 DOI: 10.35382/18594816.1.38.2020.554

INITIAL SURVEY OF HEAVY METAL CONCENTRATIONS IN PADDY SOIL AND RICE PLANTS (Oryza sativa L.) NEAR AND FAR FROM OPEN LANDFILL IN SOUTHERN VIET NAM

Nguyen Thanh Giao[1]

Abstract – *The concentrations of heavy metals in soil and rice plants around the landfill area in Dong Thang commune, Co Do District, Can Tho City, Viet Nam needed to be assessed for environmental pollution. Soil samples were collected from four sites (three sites S1, S2, S3 near and one site S4 far away from the landfill area) at soil depths of 0 to 25 and 25 to 50 cm. The rice and soil samples were simultaneously collected at the same locations for analysis of heavy metals. The heavy metals Mn, Zn, Cu, Cr, Ni, Pb and Cd were analyzed using atomic absorption spectroscopy. Six heavy metals including Mn, Zn, Cu, Cr, Ni, and Pb were detected and ranged from 12.3 to 291.0 mg/L for the top soil and 11.2 to 370.0 mg/L for 25 to 50 cm soil layer. However, concentrations of Ni, Cu, and Pb in soil tended to decrease while Mn, Zn and Cr tended to increase with an increase of soil depth near the landfill. A similar tendency of heavy metal concentration with depth was found at S4 except for Cu. The decreasing order of the selected heavy metals concentrations in the two soil layers at near the landfill was Mn>Zn>Ni>Cr>Cu>Pb and these concentrations of heavy metals were within the limits of QCVN 03-MT: 2015/BT-NMT and Canadian Council of Ministers of the Environment (CCME, 2007). The result of the bioaccumulation factor (BAF) in rice plants showed that the selected heavy metals were accumulated more in the root rather than the stem-leaf and grain. Mn was accumulated dominantly in both root and stem-leaf, while Zn, Cu, and Pb only accumulated in the root. Thus, result of this study suggests that is essential to collect and treat the heavy metals in the leachate properly to minimize the distribution of heavy metals to the paddy soil environment.*

Keywords: bioaccumulation, contamination, heavy metals, landfill, leachate, paddy soil, paddy rice.

I. INTRODUCTION

Viet Nam, like many countries, has recently been facing serious environmental pollution from solid wastes as the amounts of generated wastes have been increasing in both quantity and toxicity. According to the National Environmental Report 2011 to 2015 [1], the total amount of urban domestic solid waste generated in the country was 32,000 tons in 2014. The amount of solid waste generated in the Mekong Delta region accounted for 5% of the total generated in the whole country. Can Tho City is generating solid wastes of approximate 893 tons day^{-1} [2]. Solid wastes are being collected and treated at landfill sites. The solid waste is mainly treated in the form of burial, but this technique still faces many problems when landfill sites are not designed to meet standards, and the pollution control process has not been effective, especially with the dispersion of odors and leachate when solid waste contains 53-87% of organic matter [3]. Untreated leachate containing high levels of heavy metals was the most obvious source of surface

[1]Department of Environmental Management, College of Environment and Natural Resources, Can Tho University, Can Tho City, Viet Nam
Email: ntgiao@ctu.edu.vn
Received date: 28th February 2020; Revised date: 15th April 2020; Accepted date: 8th May 2020

water pollution, and was likely to pollute the environment of soil and underground water because it has no management solutions in place to treat and prevent dispersion into the environment [4], [5]. According to the statistics of Technical Infrastructure Department - Ministry of Construction [6], only 203 out of 660 landfill sites across the country are ‘sanitary landfill’ areas, and the remaining were ‘unsanitary’. However, many landfill sites have been overloaded, exacerbating the environmental impacts, which has led to increasingly serious and complex pollution problem in these areas.

II. BACKGROUND

The landfill at Dong Thang Commune, Co Do District, Can Tho City, Viet Nam is in a state of serious overload due to the huge disposal of of solid wastes (approximate 370 tons per day^{-1}) from many districts of Can Tho City. The untreated leachate running out from the landfill areas has significantly affected water, soil and grain rice quality in the land adjacent to the landfills [7]. Leachate contains not only high levels of organic matter and nitrogen but also significant concentrations of heavy metals, so it causes pollution of paddy soil and surface water [7], [8]. Several studies have also shown that heavy metals are often found with high concentrations in and around landfills all over the world [9]–[11], the effects can be exacerbated by the fact that, heavy metals could potentially be present already in paddy fields due to impurities of chemical fertilizers and pesticides [12], [13]. Therefore, heavy metal contamination is always a major concern in several environmental studies since it could be bioaccumulated in microorganisms and then transfer into food chains.[14]–[16]. A former study pointed out that heavy metals could move from soil and water to plant tissue via the uptaking process by roots [12], posing potential risks for human health and ecosystems [17]. Currently, several studies have reported on the quality of water and soil at the landfill and surrounding areas [7], [18]–[22], but very few studies have been carried out on the accumulation of heavy metals in rice plants and assessment of potential risk resulting from exposure. Therefore, this study was implemented to examine the occurrence of heavy metals in two different soil layers of sites both far and surrounding the studied landfill area and heavy metal accumulation in the rice plant including root, stem-leaf, and grain. The findings from this study could provide useful information for local authorities on how to best manage environment and heath risks from heavy metals in leachate from landfill.

