Estimation of heavy metals pollution in farm soil and nearby coal mine soil

Khin Maung Htwe[*], Wunna Ko[**], Tin Htun Naing[***]

Abstract

This research is the comparative study of heavy metal pollution in soil samples. Six soil samples were collected nearby Thitchauk coal mine and another six soil samples were collected from farm of Kyaukse Township. Surface soil were analyzed for selected heavy metals including iron (Fe), manganese (Mn), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), strontium (Sr) and zinc (Zn) by using EDXRF method. The average concentration values of toxic elements, chromium (Cr) and lead (Pb) in nearby coal mine soil were larger than the USEPA values, 1983 and maximum permissible limit of (WHO/FAO), 1992. Similarly the average concentration value of toxic element chromium (Cr) in farm soil was larger than the USEPA, 1983 value. Environmental risk assessments were carried out by using the factors. The geo–accumulation index (I–geo) was distinctly variable and it is suggested that both soil samples range from uncontaminated to moderately contaminate with respect to the analyzed metals. The average results indicate that the EF factor for only nickel was relatively high in nearby coal mine soil. For nearby coal mine soil, the contamination factor values for Fe and Ni were greater than elements, indicating that this environment was very high contamination. The mean value of PLI range was 2 to 3 that reflects the moderately to strongly polluted in farm soil. However, the mean value of PLI ranges was 3 to 4 that indicated strongly polluted in nearby coal mine soil at 2018. Therefore, regular monitoring of accumulation of heavy metals in soil has been conducted by using more precise and modern techniques.

Key Words: Pollution, Farm soil, Sediments, EDXRF

1. Introduction

Pollution of the natural environment by heavy metals is a universal problem because these metals are indestructible and most of them have toxic effects on living organisms, when permissible concentration levels are exceeded. Heavy metals are frequently reported in literature with regards to potential hazards, and occurrences in contaminated soil are Cd, Cr, Pb, Zn, Fe and Cu. In recent years, the use of this material in coal mining causes environmental concerns. The heavy metals such as Cd, Cr, Cu, Hg, S, As, Ni, Pb in soil around coal mines causes environmental pollution and environmental

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problems for both animals and plants. The presence of heavy metals in soil caused by industrial activities or factory waste or dust is a great danger for the environment.

The objectives of the present work were to: (1) Assess contamination of selected heavy metals in different soil samples, (2) Assess environmental risk using four factors, namely; (a) Enrichment factor (EF), (b) Geo–accumulation index (Igeo), (c) Contamination factor (CF), and (d) Pollution load index (PLI) in soil samples of farm soil from Kyaukse Township and nearby Thitchauk coal mine soil from Kalaywa Township.

2. Materials and Method

2.1 Study Site

Two study sites were selected based on different environmental conditions. The one site was farms from Kyaukse Township and the other site was Thitchauk coal mine of Kalaywa Township. The location maps of the study sites are shown in figure (1).

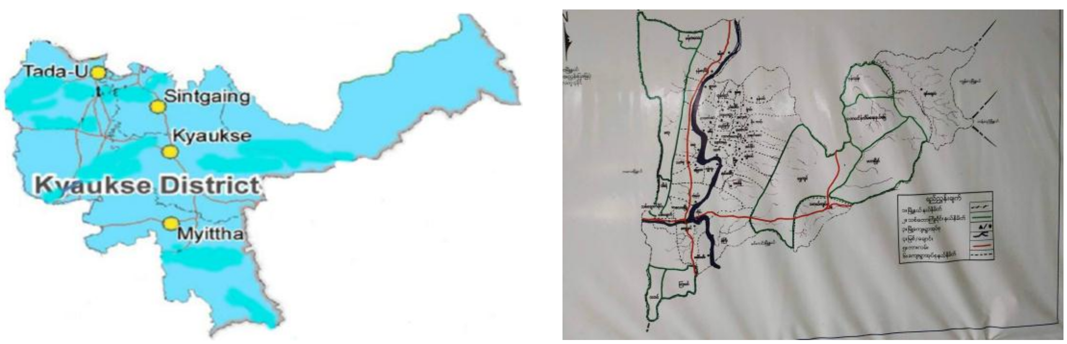

Figure 1 Location map of Farm soil and nearby coal mine soil

2.2 Sample Collection and Preparation

In this research work, farm soil samples and nearby coal mine soil samples were collected from different locations. Farm soil samples were collected from Kyaukse Township and other samples were collected nearby Thitchauk coal mine. The GPS locations of collected samples are expressed in Table 1. There are total twelve soil samples which depth is six inches collected with three feet contube pipe from the different places of coal mine region and other farms. Sample sites were located and recorded using GPS system. The samples were collected randomly but evenly distributed around the coal mine. Sample preparation is an important role in XRF measurement. These samples were cleaned and dried under the room temperature for two weeks. 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 nearly 5g. In this research work, the elemental concentrations of sediment samples were analyzed by using the SPECTRO XEPOS system. Measurements for all samples have been done in Experimental Nuclear Physics Laboratory, Physics Department, at Mandalay University.

