sediment, discharged directly into rivers. Hanoi's drainage system is a degraded mixed sewer system including rainwater, domestic, industrial and hospital waste water based on the principle of self-flowing into the drainage rivers (Thanh *et al,* 2003).

Hanoi has 4 rivers which are four main drainage axes (Lu, Kim Nguu, Set, To Lich) with a total length of 38.2 km. Lu River is one of the tributaries of the To Lich river, starting from Nam Dong Pond, merging with To Lich river in front of Cau Dau. Kim Nguu River originates from Lo Duc sluice, merging with To Lich river in Cau Son. Set River is one of the tributaries of the Kim Nguu River, starting from the Bay Mau Lake, merging with the Kim Nguu River at the Giai Do junction, about 6 km from the confluence point of the Kim Nguu River and the To Lich River.

(Vesdi *et al.,* 2003). To Lich river receives all the city's waste water before discharging into Nhue River at To Bridge with a length of 14 km. The river receives and transports a large volume of domestic, industrial and hospital waste water from the Ba Dinh area and all waste water from the three rivers Lu, Set and Kim Nguu.

Before the 1990s, To Lich River was an ancient river of Hanoi City, Vietnam with pure river water and busy commercial activities on its banks. To Lich river in Hanoi flows through the territory of 6 districts: Ba Dinh, Cau Giay, Dong Da, Thanh Xuan, Hoang Mai and Thanh Tri. To Lich river together with Kim Nguu, Lu and Set rivers have created the main drainage system of the city. However, for many years, under the pressure of urbanization, asynchronous construction planning together with the lack of awareness of people living along the river have made the river area narrowed, the protection corridor is encroached in many sections, the river water quality is seriously polluted by heavy-metal contamination. Since 1990, when the river was filled, the river has only been a waste stream of the city, heavily polluted. At present, To Lich river receives 700,000 - 900,000m^3 of waste water everyday in Hanoi.

Waste water irrigation is known to contribute significantly to the heavy –metal content of soil. In suburban areas, the use of industrial or municipal waste water is common practice in many parts of the world (Feigin, Ravina and Shalhevet 1991), including Vietnam. Bang B hamlet, Hoang Liet commune, Thanh Tri district is located in the southern part of Hanoi capital, with the last section of To Lich river flowing through, 10 km south of Hanoi city center. Currently, this hamlet is using To Lich waste water to irrigate vegetables, which is an area supplying vegetables to Hanoi *(People's Committee of Hoang Liet Commune et al*., 2003). With the terrain of the accumulation of rivers - lakes - marshes, relatively lower than that of other villages, Bang B is very favorable for agricultural production activities, especially water vegetables: neptunia (Neptunia.oleracea Lour), water dropwort cress (Oenanthe javanica), water spinach (Ludwigia hyssopifolia), watercress (Rorippa rasturtium aquaticum)....*(People's Committee of Hoang Liet Commune, et.al, 2019).* Heavy-metal contamination of soil resulting from waste water irrigation is a cause of serious concern because of the potential health impacts of consuming contaminated produce.

Some studies in Vietnam for heavy metal contamination of water and river sediment and its transfer to the soil and crops, some in Tolich river. After 16 years, from 2003 to 2019, increasing industrialization and population growth have led to increasing fluxes of many heavy metals to soils. This also has great relevance to the Hanoi agroesosystem, where the wastes produces in urban and industrial areas provide the most likely sources of heavy metal pollution, and the dominant sources of soil heavy metal pollution are sewage irrigation. In the long term, irrigation may cause the accumulation of heavy metals at toxics concentrations in the soil and adversely affect both soil microbiological processes and plant. International studies provide the relationship of heavy metals in irrigation water, soil and vegetable, their deposits, effecting on human health (Feigin *et al.,* 1985). In Vietnam, several studies have focused on the content of heavy metals in all units of production cycle, affecting on quality of products. However, there is a lack of empirical data from Vietnam for heavy metal contamination of water and its transfer to the soil and crops.

This study is based on agricultural soil in Bang B hamlet, Thanh Tri district, Hanoi, Vietnam, which is estimated as one of the most polluted agricultural soil areas of Hanoi city and where wastewater from the Tolich system has been used for irrigation of peri-urban crops for several decades. Its objective was to examine, compare, access on accumulating of heavy metal contamination of agricultural soil and plants subjected to the irrigation water polluted with wastes from various industrial plants in Hanoi in two different times (2003 and 2019).

MATERIALS AND METHODS

Samples are taken from surface water, vegetable irrigation water, vegetable cultivation soil and vegetable products. Twelve surface water samples (marked from M1 to M12, Fig. 1) at 12 different points along the To Lich River are the main drain points; thirteen samples of vegetable irrigation water (marked from M1'to M13', Fig. 2) at 13 different points in the beginning, middle and after the pumping station into the field. The beginning, middle and end of concrete water canals, earth canals, at land plots and ponds for washing vegetables before selling; 8 different soil samples (marked from TT1 to TT8, Fig. 3) are collected from the depths of 0-20, 20-40 and 40-60 cm at various distances from the canal (0-80 m) in some cultivated fields; 8 types of vegetables (marked from TT1' to

TT8′, Fig 4) with vegetables (mostly water vegetables, with shallow vegetables for comparison, the main crop in this area and grown all year round) in 8 plots (separate leaf and root). Water samples for watering vegetables, soil and vegetable products were taken in Bang B hamlet. All the samples were taken in accordance with the regulations, at the same time and assessed the content of heavy metals in the water (Pb, Cd, Zn, Cu, Hg, Cr_{TS}, As). At each sampling point, sampling was carried out at 2 different times in April 2003 and 4/2019 in order to compare quality at 2 different times.

