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Health Risk Assessment of Heavy Metals in Some Vegetables and Fishes Yielded Around Taungthaman Lake

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Abstract

The purpose of this paper is the determination of health risk assessment of the some heavy metals concentration in the human body contributed by crop, vegetables and fishes. The metal pollution indexes, the daily intake of some heavy elements in all measured samples are presented. Moreover, the health risk index are calculated and presented. The heavy metal concentrations in all measured samples, which are collected from this study site and analyzed in 2015 are compared with the safe limit of FAO/WHO recommended value. It was found that risk of Cromium, Aresnic, Cadmium and Mercury is observed by consumption of analyzed foodstuffs, because of the fact that the health risk indexes for these heavy metals are greater than one.

Key words: Health risk, Heavy metals, Crop, Vegetables, Fishes

1. Introduction

Taungthaman Lake is situated in Amarapura Township, Mandalay Region. Some of wastewater from industrial zone drains into the Taungthaman Lake. The Taungthaman Lake is exposed to flooding annually during the raining seasons. The sources of water entering into the Taungthaman Lake are flooding of Ayeyarwaddy River and Myintnge River. Due to flooding, excessive accumulation of heavy metals is a significant source of contamination of agricultural soils around the Taungthaman Lake. This is of greate concern because not only the potential health risk to the local inhabitants but also the environmental pollution of the Taungthaman Lake.

The consumption of crops, vegetables and fishes produced in contaminated areas, as well as ingestion or inhalation of contaminated particles is two principal factors contributing to human exposure to heavy metals. Potential health risks to humans from consumption of crops, vegetables and fishes can be due to heavy metal

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uptake from contaminated sediment soils via plant roots as well as direct deposition of contaminants from the atmosphere onto plant surfaces. The objectives of this paper are (1) to quantify the concentration of heavy metals in crops, vegetables and fishes by using EDXRF method; (2) to estimate the metal pollution index (MPI), daily intake of metal (DIM) and health risk index (HRI) of heavy metals through consumption of crops, vegetables and fishes, yielded around the Taungthaman Lake.

2. Materials and Method

2.1 Study Site

In the present paper, the six samples of crop and vegetables are the yields of the fields around the Taungthaman Lake. These areas have been flooded by the Taungthaman Lake. The four samples of fishes are also the obtained from the Taungthaman Lake.

2.2 Sample Collection and Preparation

In the present study, the six samples of crop and vegetables have been collected from the fields around the Taungthaman Lake. The crop and vegetable samples are rice (S-1), corn (S-2), tomato (S-3), eggplant (S-4), peanut (S-5), and gourd (S-6). The four samples of fishes, FS-1 to FS-4, have been collected from the Taungthaman Lake.

The vegetable samples are prepared by the following steps to measure by the Energy Dispersive X-ray Fluorescence (EDXRF) method.

(i) The collected vegetable samples have been washed by water.

(ii) They have been cut into suitable pieces by a stainless steel knife.

(iii) The edible parts of the samples have been dried at room temperature until constant weight was obtained.

(iv) The dried mass of each sample has been ground to fine powder by stainless steel mortar with a steel pestle.

(v) The powder samples have been sieved by using the 150-mesh.

Similarly, the fish samples are prepared as the vegetable samples except the fish samples are dried by using the oven at 100°C, and sieved by using the 325-mesh.

All fine powder samples have been preserved by plastic vials with identification mark inside desiccators. Each powder sample has been weighted as 5 g by using digital balance and has been formed as a pellet by using pellet machine. All the prepared pellets were put into the sample chamber. Sample identification and chamber number were carefully recorded. The elemental analysis of the samples has been performed using the Energy Dispersive X-ray Fluorescence (EDXRF) spectrometer at the Nuclear Physics Laboratory, Physics Department Mandalay University.

2.2 X-rays Measurements

In this paper, the elemental concentration of crop, vegetable and fish samples were analyzed by using the SPECTRO XEPOS system. Measurements for all samples have been done in Nuclear Physics Laboratory, Department of Physics, and Mandalay University.

