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ASSESSMENT OF HEAVY METALS CONTAMINATION IN SOILS AND HEALTH RISK IN RICE

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Abstract

Environmental pollution with excess content of heavy metals can lead to the possible contamination of the rice and associated soil. Rice is mainly food and nutrient for people in Myanmar. Eating rice is the most important route for accumulation most chemical elements. The purposes of this study were to assess heavy metal contamination and the potential risk in some soil and rice samples by using EDXRF techniques. Eight rice samples and associated eight soils are collected from Kyaukse, Sinkaing, Amarapura, Patheingyi and Madaya. The mean levels of selected metals concentrations in soil samples and rice samples were found to be less than safe limit but Hg's concentration values for soil and rice are 2.85 mg/kg and 1.25 mg/kg respectively. The values of Hg are above the safe limit values 1.3 mg/kg for soil and 0.03 mg/kg for rice by USEPA (1997), FAO/WHO (1992). The mean transfer values of selected metals are less than one but Hg's transfer factor value is the highest value of all the elements. EDIM value 0.007 (mg/kg day) of Pb was found higher than the permissible value 0.001 (mg/kg day) but the rest metals of EDIM values were lower. The potential health risk has been evaluated for the local adults. The risk assessment results of 2017 showed that health risk associated with these elements through consumption of rice were not present. However, regular monitoring of accumulation of heavy metals in rice and soil has been conducted by using more precise and modern techniques.

Keywords: EDXRF, heavy metals, risk assessment, transfer factor, DIM

Introduction

Rice is the main crops and it is the staple food of local residents. Rice is mainly food and nutrient for people in Myanmar. Eating rice is the most important route for accumulation most chemical elements. Chemical elements consist of essential elements and toxic elements. The present study was conducted to assess the heavy metals (Cr, Hg, Ni, Pb, As, Cu, Zn, Fe and Mn) concentration in soils of rice field and rice grown in Madaya Township, Amarapura Township, Sintgine (Sinkaing) Township and Kyaukse Township. Cu, Zn, Mn and Fe are essential heavy metals in plants nutrition but many heavy metals do not play any significant role in the plants physiology. Some of the elements in heavy metal are naturally present at very low concentrations in environment and human bodies are able to detoxify them in limited mounts. Numerous reports indicate that water, soil, vegetables and dust have been heavily polluted by lead (Pb), Arsenic (As), copper (Cu), Zinc (Zn) and cadmium (Cd) from many sources. Pb, As, Cu, and Zn are important toxic heavy metals and have been identified as health risks by World Health Organization (WHO). Due to their potential toxicity, as well as their persistent and irreversible accumulation characteristics, heavy metals, such as Pb, Hg, and Cr are listed as key monitoring pollutants by the Myanmar. Most of the heavy metals are the natural constituents of earth's crust and from there they are taken by plants and thus transferred to food chain. These metal concentrations transfer from soil to plants are accumulated in the human body through the food chain, thus posing a serious threat to human health. Heavy metals contamination is a major

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problem of our environment and they are also one of the major contamination agents of our food supply. This problem is receiving more and more attention all over the world.

The main aims of this study are to assess some heavy metals contaminations in soils, to evaluate the transfer factor from soil to rice and to calculate the health risk with respect to daily consumption of rice for general adult.

Study Area

The study area, near Mandalay region is located in the central zone of Burma by the Irrawaddy River at 21.98 North, 96.08 East, 80 meters (260 feet) above sea level. Mandalay features a tropical wet and dry climate and noticeably warmer and cooler periods of the year. The study region consists of Kyaukse Township, Sinkaing Township, Amarapura Township, Patheingyi Township and Mataya Township. The investigated area comprises functional areas as shown in Figure (1).

Method and Material

Sample Collection

There are two types of sample which are rice samples and soil samples in our research. All rice samples and soil samples were collected from agricultural lands of paddy fields. Sample positions were obtained via the global position system and all samples have been collected from Kyaukse Township, Sinkaing Township, Amarapura Township, Patheingyi Township and Mataya Township during the harvest time of 2017. GPS data of study sites were expressed in Table (1). At each sampling site, samples were collected from the paddy field by means of a random sampling method. Edible parts of crops and their rooted soil samples (at 0 - 15 cm in depth) were collected in their paddy fields. All samples were sealed in polyethylene bags.