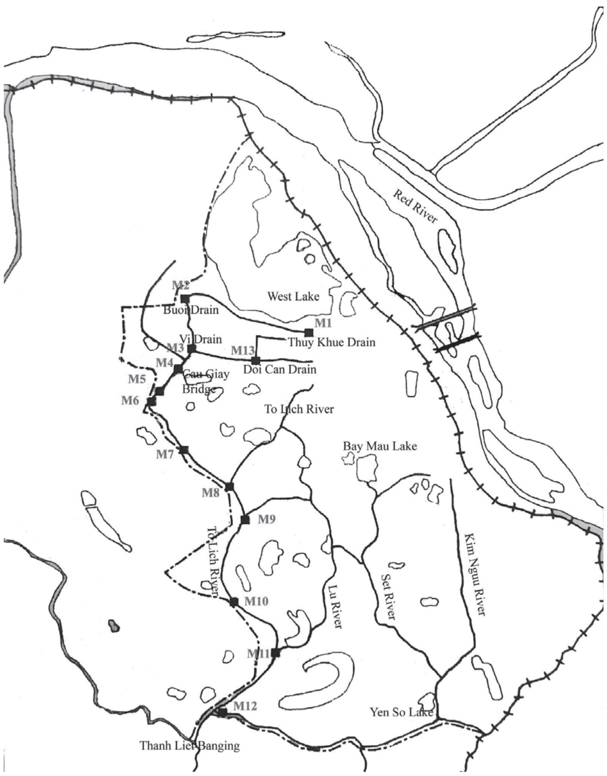

Fig. 1. Location of surface water sampling sites in To Lich river (M1-M12)

Sampling method and heavy metal pollution parameters are determined by atomic absorption spectroscopy (AAS) on the AAS 3300 Perkin Elmers system (Hulshof *et, al.*, 2006).

The analytical results are compared with the current standards of Vietnam (national technical regulation on surface water quality (QCVN 08-MT: 2015/BTNMT), national technical regulation on water quality for irrigated agriculture (QCVN 39: 2011/BTNMT), national technical regulation on the allowable limits of heavy metals in the soils (QCVN 03-MT: 2015/BTNMT, national technical regulation on the limits of heavy metals contamination in food (QCVN 8-2: 2011/BYT); Decision 46/2007/QD-BYT (Decision No. 46/2007/QD-BYT promulgating the regulation on maximum limits of biological and chemical contamination in food).

RESULTS

The total area of water vegetables grown in Bang B hamlet is 80,964 m^2, accounting for 69.2% of the cultivated area, of which neptunia (*Neptunia oleracea*

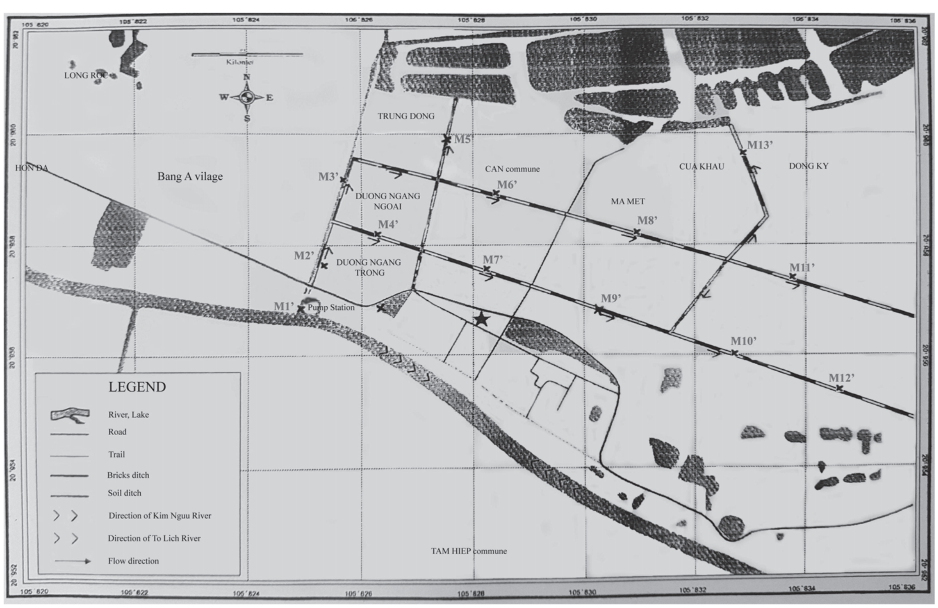

Fig. 2. Location of vegetable irrigation water sampling sites in the field in Bang B hamlet (M1'-M13')