III. MATERIALS AND METHODS

A. Study area

Co Do District is a sub-urban district and lies to the west of Can Tho City, which is the central city of the Mekong Delta region. The district has a natural area of 31,047.67 hectares and a population of 122,464 people, of which more than 9,000 people are classed as ethnic minorities (the largest one being the Khmer ethnic group). The district has 10 attached administrative units including Co Do town and Dong Hiep, Dong Thang, Thoi Dong, Thoi Xuan, Thoi Hung, Thanh Phu, Trung Hung, Trung An, and Trung Thanh communes. Co Do District has 79 hamlets. Dong Thang landfill in Co Do District, currently receives 180 tons of municipal and agricultural solid wastes from seven districts in Can Tho City. At present, leachate in the landfill has been collected in the leachate collection ponds but there is no treatment. Figure 1 is a pictorial representation of the study area, and shows where the four samples of soil and rice plants were collected, at S1 $(10^o5'11.47"N; 105^o27'47.18"E)$, $S2(10^o5'7.14"N; 105^o27'46.03"E)$, $S3(10^o5'1.02"N; 105^o27'47.52"E)$ and $S4(10^o4'56.53"N; 105^o27'41.15"E)$.

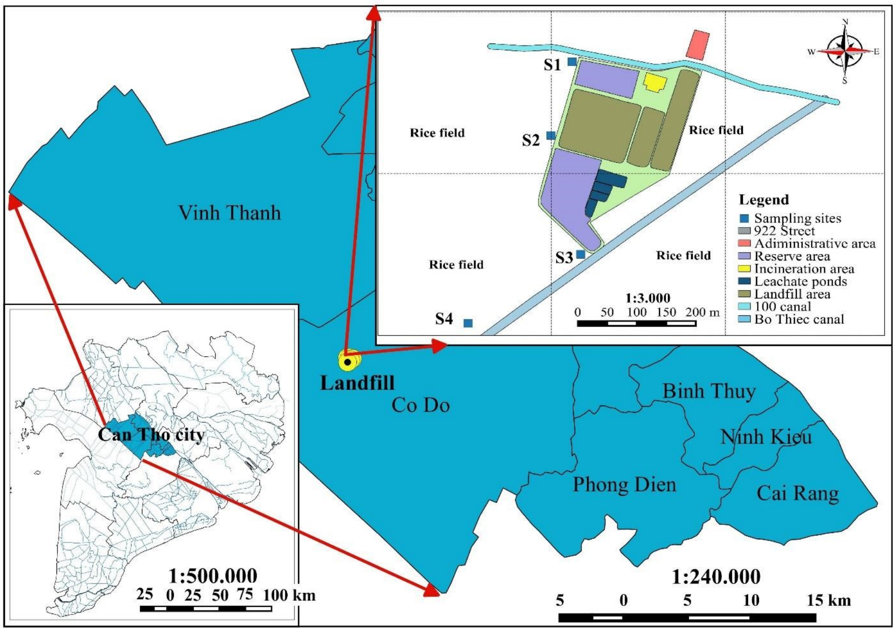

Fig. 1: Study area. (The S1, S2, S3 and S4 represents sampling sites: S1, S2, S3 represents locations near the landfill and S4 represents the rice fields far (1 km) from the landfill).

B. Soil sample collection and pretreatment

At each sampling site, soil samples were collected at 2 different depths of 0-25 cm and 25-50 cm. In total 4 sampling sites were chosen for this study, of which 3 sites were in the rice fields located around the Dong Thang landfill (Figure 1). Three sampling sites were close to the landfill (namely S1, S2, and S3) and one (S4) in the rice field located near the Bo Thiec canal approximately 1 km from the landfill (Figure 1). At each sampling site, the soil sample was collected at five points in the area of $1m^2$. At each point in the squared area, 1 kg of soil was collected as a sample. Then, the soil sample at each point was air-dried, pulverized and mixed well. After that, 50 grams of the pulverized soils were combined to be one soil sample.

C. Rice plant sample collection and pretreatment

At each sampling site in the rice field both soil and rice samples were collected at the same time. Rice samples were collected during the ripening stage (few days before the harvest) at the same locations with the soil samples (Figure 1). IR50440 was the cultivar of rice commonly planted in the study area by farmers. Five whole rice plants were carefully removed from the soil at each sampling site in an area of 1 m2. The collected rice plants were divided into three parts including the root, stem and leaf, and grain. The separated parts of the rice plants at three locations surrounding landfill (S1, S2, and S3) were pooled to be one analysis sample. The heavy metal content in the rice tissue, Cd, Cr, Cu, Ni, Mn, Pb and Zn, were analyzed.

D. Sample extraction and analysis for soil and rice tissues

After sampling, all soil samples were air-dried at room temperature, pulverized and sieved through mesh with a pore size of 0.5 mm for heavy metal analysis. Following the method set by the United State Environmental Protection Agency (EPA3051), the pulverized soil sample (0.5g) was digested using a microwave digester (Multiwave PRO - Rotor 16HF100, Anton Paar, Austria) by adding 10 mL of 65% nitric acid and operated at 1,000 watts of power, with a temperature of 175^{o}C for 15 minutes and 30 seconds. The root, stem and leaf, and grain of rice plants were harvested separately and washed three times with deionized water, oven dried at 70^{o}C and ground to pass through a 1 mm stainless steel sieve. The samples (0.5g) were digested in the microwave digester by adding 8 mL of 65% nitric acid and were run under the following conditions: a power of 1,000 watts and an ambient temperature to 180^{o}C for 40 minutes. Heavy metals, Cd, Cr, Cu, Fe, Ni, Mn, Pb and Zn, were determined by atomic absorption spectrometry (AAS, Agilent, AA240, Australia). All glasswares used in heavy metal analysis were cleaned and washed by being soaked with 0.1 M nitric acid for 24 hours and then rinsed with distilled water. Analysis of heavy metals was performed in triplicates for each soil sample.

Calculation of bioaccumulation factor

Accumulation of heavy metals in the rice was assessed using bioaccumulation factor (BAF), an indicator to determine the ability of a plant to accumulate a specific metal in relation to its concentration in soil [23], [24]. BAF value was calculated using Equation 1:

$$BAF = \frac{C_r}{C_s} BAF = \frac{C_r}{C_s} \quad (1)$$

Where C_r is the heavy metal concentration in each part of the rice plant (mg/kg); Cs is the corresponding heavy metal concentration in the soil (mg/kg); a BAF $\leq$ 1 indicates that the plant only absorbs without accumulating heavy metal; a BAF > 1 shows that the plant accumulates heavy metals; a BAF> 10 indicates the plant is classified as a "super accumulator".