Samples Preparation for XRF Measurement

Sample preparation is an important role in XRF measurement. Prepared pellets must be homogenized. If the sample is inhomogeneous, the surface layer is not representative for the whole sample. All measurement samples were made cleaned and dried under the room temperature for one week. Besides, these samples were weighed by using analytical balance (PW 254). And then, it is needed to grind the powdered samples and to get very fine powders. The powder samples were passed through the mesh. After getting very fine powder, the sample was weighed 5g. These powder samples were performed pellet type by using pellet machine. Finally, each pellet sample was placed in a small plastic bag.

Experimental Set up for Soil pH Measurement

The following procedures are performed for the soil pH measurement. The mixture of 40 g of soil with 40 mL of distilled water (1:1 soil to water ratio) was filled into the beaker and stirred with a spoon until the soil and water are thoroughly mixed. The soil-water mixture was stirred for 30 seconds. The mixture was allowed to settle (clearer liquid above the settled soil) forms for about 5 minutes. The pH of the supernatant was measured using the pH meter. According to the above procedure, each soil sample was measured in five times and then records these results on the soil pH data worksheet.

Analyzing Data and Risk Assessment

Transfer Factor (TF)

Soil to rice metal transfer was computed as transfer factor (TF), which was calculated by using following equation.

$$\text{TF} = \frac{C_{plant}}{C_{soil}} \quad (1)$$

Where C_{plant} *and* C_{soil} represents the toxic metal concentration in extracts of rice and soils on dry weight basis respectively.

Estimated Daily Intake of Metal (EDIM)

Estimated Daily intake of metal was calculated by the following equation (Eq.(2))

$$\text{EDIM} = \frac{C_{metal} \times D_{foodintake} \times C_f}{B_{averageweight}} \quad (2)$$

Where, C_{metal}= heavy metal concentrations in rice (mg/ kg).

EDIM = Estimated Daily intake of metal concentration in foodstuff

(0.425 kg of rice per day)

$C_f =$ Concentration Factor (C_f= 1 was used for rice sample)

$B_{averageweight}$ =Average body weight (for Adult 55 kg)

Health Risk Index (HRI)

The value of Health Risk Index (HRI) depends on the estimated daily intake of metals (EDIM) through foodstuff and oral reference dose (R_fD). R_fD is an estimated per day exposure of metal to human body that has no hazardous effect during life time (US-EPA IRIS, 2006). The health risk index for Cr, Mn, Co, Ni, Cu, Zn, As, Cd, and Pb by consumption of rice was calculated by the following equation Eq. (3) obtained from literature (Cui et al., 2004).

$$\text{HRI} = \frac{DIM}{RfD} \quad (3)$$

Oral reference doses (mg/kg/day) for Cr, Mn, Ni, Cu, Zn, Pb were 1.500, 0.033, 0.020, 0.040, 0.300, 0.020, 0.00 (US-EPA IRIS, 2006), for Fe 60.00(Feriberg et al.1984) and for As 0.500 (Esri Corporation, USA) respectively. Estimated exposure is obtained by dividing estimated daily intake of heavy metals by their safe limit. An index more than 1 is considered as not safe for human health (USEPA, 2002).

Hazard Index (HI)

To evaluate the potential risk to human health through more than one heavy metal, the hazard index (HI) has been developed (USEPA, 1989). The hazard index is the sum of the hazard quotients as described in the following equation Eq. (4).

$$HI = \sum HQ = HQ_{Cr} + HQ_{Hg} + HQ_{As} + HQ_{Pb} \quad (4)$$

Statistical Analysis

A standard statistical analysis (mean, standard deviation, etc.) was performed to describe one of soil properties (pH) in eight study areas. Statistical analysis had been done using Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA. Version 23).