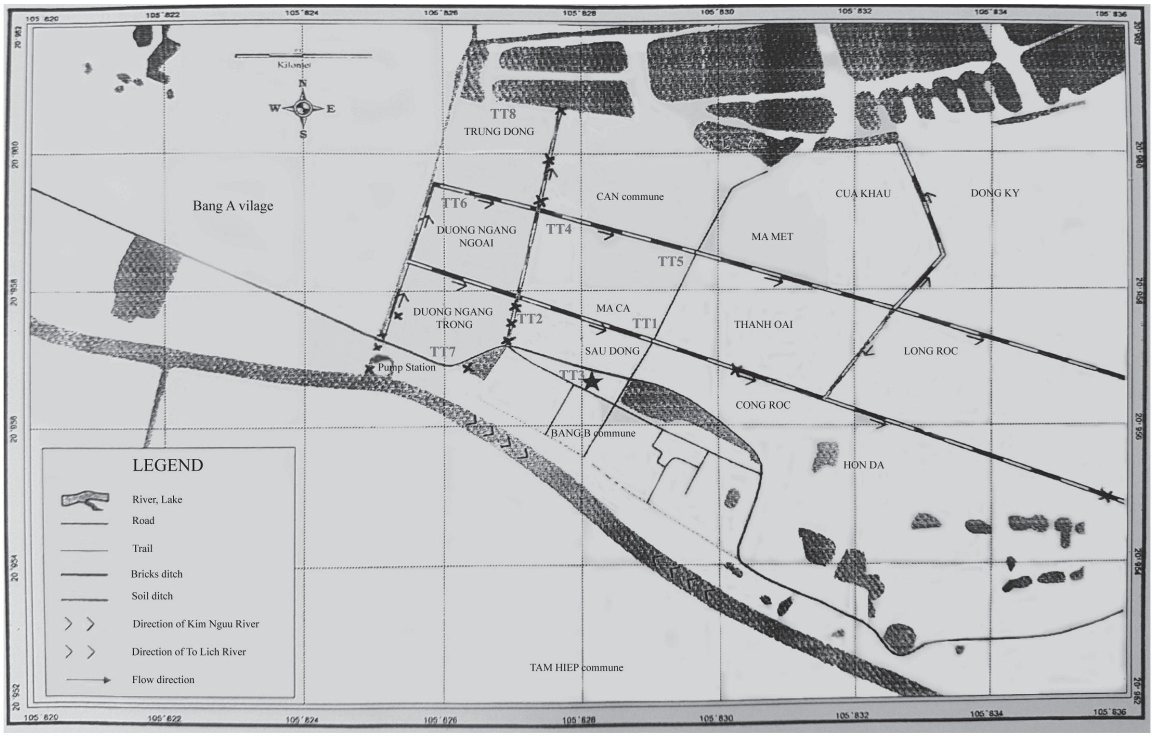

Fig. 3. Location of soil sampling sites in the field in Bang B hamlet (TT1-TT8)

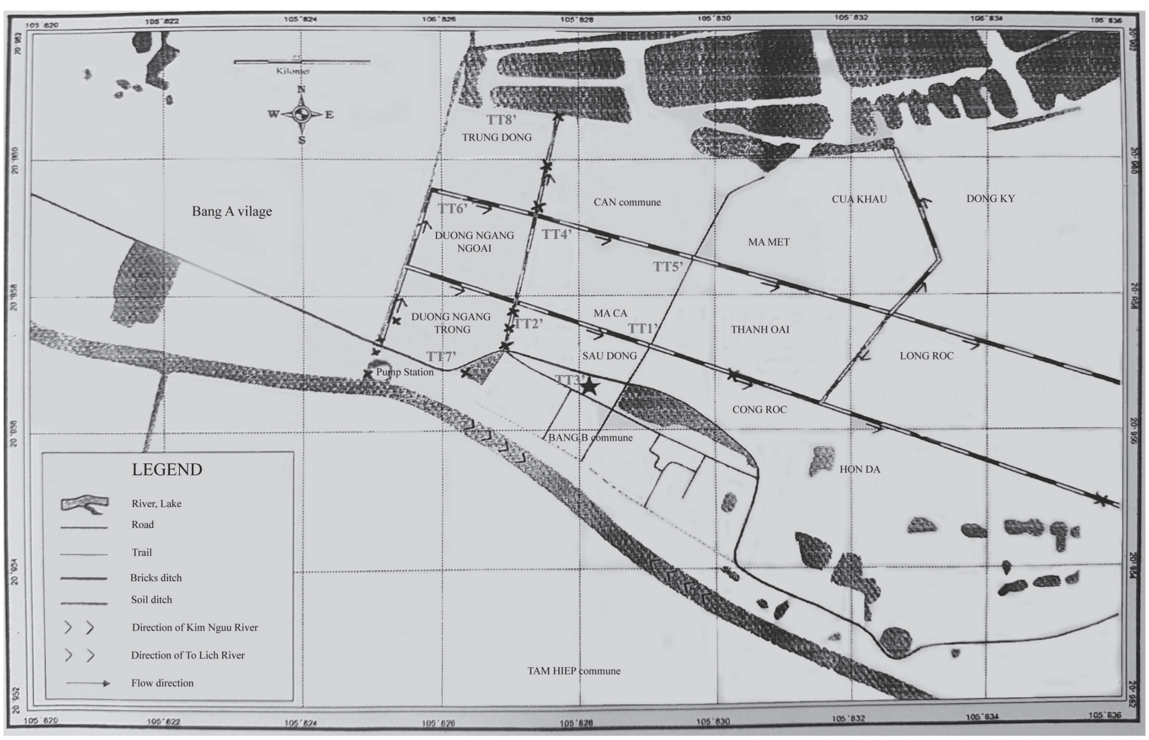

Fig. 4. Location of vegetable sampling sites in the field in Bang B hamlet (TT1′-TT8′)

Lour) accounting for 29,986.7 m^2, water dropwort cress (*Oenanthe javanica*) accounting for 17,992 m^2, water spinach (*Ludwigia hyssopifolia*) accounting for 20,990.7 m^2, watercress (*Rorippa rasturtium aquaticum*) accounting for 11,994.6 m^2, as shown in Fig. 5.

Samples of surface water of To Lich river are preserved. The results of heavy metals content

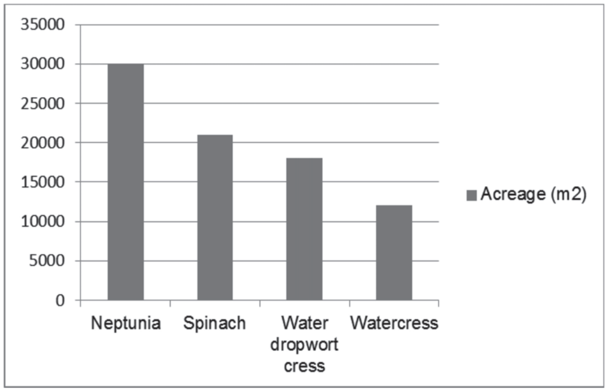

Fig. 5. Acreage of vegetable in Bang B, Thanh Tri, Ha Noi

analysis in To Lich river water, vegetable irrigation water, vegetables soil, vegetable products in April 2003 (*) and 4/2019 (**) are shown in Fig 6,7,8,9, 10,11 respectively.