3. Data Analysis

3.1 Metal Pollution Index (MPI)

Metal pollution index (MPI) is suggested to be a reliable and precise method for metal pollution monitoring of wastewater irrigation areas. The metal pollution indexes for different foodstuffs are different. Leafy vegetables are found to contain higher MPI value than which may be due to the uptake of higher amount of heavy metal available from polluted soil.

Metal Pollution index (MPI) is the one of the index associated with food and foodstuff, which is to determine overall trace elements concentrations in different foodstuff analyzed. This index is obtained by calculating the mean concentrations of all the metals in different foodstuff as follow.

$$\text{Metal Pollution Index (MPI) } (\mu g/g) = (Cf_1 \times Cf_2 \times \ldots\ldots \times Cf_n)^{1/n} \quad (1.1)$$

where, Cf_n = Concentration of metal in “n” in the sample.

3.2 Daily Intake of Metal (DIM)

The daily intake of metals (DIM) was determined by the following equation:

$$\text{Dailt Intake of Metals (DIM)} = \frac{C_{metal} \times C_{factor} \times C_{food\ intake}}{B_{average\ weight}} \quad (1.2)$$

where, C_{metal} is the heavy metal concentration in foodstuff , C_{factor} is conversion factor, $D_{food\ intake}$ is daily intake of foodstuff, and $B_{average\ weight}$ is average body weight.

For the conversion of fresh vegetable weight to dry weight, the factor of 0.085 was used for crop and vegetable samples, and the factor of 1 was used for fishes samples. The average daily vegetable intakes for a person vary according to locality and their life style. The average body weight ($B_{average\ weight}$) was taken as 70 kg for adults according to the World Health Organization (WHO 1993).

3.3 Health Risk Index (HRI)

Health risk index (HRI) is the ratio of daily intake of metal (DIM) to the reference dose (RD), and it is defined as the maximum tolerable daily intake of a specific metal that does not result in any harmful health effects. If the value of HRI less than one the exposed population is said to be safe and if greater than one indicating that there is a potential risk associated with that metal. The health risk index (HRI) was calculated by using the following equation, and the oral reference dose for some elements is shown in Table (1).

$$\text{Health Risk Index (HRI)} = \frac{\text{Daily Intake of Metal (DIM)}}{\text{Reference Dose (RD)}} \quad (1.3)$$

Table (1) Oral reference dose for some elements

Elements	Oral Reference Dose (μg/kg/day)	Reference
Cr	5	FA0/WHO (2013)
Mn	5000	Feriberg et al. 1984
Fe	60000	Feriberg et al. 1984
Co	3010	Food and Nutrition Board (2004)
Ni	20	IRIS-USEPA (1995)
Cu	40	USEPA (1989)
Zn	300	USEPA (1989) FAO/WHO (2013)
As	0.3	IRIS-USEPA (1995)
Cd	1	IRIS-USEPA (1995)
Hg	0.3	IRIS-USEPA (1995)
Pb	600	USEPA (2002)

4. Results and Discussion

The metal pollution index (MPI) for six samples of crop and vegetables, and four samples of fishes are shown in Table (2). The concentrations of the heavy metals in these samples are shown in Table (3). The daily intakes of metal (DIM) of some heavy elements for these samples are shown in Table (4) and the health risk index (HRI) for these measured samples are shown in Table (5). Figure (1) shows the bar graph for the Health Risk Index of some heavy metals, by the consumption of the measured samples.