Results and Discussions

In this research work, eight soils and eight rice samples were measured by using Energy Dispersive X- ray fluorescence Spectrometer, at Experimental Nuclear Lab, Physics department, Mandalay University. The X-rays machines of SPECTRO XEPOS EDXRF spectrometer and XLab Pro 4.5 Software have been supported by International Atomic Energy Agency (IAEA). The mean concentrations of selected heavy metal content in eight soil samples are represented in Table (1). The means concentration of Cr in eight soil samples is (96.81±20.65) mg/kg. This value is below EU standard (2006) and USEPA (1997) values of (100 and 400) mg/kg but above the world average value (47 mg/kg). The mean concentration of Mn is (647.99±238.14) mg/kg. The mean concentration of Fe in all samples is (43280±7087.04) mg/kg. This value is higher than USEPA (1997) of 2100mg/kg. Ni was detected in all samples analyzed with mean concentration is (9.58±5.28) mg/kg. This value is within USEPA (1997), EU standard (2006) and world average value of (50, 50 and 13) mg/kg respectively. The observed means concentration value of Cu is (25.32±13.64) mg/kg. This value is above the world average value of 13 mg/kg but lower than safe value and EU standard value of (50 and 100) mg/kg. The mean concentration of Zn is (87.41±15.31) mg/kg. The mean value is above world average value of 45mg/kg and lower than of safe value and EU standard is (200 and 300) mg/kg. Similarly, the mean concentration of As in measured samples is (4.74±1.82) mg/kg. This value is within the USEPA (1997) of value 40mg/kg and EU standard of 10.9 mg/kg but over the world average value of 4.4 mg/kg. The Hg mean concentration value is (2.85 ±0.48) mg/kg. This value is higher than safe limit value of 1.3 mg/kg in FAO/WHO (1992).The analyzed mean concentration value of Pb is (37.09± 8.46) mg/kg. This value is lower than of safe limit and EU standard of (300 and 100 mg/kg) but higher than of WAV of 22 mg/kg. The pH range of all measured samples is from (6.56-7.33) with average temperature at 30.23ºC. This value is within the optimum pH range (5.5 and 7.5) for most plants.

The concentration of heavy metals in rice samples that Cr, Mn, Fe, Ni, Cu, Zn, As, Hg, and Pb are represented in Table (2).The mean concentration level of Cr (9.60±0.87) mg/kg of all sample is lower than the world health organization (WHO,1996) permissible limits 50mg/kg. The mean concentration value of Fe (173.50±63.67) mg/kg is less than in FAO/WHO food standard program (1999, 2001) value of 425.00mg/kg. The mean concentration value of Ni in all sample value (0.50±0.16) is lower than food and nutrition Board Institute of medicine, 2010 acceptable value is 4 mg/kg. The mean level of Cu in all sample (3.00±0.87)mg/kg is lower than the standards value of 73.00mg/kg in FAO/WHO food standard program (2001,1999) and FAO/WHO (2004) value of 20mg/kg. The observed mean concentration value of Zn (16.10±2.62)mg/kg is below the maximum permissible limit (100mg/kg) of FAO/WHO food standard program (2001, 1999). The mean concentration value of Zn is less than the value (100 mg/kg) of FAO/WHO food standard program (1999, 2001)and higher than value of (5.00mg/kg) FAO/WHO (2004). The mean concentration value of As (0.56±0.05)mg/kg is less than the world health organization (WHO 1996) with permissible value is 7 mg/kg. Similarly, the mean concentration value of Hg (1.20±0.05) is higher than world Health organization (WHO 1996) with value is 0.03 mg/kg. The observed mean concentration value (1.01) mg/kg of Pb is lower than safe limit (Codex & Alimentarius, 2001) with value (10) mg/kg.

Transfer Factor of metals from soil to rice values are expressed in Table (3). The TF value for all selected heavy metals of rice samples varied greatly between different areas. The difference in TFs between locations may be related to soil nutrients management and soil properties. The increasing order of mean TF value order is Hg>Zn> As>Cu>Cr>Ni>Pb>Fe. The TF value of mercury is the highest in all other samples. This metal is a widespread pollutant and a threat to human health and a strong toxicant. The estimated daily intake of metal in rice data are represented in Table (4). The estimated daily intakes of metal (EDIM) values for some heavy elements have been calculated based on the 55 kg per day for adult, the food intake value of adult is 0.425 and their conversion factor is one. These data revealed that the values of daily intake of Cr, Fe, Ni, Cu, Zn of As, and Hg are within the recommended value suggested by different organization. EDIM of Pb was found higher than permissible (WHO, 1993) value because the oral reference dose is higher than in other values. The HRI values for heavy metals in all rice samples have been calculated and as shown in Table (4) for adult. The result exposed that health risk index (HRI) for adult of Cr (0.042-0.056) is lower than 1, that indicating no risk. HRI of Fe (0.014-0.035) Ni (0.155-0.348), Cu (0.309-0.773), Zn (0.353-0.564), As(0.008-0.009) and Hg(0.001-0.002) values of adult which are acceptable value. The integrated health risk values of all rice samples are less than one. Most of the HRI values were less than one.