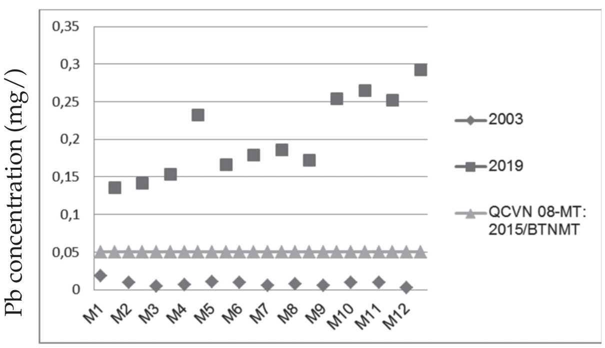

Fig 6. Changes in the concentration of Pb

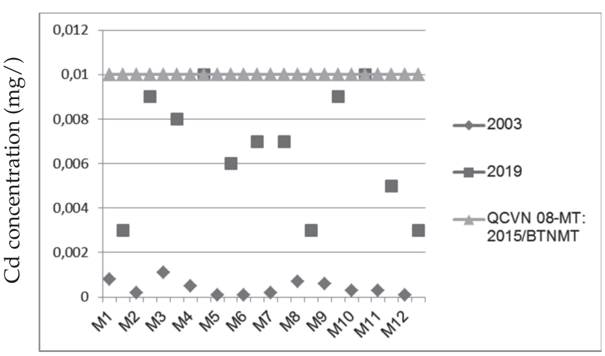

Fig. 7. Changes in the concentration of Cd

The results of heavy metal content analysis vegetable irrigation water in April 2003 (*) and 4/ 2019 (**) are shown in Fig. 12, 13, 14, 15, 16, 17, 18 respectively.

The results of heavy metal content analysis in vegetables soil in the field in Bang B hamlet in April 2003 (*) and 4/2019 (**) are shown in Fig 19, 20, 21, 22, 23, 24 respectively.