E. Data statistical analysis

The results of the soil sample analysis were compared with QCVN 03-MT: 2015/BTNMT Technical regulation on the allowable limits of some heavy metals in the agricultural soil in Viet Nam [25] and the guidance of soil quality protecting human health and the environment CCME [26]. Comparison of heavy metal concentration in rice samples with QCVN 8-2: 2011/BYT [27], FAO/WHO [28] and a number of countries' permissible level to assess heavy metal concentration in the rice grain. Bioaccumulation of heavy metals in soil and rice was assessed using BAF and a risk assessment was performed using the hazard index (HI). Data on heavy metal concentrations in soil and rice were presented as Mean $\pm$ SD. The difference in heavy metal concentrations at the sampling locations was determined using Analysis of Variance (ANOVA) at a significant level of 5% using IBM SPSS statistics for Windows Software, Version 20.0 (IBM Corp., Armonk, NY, USA).

IV. RESULTS AND DISCUSSION

A. Occurrence of heavy metals in two different soil layers

Table 1 presents the concentrations of heavy metals in two different soil layers of four different sampling sites including three sites surrounding the landfill. Six out of seven heavy metals were detected in both soil layers around the landfill with a concentration range of 12.3 to 291 mg kg^{-1} for the layer 0 to 25 cm and from 11.18 to 370 mg kg^{-1} for the layer 25-50 cm. Table 3 shows that higher concentrations of heavy metals were found in the topsoil and resulted in higher levels of heavy metals in the subsurface soil (25 to 50 cm), for example, the concentration pattern of heavy metals on the two layers was similar in decreasing order of Mn> Zn> Ni> Cr> Cu> Pb. In addition, the concentrations of Mn, Zn, Cu, and Cr on the topsoil (0 to 25 cm) and Mn, Zn, and Ni in the subsurface soil (25 to 50 cm) at the locations S1, S2 and S3 were in general higher than those at S4 (1 km away from the landfill). However, Cr concentration at S1 and Cu at S3 on the topsoil and Mn, Zn, Ni at S2 in the sub-surface soil tended to be lower than those at S4. Cd was the only metal not detected in all soil samples. Previous studies also reported that Cd was at negligible concentration at the landfill [15], [19], [21], [29].

Most of the heavy metal concentrations found in the in soil were in compliance with QCVN 03-MT: 2015/BTNMT [25], CCME [26], Pendias and Pendias [30] and Ewers [31]. The highest concentration of Mn was found in both soil layers with the concentrations ranging from 240 to 321 mg kg^{-1} (topsoil) and from 201 to 629 mg $kg^{-1(subsurface)}$ (Table 1). Mn concentration at both locations S2 and S3 of the topsoil layer tended to be higher than that at the subsurface level, whereas Mn concentration in the topsoil had a tendency of being lower than that of the subsurface layer at S1 and S4 sample sites. Former study of Nhien and Giao [7] at Dong Thang landfill reported that Mn concentrations in the leachate and soil were detected at the concentrations of 0.425 mg L^{-1} and from 190.33 to 209.33 mg kg^{-1}, at the two differing surface levels. It was reported that there was an increase of Mn concentration in the soil at the time of the study. The average Mn concentration at locations around the landfill (S1, S2 and S3) had a tendency of being higher than that at S4 regardless of soil depth, showing the negative impact of the landfill leachate on the surrounding paddy soil environment. From other studies, the mean Mn concentrations in agricultural soil reported in Malaysia (153 mg kg^{-1}), Spain (362 mg kg^{-1}), Jordan (144.6 mg kg^{-1}) and Iran (403.38 mg kg^{-1}), some central provinces in Viet Nam (105.18 to 123.25 mg kg^{-1}) [32], [33] were lower than the Mn concentration in this present study. This was also in line with the previous findings by Klinsawathom et al. [15] and Kanmani and Gandhimathi [19]. According to the research by Satachon et al. [17] Mn content in organic rice fields in Thailand ranged from 8.82 to 18.60 mg kg^{-1}. The use of chemicals in soil for agricultural purposes may also lead to an increase of Mn concentrations [17], [34]. The spread of heavy metals in soil depends on many factors such as time, chemical properties of leachate, the hydraulic regime of underground water [4]. Cr concentration at S4 had a tendency of being lower than S2 and S3 in the topsoil, this could be because the amount of Cr in soil at S4 is not directly affected by the landfill leachate, but agricultural activity. Further study is needed to elaborate this point. The concentration of Cr in the Central Coast region was recorded from 1.99 to 2.18 mg kg^{-1} [32] which was much lower than found in this study. The presence of Cr in soil is a major threat to plants and humans because under appropriate environmental conditions Cr (III) is easily converted to Cr (VI) - a toxic form [35].