Table (2) Metal pollution indexes for measured samples

Sample	MPI(mg/kg)						n	Mean	S.E	S.D
	1	2	3	4	5	6				
Crop and Vegetables	7.31	7.35	10.44	9.11	6.75	12.00	6	**8.83**	**0.85**	**2.08**
Fishes	23.86	16.99	17.86	12.67	-	-	4	**17.85**	**2.30**	**4.61**

S.E = Standard Error, S.D = Standard Deviation

Table (3) Heavy metal concentration in vegetable samples

Sample Code	Concentration (mg/kg)										
	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Cd	Hg	Pb
S-1	10.1	48.6	168.3	3	0.4	4.7	41.5	0.6	2	1.1	0.1
S-2	10.1	53.9	187.9	3	0.9	4.6	78.2	0.5	2	1.3	0.5
S-3	7.7	40.4	203.5	3	0.5	15.9	57.9	0.6	0.6	1.7	0.8
S-4	5.7	37.6	152.1	3	0.3	23.2	48.7	0.3	0.5	1.3	0.9
S-5	7.8	26	48.4	3	0.6	11.5	38.8	0.4	0.5	1.5	0.3
S-6	12.9	42.1	432.8	3	0.8	8.9	56.3	0.5	2	1.3	2.2
Mean	**9.05**	**41.43**	**198.83**	**3**	**0.58**	**11.47**	**53.57**	**0.48**	**1.27**	**1.37**	**0.8**
S.E	**1.03**	**3.92**	**51.84**	**0**	**0.09**	**2.92**	**5.83**	**0.05**	**0.33**	**0.08**	**0.3**
S.D	**2.52**	**9.6**	**126.97**	**0**	**0.23**	**7.17**	**14.29**	**0.12**	**0.8**	**0.21**	**0.75**
FS-1	24.2	193.9	4949	3	2.6	13.3	112.2	1.1	2	1.1	3.3
FS-2	35.2	65.8	2095	3	1.3	4.2	186.6	0.6	0.6	1.3	1.4
FS-3	33.6	61.3	2185	3	1.9	4.5	83	0.7	2	2	1.9
FS-4	9.4	50.9	1019	3	0.4	3.3	119.3	0.6	0.5	1	0.8
Mean	**25.6**	**92.98**	**2562**	**3**	**1.55**	**6.32**	**215.28**	**0.75**	**1.28**	**1.35**	**1.85**
S.E	**5.92**	**33.79**	**838.59**	**0**	**0.47**	**2.34**	**21.9**	**0.12**	**0.42**	**0.23**	**0.53**
S.D	**11.84**	**67.57**	**1677.18**	**0**	**0.93**	**4.68**	**43.79**	**0.24**	**0.84**	**0.45**	**1.07**
Safe limit	*50†*	*500**	*425**	*50**	*4‡*	*73**	*100**	*7†*	*1.5***	*0.03**	*10***

*FAO/WHO food standard program 2001, † WHO(1996), ‡ Food and Nutrition Board, Institute of medicine (2010), ** Indian standard (Codex & Alimentarius, 2001)

Table (4) Mean DIM values for some elements

Sample Code	DIM (μg/kg)										
	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Cd	Hg	Pb
S-1	5.21	25.08	86.85	1.55	0.21	2.43	21.42	0.31	1.03	0.57	0.05
S-2	1.59	8.51	29.66	0.47	0.14	0.73	12.34	0.08	0.31	0.21	0.08
S-3	1.22	6.38	32.12	0.47	0.08	2.51	9.14	0.09	0.09	0.27	0.13
S-4	0.9	5.94	24.01	0.47	0.05	3.66	7.69	0.05	0.08	0.21	0.14
S-5	1.23	4.1	7.64	0.47	0.09	1.82	6.12	0.06	0.08	0.24	0.05
S-6	2.04	6.64	68.32	0.47	0.13	1.4	8.89	0.08	0.32	0.21	0.35
FS-1	8.3	66.48	1696.8	1.03	0.89	4.56	38.47	0.38	0.69	0.38	1.13
FS-2	12.07	22.56	718.29	1.03	0.45	1.44	63.98	0.21	0.21	0.45	0.48
FS-3	11.52	21.02	749.14	1.03	0.65	1.54	28.46	0.24	0.69	0.69	0.65
FS-4	3.22	17.45	349.37	1.03	0.14	1.13	40.9	0.21	0.17	0.34	0.27