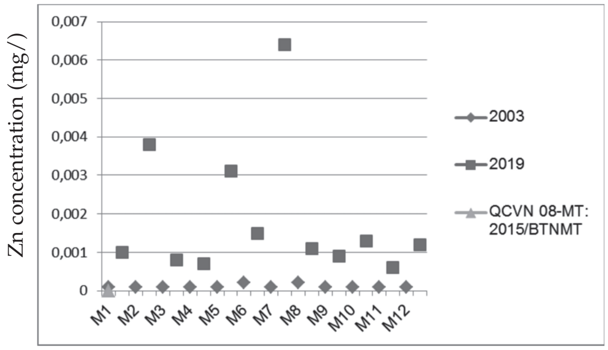

Fig. 8. Changes in the concentration of Zn

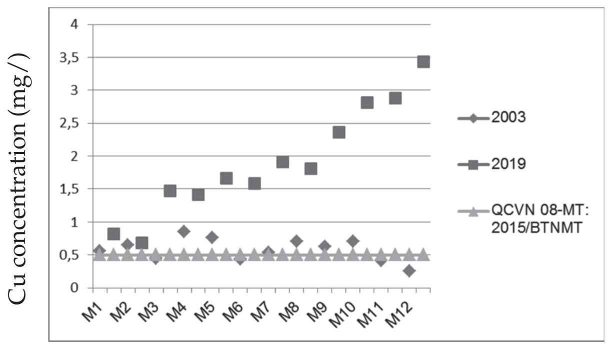

Fig 9. Changes in the concentration of Cu

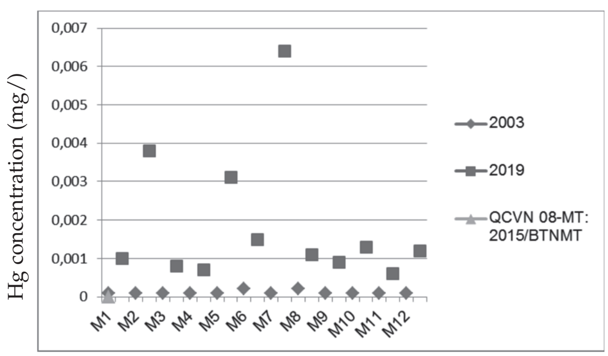

Fig. 10. Changes in the concentration of Hg

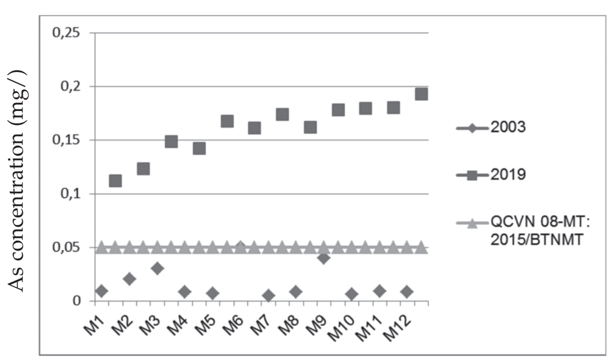

Fig. 11. Changes in the concentration of As

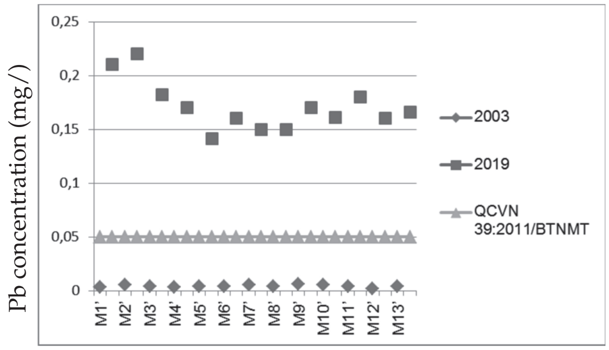

Fig. 12. Changes in the concentration of Pb

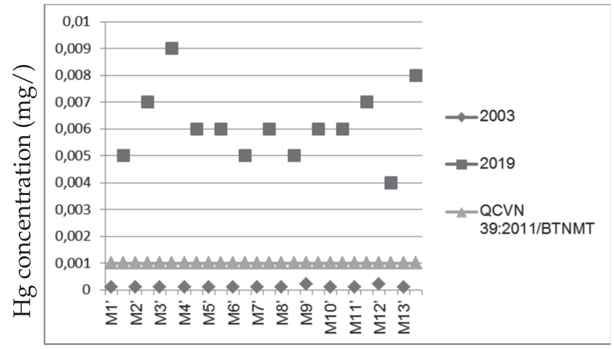

Fig. 16. Changes in the concentration of Hg

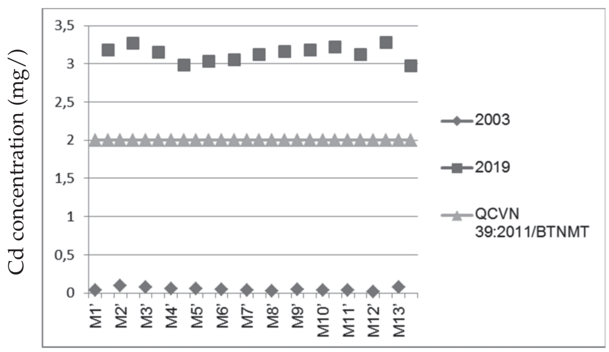

Fig 13. Changes in the concentration of Cd

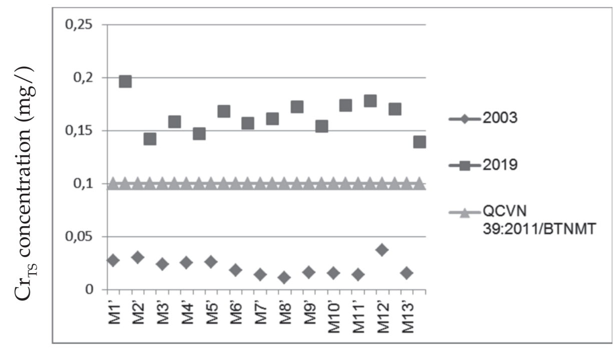

Fig. 17. Changes in the concentration of Cr_{TS}

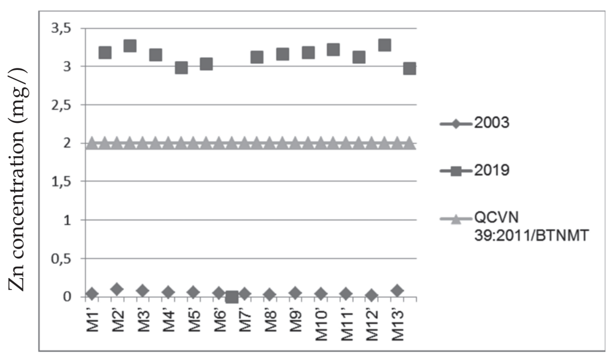

Fig. 14. Changes in the concentration of Zn

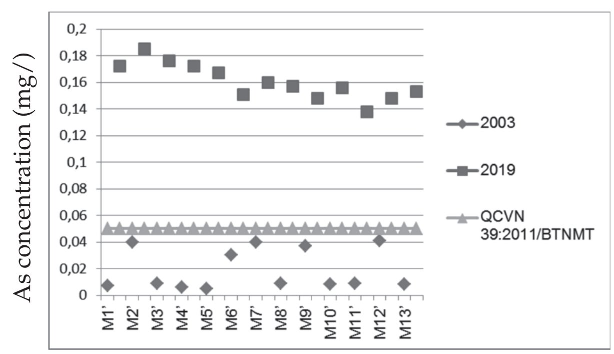

Fig. 18. Changes in the concentration of As

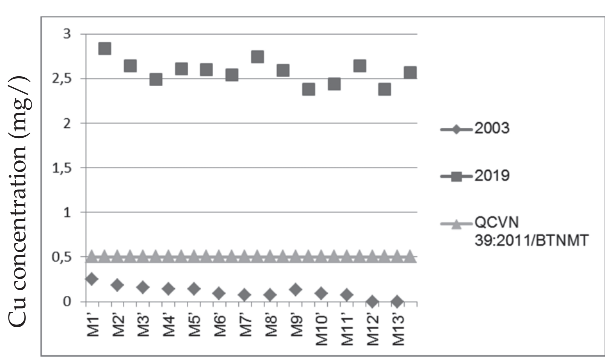

Fig. 15. Changes in the concentration of Cu

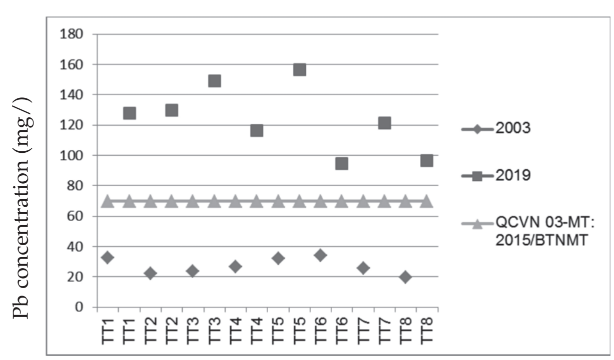

Fig. 19. Changes in the concentration of Pb

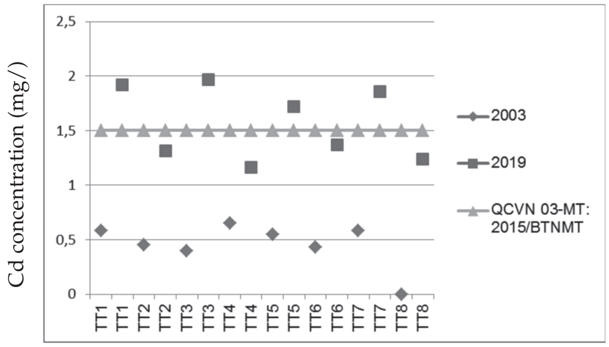

Fig. 20. Changes in the concentration of Cd

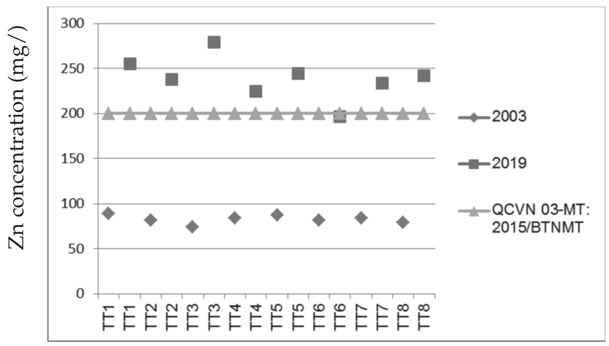