At locations around the landfill sites (S1, S2 and S3), the average Ni concentration tended to decrease with depth, ranging from 33.9 mg kg^{-1} (in topsoil) to 32.7 mg kg^{-1} (subsurface). Zn concentration ranged from 65.8 to 82.7 mg kg^{-1} for 0 to 25 cm layer and from 60.5 to 93.8 mg kg^{-1} for 25 to 50 cm layer. In contrast to Ni, the average Zn concentration in topsoil tended to be higher than that at site S4 and tended to increase with soil depth (Table 1), which could pose a threat to groundwater quality because Zn concentration appeared with the high concentration (after Mn). Previous study also reported that Ni and Zn in the Dong Thang landfill ranged from 13.03 to 27.17 mg kg^{-1} and from 63.93 to 84.33 mg kg^{-1}, at the two soil depths [7]. The concentration of Ni ranged from 5.05 to 26.30 mg kg^{-1} and Zn varied from 27.70 to 55.60 mg kg^{-1} in the soil sampling sites surrounding landfill in Thailand [15]. Ni and Zn concentrations in this study tended to be higher and than those found in agricultural soil in the Mekong Delta, Central Coast Delta (Viet Nam) and Thailand [12], [17], [32], [36]. The distribution of Ni and Zn

Table 1: Heavy metals concentrations in two different soil layers of 4 different sites

Depth	Heavy metals	Heavy metal concentration (mg kg^{-1})					QCVN 03-MT:2015/BTNMT	CCME, 2007
		S1	S2	S3	S4	Average (S1, S2, S3)		
0-25cm	Mn	321.0±2	240.0±0	315.0±2	234.0±8	291.0±38.85	-	-
	Zn	78.8±0	82.7±0.70	65.8±0.35	74.7±0	75.8±7.70	200	200
	Cu	20.4±0	19.0±0.27	14.7±0.01	17.6±0	18.1±2.66	100	63
	Cr	9.7±0.56	27.5±0.70	28.3±0.05	11.1±0.4	21.8±9.12	150	64
	Ni	34.9±0	36.3±0.50	30.5±0.25	35.6±0.45	33.9±2.66	-	50
	Pb	14.6±0.03	12.6±0.02	9.7±0.08	13.1±0.50	12.3±2.14	70	70
	Cd	ND	ND	ND	ND	ND	-	3
25-30cm	Mn	629.0±7	201.0±0	280.0±6	257.0±1	370.0±197.12	-	2,000
	Zn	91.7±0.35	60.5±0.05	93.8±0.05	75.2±0	82.0±16.15	200	200
	Cu	14.7±0	15.3±0.01	19.4±0.02	18.8±0	16.3±2.20	100	63
	Cr	28.3±1.05	26.8±0.00	22.5±1.40	32.5±0	25.9±2.73	150	64
	Ni	34.2± 0.05	26.1±0.05	37.8±0.10	31.5±0.90	32.7±5.21	-	50
	Pb	11.7± 0.01	10.7± 0.06	11.2±0.48	13.6±0.03	11.2±0.46	70	70
	Cd	ND	ND	ND	ND	ND	-	3

(Notes: ND: not detected)*

concentration at all study locations and the soil layers were mainly influenced by the impact of leachate, mobility of the metals and soil properties. At the same time, the impact of physicochemical processes in soil or the use of fertilizers may also affect the heavy metal distribution [37], [38].

Cu and Pb were presented in soil with relatively low concentration varied from 16.3 - 18.1 mg kg^{-1} and 11.2 - 12.3 mg kg^{-1}, respectively (Table 1). Cu in the topsoil layer at S1 and S2 sites tended to be higher than that of S4 in the same layer while Cu of S3 site was lower. In contrast to this Cu at the subsurface layer of (25 to 50 cm) of the sites S1 and S2 tended to be lower than that of S3 but higher than that of S4. The use of agrochemicals for agricultural cultivation may also contribute to the high level of Cu in the paddy soil regardless of the location whether close by or far away from the landfill [39]. However, the mean concentration of Cu of the sites around the landfill tended to decrease with depth of soil which was in similar trend to that found at Ampar Tenang landfill in Malaysia [40]. For some agricultural cultivation areas around the landfill, Cu concentrations were recorded at a variation between 18.43 and 26.7 mg kg^{-1} [7] and between 24.52 and 28.54 mg kg^{-1} [15]. Previous studies showed that the concentration of Cu in agricultural soil of the Mekong Delta (Viet Nam), Samut Songkhram (Thailand) and Tanzania were in the ranges of 15 - 18 mg kg^{-1}, 17.01 - 19.92 mg kg^{-1} and 15.5 - 20.13 mg kg^{-1}, respectively [12], [36], [41]. This comparison indicates that concentrations of Cu in the agricultural soil surrounding the Dong Thang landfill was close to those in natural soils in the agricultural areas without the influence of landfilling activity.

The Pb concentration in the topsoil at the S4 site was calculated to be 13.1 mg kg^{-1} and tended to be higher than those of other sites (9.66 - 12.6 mg kg^{-1}) and Pb of the topsoil tended to be higher than that of subsurface soil layer regardless of the soil sampling sites. In the same study area, Pb concentration in the current study (11.2 -

12.3 mg kg^{-1}) tended to accumulate higher than the previous study of Nhien and Giao [7] (2.31 - 4.23 mg kg^{-1}). Several previous studies also reported that Pb concentrations in soil samples surrounding landfills were relatively high, ranging from 5.28 mg kg^{-1} (Thailand) to 8.35 mg kg^{-1} (Nigeria) [5], [13], [19] and from 6.23 to 8.79 mg kg^{-1} [32].

Six out of the seven heavy metals were detected in the soil sampling sites surrounding landfill and one km away from landfill at two different soil depths. The varying distribution of each heavy metal at the study sites was partly due to the impact of the landfill leachate, properties of soil, and heavy metals [8], [42], [43]. The occurrence of heavy metals could be also from the use of fertilizers and pesticides for agricultural activities [7], [17], [44]. The presence of heavy metals in paddy soil not only affects the quality of the soil but also threatens the groundwater and rice grain quality.

B. Heavy metals in rice plant

It was found that six out of the seven heavy metals tested for occurred in parts of the rice plant including the root, stem-leaf, and rice grain (Table 2). The Cd concentration was below the detection limit, and below the FAO/WHO regulatory standard (0.2 mg kg^{-1}).