Table (5) Health Risk Index of some elements

Sample code	HRI										
	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Cd	Hg	Pb
S-1	1.04	0.005	0.001	0.0005	0.01	0.06	0.07	1.03	1.03	1.89	8.60E-05
S-2	0.32	0.002	0.0005	0.0002	0.007	0.02	0.04	0.26	0.32	0.68	1.00E-04
S-3	0.24	0.001	0.0005	0.0002	0.004	0.06	0.03	0.32	0.09	0.89	2.00E-04
S-4	0.18	0.001	0.0004	0.0002	0.002	0.09	0.03	0.16	0.08	0.68	2.00E-04
S-5	0.25	0.0008	0.0001	0.0002	0.005	0.05	0.02	0.21	0.08	0.79	7.80E-05
S-6	0.41	0.001	0.001	0.0002	0.006	0.04	0.03	0.26	0.32	0.68	5.80E-04
FS-1	1.66	0.013	0.028	0.00034	0.045	0.11	0.13	1.26	0.69	1.26	1.89E-03
FS-2	2.41	0.0045	0.012	0.00034	0.023	0.04	0.21	0.69	0.21	1.49	8.00E-04
FS-3	2.3	0.0042	0.012	0.00034	0.032	0.04	0.09	0.8	0.69	2.29	1.10E-03
FS-4	0.645	0.0035	0.006	0.00034	0.007	0.03	0.13	0.69	0.17	1.14	4.57E-04

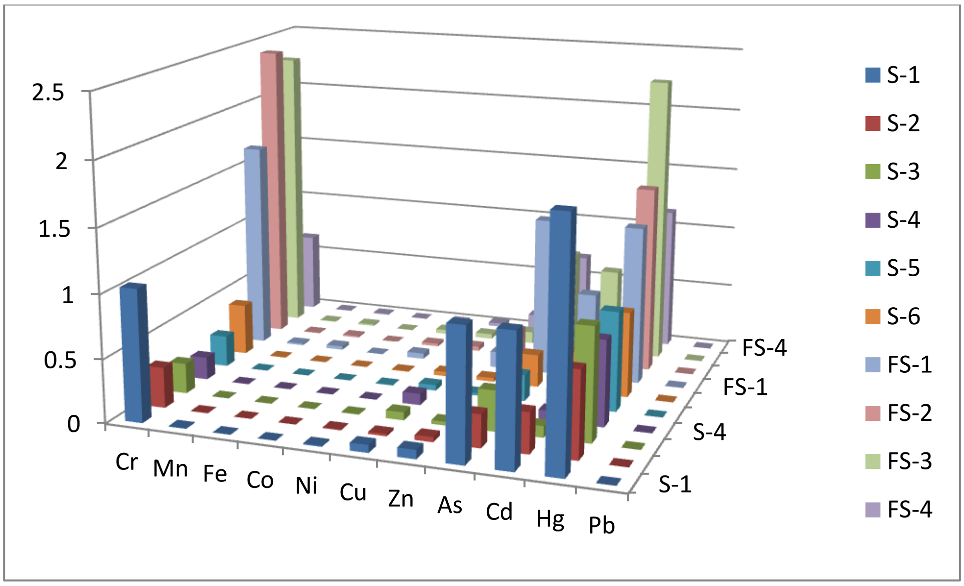

Figure (1) Health risk indexes of some heavy elements

According to Table (2), the mean MPI value for crop and vegetables samples is 8.83 mg/kg with the standard deviation of 2.08 mg/kg and that for fish samples is 17.85 mg/kg with the standard deviation of 4.61 mg/kg. The mean MPI for fish samples is higher than that of crop and vegetables samples.

The concentrations of some heavy metals are presented with the comparison of safe limit (FAO/WHO food standard program, 2001) in Table (3). The mean concentrations of Cr, Mn, Fe, Ni, Zn, As, and Pb in fish samples are more than that in crop and vegetables samples. For both kinds of samples, the mean concentrations of Cr, Mn, Ni, As, and Pb are within their respective safe limits.