Fig. 21. Changes in the concentration of Zn

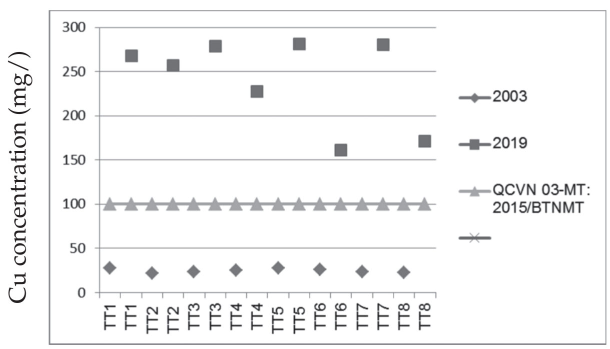

Fig. 22. Changes in the concentration of Cu

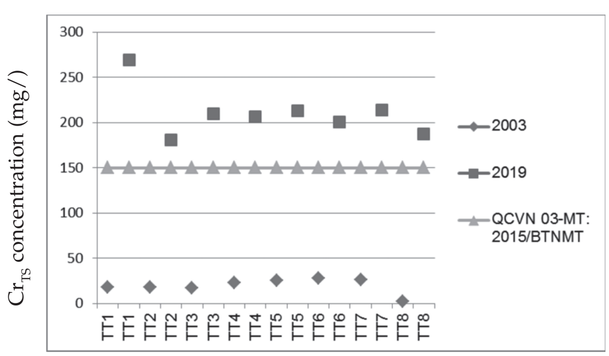

Fig. 23. Changes in the concentration of Cr_{TS}

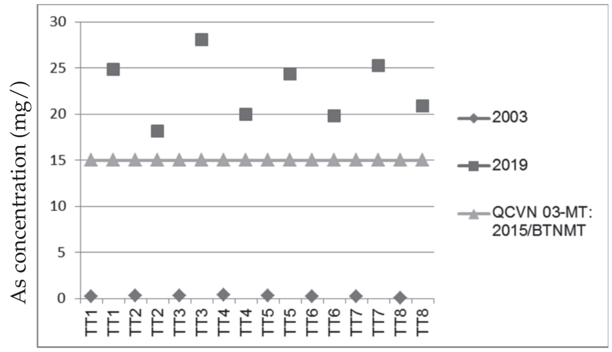

Fig 24. Changes in the concentration of As

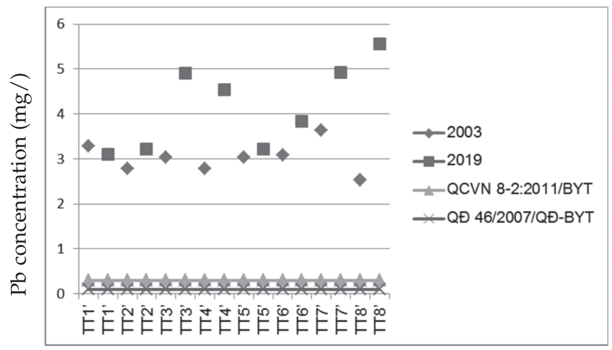

Fig. 25. Changes in the concentration of Pb

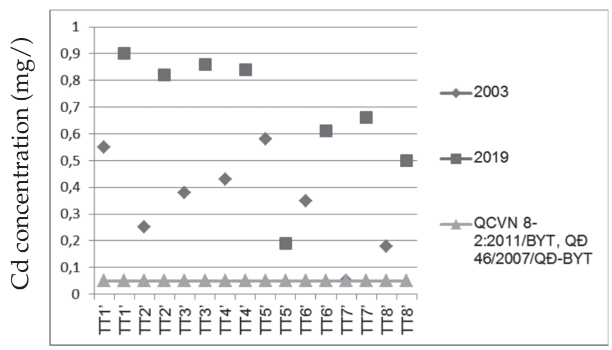

Fig. 26. Changes in the concentration of Cd

TT1 *(0-20 cm)*, TT2 *(20-40 cm)*, TT3 *(0-20 cm)*, TT4 *(40-60 cm)*, TT5 *(0-20 cm)*, TT6 *(40-60 cm)*, TT7 *(0-20 cm)*, TT8 *(20-40 cm)*.

The results of heavy metal content analysis in vegetable products in April 2003 (*) and 4/2019 (**) are shown in Fig. 25, 26, 27, 28, 29, 30 respectively.

Heavy metals moves from river water to vegetable irrigation water and accumulating in vegetables soil in long periods, from 2003 to 2019 are shown in Fig. 31. The analysis results of surface water in To Lich river compared with QCVN 08-MT: 2015/BTNMT at April 2019 decreases in the order Pb>Cu>As>Hg>Zn>Cd>Cr_{TS}. The analysis results of vegetable irrigation water compared with QCVN