Conclusion

Analyzing of heavy metals concentration in soil and rice is important for health risk assessment during food consumption. This kind of study can be used as a tool for the farmers so that they may adopt such strategies which lead them to reduce the health problems related to metal toxicities. The mean concentration of selected heavy metal (Cr, Fe, Ni, Cu, Zn, As, and Pb) in all the soil samples are lower than recommended value by USEPA, WHO/FAO not including Hg. The mean concentration value (2.85mg/kg) of Hg is greater than 2 times by FAO/WHO (1992) value of 1.3 mg/kg. The most of selected mean concentrations in rice sample are less than acceptable value by WHO/FAO concentration value except of mercury. Moreover, the mean concentration of mercury (1.2 mg/kg) is significantly greater than the acceptable value (0.03mg/kg) by WHO (1996). All of the transfer values of selected heavy metals are less than one. EDIM mean values of nine selected metal in rice samples are within permissible value by WHO/FAO except of lead. The daily intake of lead value is higher than of safe limit value. Health risk assessment value is the ratio of daily intake of metal by oral reference dose. If the oral reference dose is greater, health risk index is lower value. In conclusion, it has been found that eating rice cannot be risk for human health. Therefore, we can recommend that regular monitoring of toxic and heavy metal in soil samples, rice samples and other foodstuff are essential to prevent their excessive build up in food chain. The factors leading to the different levels of heavy metals will be investigated in our future studies.

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Reference

C. Magamage, W.H.M.C.U. Waidyaratna, W.P.A.P. Dhanapala and D.M.Panampitiya, "Determination of Heavy Metals in Rice Available in Kandy District, Sri lanka", Annals of Sri Lanka Department of Agriculture. 19: 351 – 368, 2017.

Daping Song, Jiangying Fu and QiaoWang, "Integrated Health Risk Assessment of Heavy Metals in Suxian Country, South China"Int.J. Environ. Res. Public Health 2015, 12, 7100-7117(14 May 2015).

Farooq Ahmad " Karnal/Kallar grass cultivation in stoic alkaline soils in Pakistan" (January 22, 2013)

IvanGržetić and Rabia H. Ahmed Ghariani, "Potential health risk assessment for soil heavy metal contamination in the central zone of Belgrade (Serbia)", *J. Serb. Chem. Soc. 73* (8–9) 923–934 (2008)

Jennifer Clever and Ma Jie"China Maximum Levels for Contaminants in Foods'' USDA Forgein Agricultural Service, Global Agricultural Information Network, (12 November 2014)

John Peterson, Margargaret MacDonell, Lynne Haroun, and Fred Monett "Radiological and Chemical Fact Sheets to Support Health Risk Analyses for Contaminated Areas'' Argon National Laboratory, Environmental Science Division, U.S Department of Energy Richland Operations Office. (March 2007)

Khin Phyu Phyu, Mya Mar Lar, Tin New Htwe, Tin Tin Han, Khin Moe Latt, Ohnmar Win, KyawSoe&Myat Phone Kyaw, "Accumulation and Distribution of Heavy Metals in Rice Grains, Soil and Water in Kyonpyaw Township", *Myanmar Health Sciences Research Journal,* Vol. 29, No. 2, 2017.

Tasrina et al., J Environ Anal "ChemResearch article Open Access Heavy Metals Contamination in Vegetables and its Growing Soil'' Atomic Energy Center, Dhaka-1000, Bangladesh and Shizuoka University, Japan (2 March 2015)

WHO, World Health Organization, "Provisional Tolerable Weekly Intake of Toxic Heavy Metals", (2003).