Heavy metals were found to accumulate in the rice roots (Table 2), where the concentration of Mn, Zn, Cu, Pb, Ni and Cr in the rice root of S1-S3 sites was 674 mg kg^{-1}, 87.6 mg kg^{-1}, 29.3 mg kg^{-1}, 11.7 mg kg^{-1}, 16.9 mg kg^{-1}, and 10.4 mg kg^{-1}, respectively, and from site S4 was 403 mg kg^{-1}, 104 mg kg^{-1}, 28.0 mg kg^{-1}, 14.5 mg kg^{-1}, 7.95 mg kg^{-1}, and 5.04 mg kg^{-1}, respectively (Table 2). In addition, the concentration of Mn, Cu, Cr and Ni at S4 had a tendency to be lower than the locations near the landfill; whereas Zn and Pb at S4 tended to be higher than those of mean values of S1-S3. The occurrence of Pb in the roots with levels greater of than 10 mg kg^{-1} could affect rice growth [45]. The concentrations of Mn, Zn, Cu, Pb and Ni in roots in the current study were higher than those found in the previous study by Klinsawathom et al. [15]. In addition, the concentration of Zn and Cu in the root of rice in the paddy field in Thailand was 29.36 - 42.91 mg kg^{-1}, and 6.21 - 14.62 mg kg^{-1}, respectively [12]. The results imply that heavy metal concentrations in rice roots in the area are influenced by the landfill leachate. The content of Mn, Zn, Cu, Ni, and Cr of the locations surrounding the landfills (S1-S3) in the stem-leaf of the rice plants was 645 mg kg^{-1}, 47.6 mg kg^{-1}, 5.42 mg kg^{-1}, 4.37 mg kg^{-1}, and 2.30 mg kg^{-1}, respectively, whereas from the site S4 only Mn, Zn, Ni, and Cu were found in this part of rice plant collected with the concentration of 544 mg kg^{-1}, 61.5 mg kg^{-1}, 2.78 mg kg^{-1}, and 1.96 mg kg^{-1}, respectively (Table 2). Except Zn, from the site S4, the other parameters that detected elements in the stem-leaf of the plant had a lower concentration than those of S1-S3 in the same part of rice plant.

The concentration of Mn, Zn, Cr, Cu, and Ni in the rice grains of the sampling sites (S1-S3) surrounding the landfill was 237 mg kg^{-1}, 35.8 mg kg^{-1}, 5.67 mg kg^{-1}, 4.27 mg kg^{-1}, and 4.25 mg kg^{-1}, respectively while the concentration of Mn, Zn, Ni, Cu, and Cr in rice grain of the site S4 was 129 mg kg^{-1}, 17.7 mg kg^{-1}, 1.68 mg kg^{-1}, 1.45 mg kg^{-1}, and 0.57 mg kg^{-1}, respectively. The average concentration of heavy metals in the rice grains at the sites S1-S3 had a tendency of being higher than those of S4, by about 1.49 to 2.94 times. This study found that the accumulation of heavy metals in the rice grain in the paddy field surrounding the landfill was higher than those found in the previous study by Klinsawathom et al. [15]. Former studies have found that Mn, Cr, Ni, Zn, and Cu can accumulate in rice grains in paddy soils with the concentrations of 15 - 80 mg kg^{-1}, 0.014 - 0.79 mg kg^{-1},

Table 2: Concentrations of heavy metals in different parts of rice plants from different sampling sites

Sampling sites	Heavy metals	Concentration of heavy metals (mg kg^{-1})			QCVN 8-2:2011/BYT
		Root	Stem - Leaf	Grains	
S4	Mn	403.0±6.66	544.0±15.87	129.0±11.59	-
	Zn	104.0±2.08	61.5±0.55	17.7±0.82	-
	Cu	28.0±1.85	2.0±0.82	1.5±0.13	-
	Cr	5.0±0.09	ND	0.6±0.01	-
	Ni	8.0± 0.34	2.8±0.09	1.7±0.30	-
	Pb	14.5±0.80	ND	ND	0.2
	Cd	ND	ND	ND	0.4
Mean value (S1, S2 and S3)	Mn	674.0±12.53	645.0±8.72	237.0±21.79	-
	Zn	87.6±0.93	47.6±1.08	35.8±0.17	-
	Cu	29.3±0.20	5.4±0.34	4.3±0.07	-
	Cr	10.4±0.06	2.3±0.05	5.7±0.25	-
	Ni	16.9±0.68	4.4±0.16	4.3±0.13	-
	Pb	11.7±0.07	ND	ND	0.2
	Cd	ND	ND	ND	0.4

(Notes: Data were presented as Mean ± SD, n = 3. ND: not detected)*

0.12 - 3.6 mg kg^{-1}, 3.47 - 14.70 mg kg^{-1}, and 2.08 - 2.8 mg kg^{-1}, respectively [13], [17], [30], [32], [46]–[49]. The findings from the current study and the literature review indicate that the accumulation of heavy metals in rice grains from paddy soil surrounding the landfill is higher than those from sites being far, or without being affected by the landfill leachate. The concentration of Cr in rice grain collected from the site S1-S3 (near the landfill) was ten times higher than that of the site S4 (1000 m away from the landfill). This fact could indicate the serious impact of landfill leachate on the rice grain quality and pose a threat to rice consumers since Cr is considered a carcinogenic metal [35], [50], [51]. A Cr limit has not been established in Viet Nam, but Cr concentration in the current study in the rice grain exceeded approximately 5 times compared with the allowed MAC threshold in China (1 mg kg^{-1}) [53]. It could be concluded that higher concentration of heavy metals in soil influenced by the landfill leachate resulted in higher accumulation of heavy metals in rice grain.

Among the heavy metals, Mn was highly accumulated in rice plants which could be due to its higher mobility compared to the other metals [54]. This study found that the accumulation of heavy metals in most parts of rice at S1-S3 was higher that those of S4 (except for Zn and Pb in rice roots) and decreased in the order of Mn> Zn> Cu> Ni> Cr (except in rice grain, Cr> Cu> Ni). Heavy metals accumulated in different parts of rice plant can be ranked with decreasing order of root > stem - leaf > grain (except for Mn at S4 and Cr at S1 - S3).