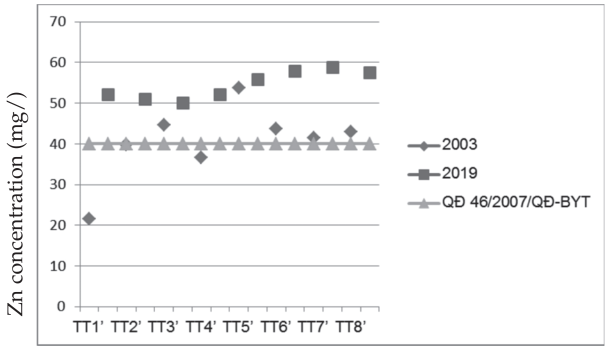

Fig. 27. Changes in the concentration of Zn

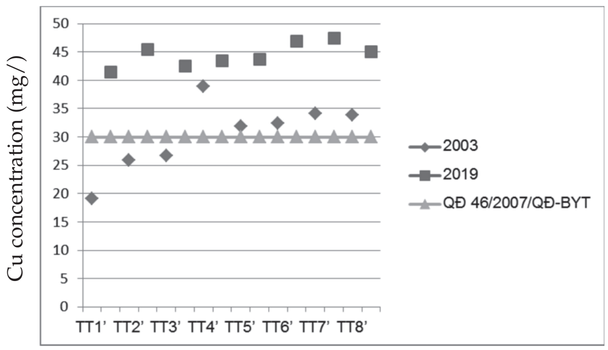

Fig. 28. Changes in the concentration of Cu

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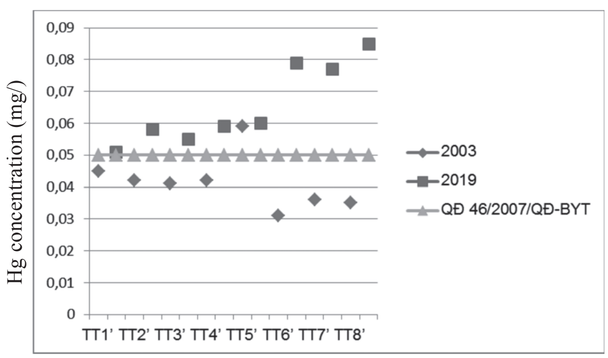


Fig. 29. Changes in the concentration of Hg

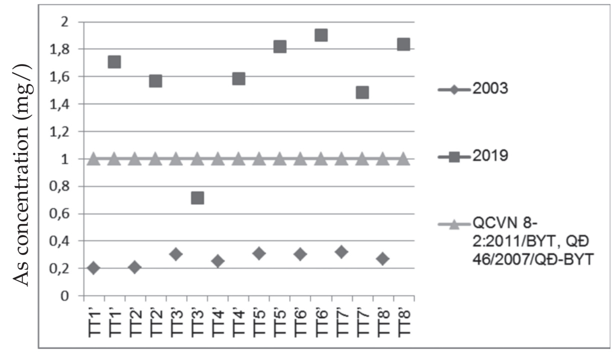
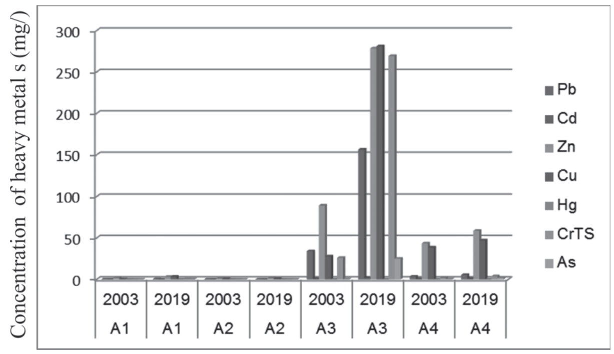


Fig. 30. Changes in the concentration of As



A1: surface water in To Lich, A2: vegetable irrigation water, A3: vegetables soil, A4: vegetables

Fig. 31. Accumulating of heavy metal in river water, vegetable irrigation water, vegetables soil and vegetables from 2003 to 2019

39: 2011/BTNMT at April 2019 decreases in the order Hg>Cu>Pb>Zn>Cr_{TS}>As>Cd. The analysis results of vegetable soil compared with QCVN 39: 2011/BTNMT at April 2019 decreases in the order Pb>Cu>As>Cr_{TS}>Cd>Zn>Hg.

Heavy metals in vegetables are originate from vegetable irrigation water and vegetables soil. The analysis results compared with QCVN 8-2: 2011/BYT and Decision 46/2007/QD-BYT at April 2019 decreases in the order Pb>Cd>As>Cu>Zn>Hg>Cr_{TS}.

DISCUSSION

The analysis results compared with QCVN 08-MT: 2015/BTNMT, as of April 2003, concentrations of heavy metals (Pb, Cd, Zn, Hg, Cr_{TS}, As) in surface water in the above samples of To Lich river all meets the permitted standards. The concentration of heavy metal Zn in some samples is 1.12-1.43 times higher than the permitted standard, with a value of 1.68-2.14 mg/L. The concentration of heavy metal Cu in some samples is 1.08-6.86 times higher than the permitted standard, with a value of 0.54-3.43 mg/L. As of April 2019, with water samples taken at similar locations, the concentration of heavy metals (Pb, Cd, Hg, As, Cr_{TS}) reached the permitted standard. 80% of samples have lower heavy metal content than permitted standards. In April of 2019, the heavy metal content of Pb in some samples is 2.72-5.84 times higher than the permitted standard, with a value of 0.136-0.292 mg/L. The concentration of heavy metal Zn in some samples is 1.06-2.23 times higher than the permitted standard, with a value of 1.59-3.34 mg/L. The content of heavy metal Cu in some samples is 1.08-6.86 times higher than the permitted standard, with a value of 0.54-3.43 mg/L.

The content of heavy metal Hg in some samples is 1.1-3.1 times higher than the permitted standard, with a value of 0.0011-0.0031 mg/L. The heavy metal As content in all samples was 2.24-3.86 times higher than the permitted standard, with a value of 0.112-0.193 mg/L.

Comparing the time 4/2003 with 4/2019, heavy metal content in the samples in April 2003 is low, many samples are lower compared to the permitted standard many times and 1.42-48.6 times lower than at the time April 2019. Most of the heavy metal indicators over time, development trends and specific pollution level have both increased, with concentrations exceeding the allowed standards (Pb, Cu, Hg, As) from 1.06 to 6.86 times. The metal concentration in the surface water exhibited marked increases with distance from the first location.