For all measured samples, the mean Co concentrations are the same and are within the safe limit. For the elements Cd and Hg, their respective mean concentrations are the same in both kinds of samples. The concentration of Cd is within the safe limit, while that of Hg is above the safe limit for two kinds of samples.

For the crop and vegetables samples, the mean concentrations of Fe and Zn are within their respective safe limits, while that in fish samples are above the safe limit. The mean Fe concentration is the highest among the other metals in all samples.

The mean Cu concentration for fish sample is lower than that for crop and vegetables samples. For both kinds of samples, the mean Cu concentration is within the safe limit.

From the survey on individual rice consumption in Myanmar, which is supported by Myanmar Rice Federation in cooperation with Myanmar Rice and Paddy Traders Association and Agricultural University, average individual rice consumption per head is 155 kg per year with 43 kg for the minimum and 326 kg for the maximum. The daily intakes of metal (DIM) values for some heavy elements have been calculated based on the 425 g per person per day of the consumption of rice. It has been assumed that the consumption of vegetables and fishes are 130 g and 24 g per person per day respectively.

According to Table (4), iron (Fe) has the highest DIM value in all samples by the consumption of crop, vegetables, and fishes, which are produced from this study area analyzed in 2015.

In Table (5), the HRI for Cr is greater than one for the samples S-1, FS-1, FS-2, and FS-3, and it is nearly one for the samples FS-4. Thus, for the crop (rice) and the fish samples, the HRI of Cr is greater than one.

The HRI of As is greater than one for the samples S-1, and FS-1. In addition, it is nearly one for the other rest samples, FS-2, FS-3, and FS-4. Thus, the HRIs of As for all fish samples are greater than that for crops and vegetables samples.

Only for the samples S-1, the HRI of Cd is greater than one, and it is nearly one for the samples FS-1, and FS-3.

The HRI of Hg is greater than one for the sample S-1 and for all fish samples. For the rest other vegetables samples, the value of HRI for Hg is from 0.68 to 0.89. Thus, risk of mercury is very considerable for the consumption of crops, vegetables and fishes, yielded around the Taungthaman Lake. For the other heavy elements such as Mn, Fe, Co, Ni, Cu, Zn, and Pb, the HRI value is lower than one in all measured samples.

The health risk assessment associated with heavy metal (Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, Hg, Pb) in some crop and vegetables, which are grown near the Taungthaman Lake and that in some fishes from the Taungthaman Lake have been estimated and associated risk index have been calculated. Health risk indexes of some elements, Mn, Fe, Co, Ni, Cu, Zn and Pb were found below one in all measured samples. The elements, Mn, Fe, Co, Ni, Cu, Zn and Pb were not found to cause any risk to the people by consuming crop, vegetables, and fishes, which are produced from the Taungthaman Lake and which are analyzed in 2015. The risk of Cromium, Aresnic, Cadmium and Mercury can take place by the consumption of the crop, vegetables and fishes, which are produced from this study site. The HRI value for heavy elements in all varieties of vegetables lower than one and this may be due to intake of lower amounts in diet, and which consequently decreased the health risk index.

5. Conclusion

The drain of wastewater leads to contamination of soils and food crops in the study site. Heavy metal depositions due to wastewater were significantly increased over reference soils. Heavy metal concentrations indicated that the wastewater-irrigated soils were moderately enriched with Fe, Zn and Cd, and strongly enriched with Hg for crops and vegetables. In fish samples, the concentrations of Cr and Cd are moderately enriched and strongly enriched with Fe, Zn and Hg. Moreover, it can be concluded that the wastewater-drained grown plants and fishes in wastewater- drained water were contaminated with those heavy metals. Some heavy metals exceeded the permissible limits for crops and vegetables set by FAO/WHO food standard program 2001. The HRIs of the studied metals (Cr, As, Cd, Hg) were greater than one, and it indicates that there is a relative presence of health risks associated with the consumption of contaminated food staffs.

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