C. Bioaccumulation factor of heavy metals in rice plants

The bioaccumulation factor (BAF) was calculated for the accumulation of heavy metals from the soil into parts of rice plants which was presented in Figure 2. The BAF coefficients pointed out that the accumulation of heavy metals in the rice grain was not readily detected (BAF <1).

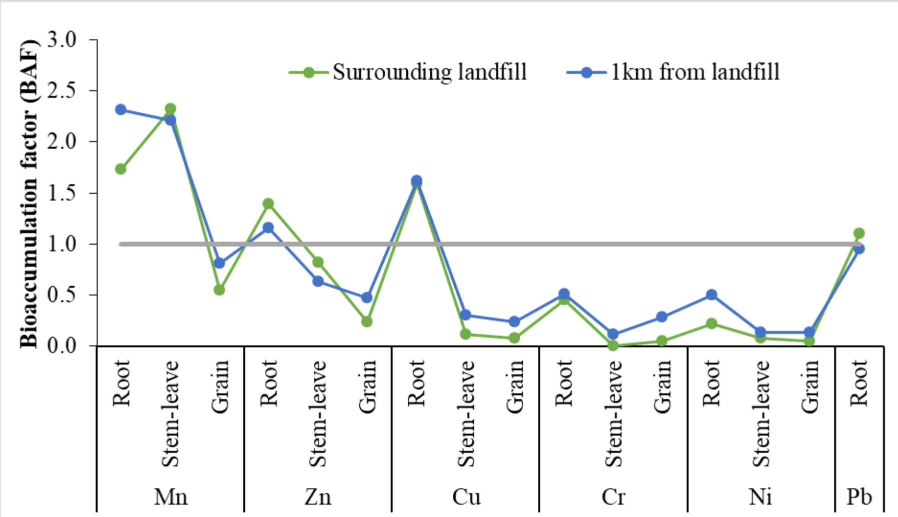

Fig. 2: BAF values for heavy metals in the different parts of rice plants

The BAF value for Mn, Zn, Cr, Cu, and Ni was 0.81, 0.47, 0.28, 0.24 and 0.13 respectively. As could be seen from Figure 2, Mn was the metal with the highest BAF in the root and stem-leaf of the plant while Ni was one with the lowest BAF in all different parts of rice plants. Previous studies also found that although heavy metals were detected in rice grains, the BAF values in the rice plant were still lower than 1 [15], [32]. In addition, previous studies have also showed that Mn, Zn, and Cu were also strongly absorbed by plants [17]. However, continual consumption of heavy metal contaminated rice grain could lead to a bioaccumulation of heavy metals in the human body and consequently result in adverse health impacts [55]. The current study found that Mn, Cu, Zn, and Pb accumulated mainly in the root of the plant with BAF values of 2.31, 1.62, 1.16 and 0.95, respectively. However, only Mn was found to be accumulated in the stem - leaf of the rice plant with the BAF value being relatively high (2.21). Previous studies also reported that Mn could accumulate in the root, stem-leaf of the rice plants planted around the landfill and uncontaminated agricultural land [15], [17]. This study found that BAF values for heavy metals in most parts (root, stem-leaf, and grain) of the rice plants at locations S1-S3 tended to be higher than those at S4 (except for Zn and Pb in root, Mn and Zn in stem-leaf). The findings show the influence of the landfill leachate to the surrounding environment and the dispersion of pollutants to the vicinity. Accumulation of heavy metals in the different parts of rice plants was varied with a decreasing order of root> stem-leaf > grain (except Mn and Cr). Despite the BAF <1, the presence of heavy metals in different rice parts, especially Ni, Cu, and Cr could pose a serious threat to human health and ecosystems.

V. CONCLUSION

Six out of the seven heavy metals, Mn, Zn, Ni, Cr, Cu, and Pd, were detected and were under the permitted limits of QCVN 03-MT: 2015/BTNMT and CCME in two different soil layers at two different study sites. The concentration of the detected heavy metals in the topsoil (0-25cm) of the sampling site of S1-S3 around the landfill had a tendency of being higher than those of the site S4, 1 km away from the landfill with the exception for Ni, and Pb. For the subsurface soil depth of 25-50 cm, the concentrations of Cr, Pb, and Cu of S4 were higher than those at the sites S1-S3. The presence of the heavy metals (except Cd) in soil depth of 25-50 cm could potentially result in serious groundwater pollution. The concentration of the heavy metals in the different rice parts cultivated in paddy soil surrounding landfill site ranked with a decreased order of Mn> Zn> Cu> Ni> Cr (except for the heavy metals in the rice grain with the order of Cr > Cu > Ni). Cd was not detected in the rice plant and Pb only appeared in the roots. Most of the heavy metals in the rice parts sampled in paddy soils around the landfill tended to be higher than those of the site being 1km away from the landfill. The detected heavy metals were found in the decreasing order of root > stem and leaf > grain. BAF values indicate that heavy metals, Mn, Zn, Cu, and Pb, accumulated in rice roots and Mn was found both in the rice root and rice stem-leaf. More soil, surface water and ground water samples of sites surrounding and far from the landfill should be sampled to determine the concentration of heavy metal and a management strategy should be taken to minimize the leakage of leachate into rice fields.

REFERENCES

[1] Ministry of Natural Resources and Environment. *Viet Nam state of environment report for the period 2011-2015*; 2015.

[2] People's Committee of Can Tho City. *Report on state of environment in Can Tho City in the period of 2011 – 2015*; 2015.

[3] Hoang N.X., Viet N.H. Solid waste management in Mekong Delta. *J. Viet. Env*. 2011;1(1): 29-35.

[4] Ha H.N. Heavy metal pollution from landfill site to soil environment: Kieu Ky - Gia Lam - Hanoi landfill. *Hanoi National University Journal of Science: Earth and Environment Sciences*. 2018;2:86-94.