The analysis results compared with QCVN 39: 2011/BTNMT, as of April 2003, the concentration of heavy metals in vegetable irrigation water in Bang B hamlet all meets the permitted standards. As of April 2019, with water samples taken at similar locations, the concentration of heavy metals increased (Cd, Zn, Hg, Cr_{TS}) but also meets the permitted standards. In 2019, the heavy metal content of Pb in some samples is 2.82-4.4 times higher than the permitted standard, with a value of 0.141-0.220 mg/L. The concentration of heavy metal Zn in some samples is 1.49-1.64 times higher than the permitted standard, with a value of 2.97-3.28 mg/L. The concentration of heavy metal Cu in some samples is 4.76-5.72 times higher than the permitted standard, with a value of 2.38-2.84 mg/L. The content of heavy metal Hg in some samples is 4-9 times higher than the permitted standard, with a value of 0.004-0.009 mg/L. The heavy metal $Cr_{TS'}$ content in some samples is 1.42-1.96 times higher than the permitted standard, with a value of 0.142-0.196 mg/L. The heavy metal As content in some samples is 1.42-1.96 times higher than the permitted standard, with a value of 0.142-0.196 mg/L.

Comparing April 2003 with April 2019, heavy metal content in 83.5% of vegetable watering samples is low, many samples are lower compared to the permitted standard many times and 1.36-64 times lower than the content at April 2019. Most heavy metal indicators over time, trends of development and pollution characteristics increase, with concentrations exceeding the permitted standards (Pb, Zn, Cu, Hg, Cr_{TS}, As) from 1.49-9 times. The metal concentration in the surface water exhibited marked decreases with distance from the beginning location, middle and after the pumping station into the field.

The analysis results compared with QCVN 03-MT: 2015/BTNMT, as of April 2003, the concentration of heavy metals at the layer 0-60 cm of soils in Bang B hamlet mostly meets the allowed standards. As of April 2019, with soil samples taken at similar locations, the concentration of heavy metals increased many times. In 2019, the heavy metal content of Pb in some samples is 1.35-2.24 times higher than the permitted standard, with a value of 94.53-156.48 mg/L. Content of Cd in some samples is 1.15-1.31 times higher than the permitted standard, with a value of 1.72-1.97 mg/L. The concentration of heavy metal Zn in some samples is 1.12-1.39 times higher than the permitted standard, with a value of 224.3-278.64 mg/L. The concentration of heavy metal Cu in some samples is 1.61-2.81 times higher than the permitted standard, with a value of 161.21-281.13 mg/L. The heavy metal $Cr_{TS'}$ content in some samples is 1.21-1.80 times higher than the permitted standard, with a value of 180.91-269.43 mg/L. The heavy metal As content in some samples is 1.21-1.88 times higher than the permitted standard, with a value of 18.12-28.08 mg/l.

Comparing April 2003 with April 2019, heavy metal content in 81.7% of vegetable soil samples is low, many samples are lower compared to the permitted standard many times and 2.26-37 times lower than the content at April 2019. Most heavy metal indicators over time, trends of development and pollution characteristics increase, with concentrations exceeding the permitted standards (Pb, Zn, Cu, Hg, Cr_{TS}, As) from 1.12-2.24 times. The metal concentration was greater in the surface soil than in the subsurface soil for all locations and metal types. The metal concentration in the surface soil exhibited marked decreases with distance from the canal.

The analysis results compared with QCVN 8-2: 2011/BYT and Decision 46/2007/QD-BYT, at April 2003 and April 2019, concentrations of heavy metals (Cu, Hg, Cr_{TS}, As) in vegetables in Bang B hamlet both meet the permitted standards. At the time of April 2003, the Pb content exceeded the permitted standard by 25.3 - 49.1 times; Cd content exceeds the permitted standard 3.6-11.6 times, with a value of 0.18-0.58 mg/kg; Zn content exceeds the allowed standard 1.03-1.34 times, with a value of 41.55-53.75 mg/L.

As of April 2019, 78.5% of the samples had a reduced heavy metal content in the vegetable product, but 85,6% of the samples had an increased concentration. Pb content exceeds the permitted standard by 30.3-55.6 times; Cd content exceeds the permitted standard by 10-18 times, with a value of 0.5-0.9 mg/kg; Zn content exceeds the permitted standard of 1.28-1.47 times, with a value of 51.03-58.76 mg/L; Cu content exceeds the permitted standard of 1.38-1.58 times, with a value of 41.45-47.42 mg/L; Hg content exceeds the permitted standard of 1.02-1.7 times, with a value of 0.051-0.085 mg/L; As content exceeds the permitted standard of 1.57-1.9 times, with a value of 1.568-1.903 mg/L.

Comparing the time 4/2019 with 4/2003, the heavy metal content in the samples is higher, many samples are many times higher than the permitted standard and 3.02-38.1 times higher than the content at the time of 4/2003. All of the heavy metal indicators over time, development trends and specific pollution are increased, all with concentrations exceeding the permissible standards. Initial analysis results also showed that the concentration of heavy metals is higher for water spinach, higher than other water vegetables and especially higher than shallow spinach (spinach grown in dry land, less water demand).

The analysis results and comparison of heavy metal pollution in surface water of To Lich river, irrigation water for vegetables, cultivation soil and vegetable products in Bang B hamlet, Thanh Tri district, Hanoi, Vietnam show that the majority of samples with heavy metal content increased over time (16 years) due to pollution characteristics as well as accumulation capacity, affecting the surface water quality, irrigation water, soil and especially vegetable products supplied to the markets (Ellis *et al.,* 1995). This is a warning that causes a great impact on public health, epidemics and requires in-depth studies on the effects of products and heavy metal content on humans to have specific solutions in the treatment and management of waste water, irrigation water and farming environment, ensuring environmental standards (Gallegos *et al.,* 2009).

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