Figure 1 Samples Location Map

Table 1 Coordination of study site		
Study site	N	E
Position - 1,Madaya	22□ 3□ 39□	96□ 6□ 21□
Position - 2,Madaya	22□ 4□ 40□	96□ 6□ 13□
Position - 3, Patheingyi	21□ 54□ 52□	96□ 10□ 33□
Position - 4, Patheingyi	21□ 58□ 36□	96□ 10□ 1□
Position - 5, Amarapura	21□ 53□ 37□	96□ 4□ 24□
Position - 6, Amarapura	21□ 53□ 38□	96□ 3□ 47□
Position - 7, Sintkaing	21□ 43□ 27□	96□ 7□ 36□
Position - 8, Kyaukse	21□ 36□ 1□	96□ 11□ 3□

Table 2 Elemental concentrations in soil sample (mg/kg)

	Cr	Fe	Ni	Cu	Zn	As	Hg	Pb
Mean	**96.81**	**43280**	**9.58**	**25.32**	**87.41**	**4.74**	**2.85**	**37.09**
Min	57.00	28750	3.70	7.90	56.80	2.00	2.3	26.20
Max	120.60	51500	14.80	39.60	100.90	7.90	3.6	52.90
SD	20.65	7087.04	5.28	13.64	15.31	1.82	0.48	8.46
Safe value	400^{a}	21000^{a}	50^{a}	50^{a}	200^{a}	40^{a}	1.3^{b}	300^{a}
Standard	100^{x}	-	50^{x}	100^{x}	300^{x}	10.9^{x}	-	100^{x}
WAV	47^{y}	-	13^{y}	13^{y}	45^{y}	4.4^{y}	-	22^{y}
Number of sample	8	8	8	8	8	8	8	8

a= USEPA (1997); b= FAO/WHO (1992); x=European Union Standard (2006)
y=World Average Value (Pendias and Pendias, 2000)

Table 3 Elemental concentrations in rice sample (mg/kg)

	Cr	Fe	Ni	Cu	Zn	As	Hg	Pb
Mean	9.60	173.50	0.50	3.00	16.10	0.50	1.20	<1.01
Min	8.1	111.4	0.4	1.6	13.7	0.5	1.1	0
Max	10.9	271.3	0.9	4	21.9	0.6	1.3	0
SD	0.87	63.67	0.16	0.87	2.62	0.05	0.05	0.00
Safe limit	50.00*	425.00#	4.00$	73.00#	100.00#	7.00*	0.03*	10.00@
FAO/WHO	-	-	-	20.00	5.00	-	-	0.20
Number of sample	8	8	8	8	8	8	8	8

*= WHO, 1996; #=FAO/WHO food standard program (2001), FAO/WHO,1999
$=Food and Nutrition Board, Institute of Medicine, 2010; @= Codex & Alimentarius, 2001

Table 3 Transfer factor (TF) values of analyzed samples (n = 8)

	Cr	Fe	Ni	Cu	Zn	As	Hg	Pb
Mean	**0.104**	**0.004**	**0.069**	**0.154**	**0.197**	**0.133**	**0.432**	**0.028**
Min	0.075	0.003	0.028	0.051	0.142	0.063	0.306	0.019
Max	0.168	0.007	0.108	0.291	0.287	0.300	0.522	0.038
SD	0.032	0.002	0.034	0.097	0.059	0.076	0.078	0.006

Element	**Table 4)Estimated Daily intake of metal and Health Risk Index of rice; N = 8**								
	Estimated Daily intake of metal (mg/kg. bw/day),					**Health Risk Index of rice**			
	Mean	SD	Min	Max	R- value	Mean	SD	Min	Max
Cr	0.074	0.007	0.063	0.084	0.05-0.20*	0.049	0.004	0.042	0.056
Fe	1.341	0.492	0.861	2.096	-	0.022	0.008	0.014	0.035
Ni	0.004	0.001	0.003	0.007	0.005‡	0.193	0.063	0.155	0.348
Cu	0.023	0.007	0.012	0.031	2.00-3.00	0.580	0.169	0.309	0.773
Zn	0.124	0.020	0.106	0.169	1.00*	0.415	0.067	0.353	0.564
As	0.004	0.000	0.004	0.005	0.001	0.008	0.001	0.008	0.009
Hg	3E-5	3E-6	3E-5	4E-5	-	0.001	0	0.001	0.002
Pb	0.008	0.00	0.008	0.008	0.0036§	-	-	-	-

R-value =recommended value, * JECFA, †FAO/WHO, ‡ WHO1997; § WHO 1993
SD= standard deviation N, = number of sample