[5] Fatta D., Papadopoulos A., Loizidou M. A study on the landfill leachate and its impact on the groundwater quality of the greater area. *Environ Geochem Health*. 1999;21(2):175-190.

[6] Department of Technical Infrastructure - Ministry of Construction. *Finnish - Vietnamese cooperation forum on water supply, drainage and solid waste treatment*. Ho Chi Minh City, Viet Nam; 2016.

[7] Nhien H.T.H., Giao N.T. Environmental Soil, Water, and Sediment Quality of Dong Thang Landfill in Can Tho City, Viet Nam. *Applied Environmental Research*. 2019;41(2):73-83.

[8] Ha H.N. Heavy metal pollution from landfill to land environment: Kieu Ky - Gia Lam - Hanoi landfill. *Journal of Science Hanoi National University: Earth and Environment Sciences*. 2018;2:86-94.

[9] Alam S.S., Osman K.T., Kibria G. Heavy metal pollution of soil from industrial and municipal wastes in Chittagong, Bangladesh. *Archives of Agronomy and Soil Science*. 2012;58(12):1427-38.

[10] Nava-Martinez E.C., Flores-Garcia E., Espinoza-Gomez H., Wakida F.T. Heavy metals pollution in the soil of an irregular urban settlement built on a former dumpsite in the city of Tijuana, Mexico. *Environmental Earth Sciences*. 2012;66(4):1239-1245.

[11] Ajah K.C., Ademiluyi J., Nnaji C.C. Spatiality, seasonality and ecological risks of heavy metals in the vicinity of a degenerate municipal central dumpsite in Enugu, Nigeria. *Journal of Environmental Health Science and Engineering*. 2015;13:1-14.

[12] Kingsawat R., Roachanakanan R. Accumulation and distribution of some heavy metals in water, soil and rice fields along the Pradu and Phi Lok canals, Samut Songkhram province, Thailand. *Environment and Natural Resources*. 2011;9(1):38-48.

[13] Liu J., Li K., Xu J., Zhang Z., Ma T. Lead toxicity, uptake and translocation in different rice cultivars. *Plant Science*. 2003;165:793-802.

[14] Munees A., Abdul M. Bioaccumulation of heavy metals by Zn resistant bacteria isolated from agricultural soils irrigated with waste water. *Bacteriology Journal*. 2012;2(1):12-21.

[15] Klinsawathom T., Songsakunrungrueng B., Pattanamahakul P. Heavy Metal Concentration and Risk Assessment of Soil and Rice in and around an Open Dumpsite in Thailand. *EnvironmentAsia*. 2017;10(2):53-64.

[16] Purves D. *Trace-element contamination of the environment*. Amsterdam: Elsevier; 1985, 235 pages.

[17] Satachon P., Keawmoon S., Rengsungnoen P., Thummajitsakul S., Silprasit K. Source and Health Risk Assessment of Some Heavy Metals in Non-Certified Organic Rice Farming at Nakhon Nayok Province, Thailand. *Applied Environmental Research*. 2019;41(3):96-106.

[18] Loi L.T., Pham Thanh Vu P.T., Thao N.V. Land situation and proposing solutions for using agricultural land in Phong Dien District, Can Tho City. *Science Journal of Can Tho University*. 2012;22:40-48.

[19] Kanmani S., Gandhimathi R. Assessment of heavy metal contamination in soil due to leachate migration from an open dumpingsite. *Applied Water Science*. 2013;3(1):193–205.

[20] Nga B.T., Vy N.T.T. Situation of daily-life solid waste management in Binh Thuy District, Can Tho City.

Science Journal of Can Tho University. 2014;48:8-14.

[21] Amos-Tautua Bamidele Martin W., Onigbinde Adebayo O., Ere Diepreye. Assessment of some heavy metals and physicochemical properties in surface soils of municipal open waste dumpsite in Yenagoa, Nigeria. *African Journal of Environmental Science and Technology*. 2014;8(1):41-47.

[22] Huang Z., Pan X.D., Wu P.G., Han J.L., Chen Q. Health Risk Assessment of Heavy Metals in Rice to the Population in Zhejiang, China. *PLoS ONE*. 2013;8(9):e75007.

[23] Hang X., Wang H., Zhou J., Ma C., Du C., Chen X. Risk assessment of potentially toxic element pollution in soil and rice (Oryza sativa) in a typical area of the Yangtze River delta. *Environmental Pollution*. 2009;157(8-9):2542-2549.

[24] Ferreira-Baptista L., de Miguel E. Geochemistry and risk assessment of street dust in Luanda, Angola: a tropical urban environment. *Atmospheric Environment*. 2005;39(25): 4501-4512.

[25] Ministry of Natural Resources and Environment. *QCVN 03-MT: 2015/BTNMT National technical regulation on the allowable limits of heavy metals in the soil*; 2015.

[26] Canadian Council of Ministers of the Environment. *Soil quality guidelines for the protection of environmental and human health*. CCME; 2007.

[27] Ministry of Health. *QCVN 8-2: 2011/BYT national technical regulation on heavy metal limits in food*; 2011.

[28] Joint FAO/WHO expert committee on food additives. *Evaluation of Certain Food Additives and Contaminants: Sixty-First Report of the Joint FAO/WHO Expert Committee on Food Additives*. World Health Organization; 2004.

[29] Pongpom A., Bhaktikul K., Wisawapipat W., Teartisup P. Spatial distribution of potentially toxic trace elements of agricultural soils in the lower central plain of Thailand after the 2011 flood. *Environment and Natural Resources Journal*. 2014;12(1):68-79.

[30] Pendias A.K., Pendias H. *Elements of Group VIII*. In Trace Elements in Soils and Plants. CRC Press: Boca Raton. 1992:271–276.

[31] Ewers U. *Standards Guidelines and Legislative Regulations Concerning Metals and Their Compounds*. In Metals and Their Compounds in the Environment: Occurrence: Merian E., Ed., Analysis and Biological Relevance, VCH: Weinheim. 1991:458–468.

[32] Cuong D.C. *Assessing the risk of heavy metals in rice in some agricultural areas of Da Nang and Quang Nam*. Summary report on science and technology topics. University of Danang; 2014.

[33] Mohammadpour G.A., Karbassi A.R., Baghvand A. Origin and spatial distribution of metals in agricultural soils. *Global Journal of Environmental Science and Management*. 2016;2(2):145-156.

[34] Hart J., Fletcher R., Landgren C., Horneck D., Webster S., Bondi M. *Christmas Tree Nutrient Management Guide for Western Oregon and Washington, EM 8856-E, Oregon State University Extension*; 2004.

[35] Ba L.H. *Fundamental on Environmental Toxicology, third edition*. Ho Chi Minh City: Ho Chi Minh City National University Press; 2008, 639 pages.

[36] Hao L.T.M., Luong B.B., An B.H. Micro element contents in paddy rice soils in Red river and Mekong river delta. *Viet Nam Journal of Agricultural Science and Technology*. 2016; 1(9):1-10.

[37] Tasrina R.C., Rowshon A., Mustafizur A.M.R., Rafiqul I., Ali M. P. Heavy metals contamination in vegetables and its growing soil. *Journal of Environmental Analytical*. Chemistry. 2015;2(3):1-6.

[38] Addis W., Abebaw A. Determination of heavy metal concentration in soils used for cultivation of Allium sativum L. (garlic) in East Gojjam Zone, Amhara Region, Ethiopia. *Journal Cogent Chemistry*. 2017;3(1): 1-12.

[39] Kananke T., Wansapala J., Gunaratne A. Heavy Metal Contamination in Green Leafy Vegetables Collected from Selected Market Sites of Piliyandala Area, Colombo District, Sri Lanka. *American Journal of Food Science and Technology*. 2014;2(5):139–144.

[40] Adnan S.N.S.B.M., Yusoff S., Piaw C.Y. Soil chemistry and pollution study of a closed landfill site at Ampar Tenang, Selangor, Malaysia. *Waste Management & Research*. 2013;31(6):599–612.

[41] Kacholi D.S., Sahu M. Levels and Health Risk Assessment of Heavy Metals in Soil, Water, and Vegetables of Dar es Salaam, Tanzania. *Journal of Chemistry*; 2018, 9 pages.

[42] Soon Y.K., Bates T.E. Chemical pools of cadmium, nickel and zinc in polluted soil and some preliminary indications of their availability to plants. *Journal of Soil Science*. 1981; 33:477–488.

[43] Olajire A.A., Ayodele E.T. Heavy metal analysis of solid municipal wastes in the western part of Nigeria. *Water Air Soil Pollution*. 1998;103:219–228.

[44] Opaluwa O. D., Aremu M. O., Ogbo L. O., Abiola K. A., Odiba I. E., Abubakar M. M., Nweze N.O. Heavy metal concentrations in soils, plant leaves and crops grown around dump sites in Lafia Metropolis, Nasarawa State, Nigeria. *Applied Science Research*. 2012;3(2):780-784.

[45] Ba L.H. *Studying and developing a number of indicators of heavy metal toxicity (Pb, Cd, As, Hg) in the soil environment for agricultural crops (Rice, Vegetables)*. Institute of Environmental Technology and Management - Ho Chi Minh City University of Industry; 2018.

[46] Yousefi N., Meserghani M., Bahrami H., Mahvi A.H. Assessment of Human Health Risk for Heavy Metals in Imported Rice and its Daily Intake in Iran. *Research Journal of Environmental Toxicology*. 2016;10(1):75-81.

[47] World Health Organisation. *Joint FAO/WHO expert standards program codex alimentation commission*.

World Health Organization, Geneva, Switzerland; 2004.

[48] Lin H.T., Wong S.S., Li G.C. Heavy metal content of rice and Shellfish in Taiwan. *Journal of Food and Drug Analysis*. 2004;12:167-174.

[49] Fu J., Zhou Q., Liu J., Liu W., Wang T., Zhang Q., Jiang G. High levels of heavy metals in rice (Oryza sativa L.) from a typical E-waste recycling area in Southeast China and its potential risk to human health. *Chemosphere*. 2008;71:1269-1275.

[50] Tchounwou P.B., Yedjou C.G., Patlolla A.K., Sutton D.J. *Heavy metals toxicity and the environment*. In: Molecular, clinical and environmental toxicology Vol. 3: Environmental toxicology (Ed: Luch A). Vol. 101 of the series Experientia Supplementum. Springer Basel. 2012, 133-164.

[51] Aschale M., Yilma Sileshi Y., KellyQuinn M. Health risk assessment of potentially toxic elements via consumption of vegetables irrigated with polluted river water in Addis Ababa, Ethiopia. *Environmental Systems Research*; 2019, 8, 29 pages.

[52] Ministry of Health of the People's Republic of China (MHPRC). *Maximum levels of contaminants in foods (GB2762–2005)*. Beijing: MHPRC; 2005.

[53] Prechthai T., Parkpian P., Visvanathan C. Assessment of heavy metal contamination and its mobilization from municipal solid waste open dumping site. *Journal of Hazardous Materials*. 2008;156(1-3):86-94.

[54] Singh J., Upadhyay S.K., Pathak R.K., Gupta P.V. Accumulation of heavy metals in soil and paddy crop (Oryza sativa), irrigated with water of Ramgarh lake, Gorakhpur, UP, India. *Toxicological and Environmental Chemistry*. 2011;93(3):462-73.

[55] Opaluwa O.D., Umar M.A. Level of heavy metals in vegetables grown on irrigated farmland. *Bulletin of pure and applied sciences*. 2010;29(1):39-55.