Table 1 The coordination of collected samples

Study sides	Sample Code	GPS Position		Study sides	Sample Code	GPS Position	
		Latitude	Longitude			Latitude	Longitude
Kyaukse Township	FS–1	N–21 36 1	E–96 11 3	Thitchauk coal mine area	TCS–1	N–23 09 51	E–94 14 51
	FS–2	N–21 38 1	E–96 7 26		TCS –2	N–23 09 52	E–94 14 52
	FS–3	N–21 30 35	E–96 10 55		TCS –3	N–23 09 51	E–94 14 52
	FS–4	N–21 30 38	E–96 10 39		TCS –4	N–23 09 51	E–94 14 50
	FS-5	N-21° 29' 54"	E-96° 11' 40"		TCS -5	N-23° 09' 53"	E-94° 14' 52"
	FS-6	N-21° 29' 54"	E-96° 11' 40"		TCS -6	N-23° 09' 51"	E-94° 14' 49"

Several indices were used to assess the metal contamination levels in the sediment samples, namely Geo–accumulation index (I–geo), Enrichment Factors (EF), Contamination Factor (CF) and Pollution Load Index (PLI).

3.1 Geo–accumulation index

Geo–accumulation index (I–geo) was applied to evaluate the heavy metals pollution in the different soil samples. This method has been used by Müller since the late 1960s. I–geo was calculated using the following equation:

$$\mathrm{I-geo} = \mathrm{Log}_2\left(\frac{C_n}{1.5B_n}\right) \qquad (1)$$

Where C_n is the measured content of the examined metal in the soil samples, B_n is the geochemical background content of the same metal. The constant 1.5 is introduced to minimize the effect of possible variations in the background values, which may be recognized to anthropogenic influences. The following classification is given for I–geo: <0 = practically unpolluted, 0–1 = unpolluted to moderately polluted, 1–2 = moderately polluted, 2–3 = moderately to strongly polluted, 3–4 = strongly polluted, 4–5 = strongly to extremely polluted, and > 5 = extremely polluted.

3.2 Enrichment factor (EF)

Enrichment Factors (EF) were considered to estimate the abundance of metals in sediment samples. EF was calculated by a comparison of each tested metal concentration with that of a reference metal. The normally used reference metals are Mn, Al and Fe. In this study iron was used as a conservative tracer to differentiate natural from anthropogenic components, following the hypothesis that its content in the earth crust has not been troubled by anthropogenic activity and it has been chosen as the element of normalization because natural sources (98%) greatly dominate its contribution.

According to Rubio *et al.*, the EF is defined as follows:

$$\mathrm{EF} = \frac{\mathrm{(M/Fe)Sample}}{\mathrm{(M/Fe)Background}} \quad (2)$$

Where EF is the enrichment factor, (M/Fe) sample is the ratio of metal and Fe concentration of the sample and (M/Fe) background is the ratio of metals and Fe concentration of a background. Five contamination categories are reported on the basis of the enrichment factor: EF <2 deficiency to minimal enrichment, EF = 2~5 moderate enrichment, EF = 5~20 significant enrichment, EF = 20~40 very high enrichment, EF>40 extremely high enrichment.

3.3 Contamination factor

Generally sediments have been used as environmental indicators, and this ability to identify heavy metal contamination sources and monitor contaminants is also well documented. The level of metal contamination was expressed by the contamination factor. Contamination Factor (CF) was used to determine the contamination status of soil in the current study. CF was calculated according to the equation described below:

$$CF = \frac{M_C}{B_C} \quad (3)$$

Where M_c Measured concentration of the metal and B_c is the background concentration of the same metal. Four contamination categories are documented on the basis of the contamination factor. CF <1 low contamination; 1≤ CF ≥3 moderate contamination; 3≤ CF < 6 considerable contamination; CF >6 very high contamination indicating serious anthropogenic pollution.

3.4 Pollution Load Index

Pollution Load Index (PLI) was used to evaluate the extent of pollution by heavy metals in the environment. The range and class of pollution load index (PLI) are same as I_{geo}. PLI for a particular site has been calculated following the method planned by Tomlinson et al. as follows:

$$\mathrm{PLI} = (\mathrm{CF}_1 \times \mathrm{CF}_2 \times \mathrm{CF}_3 \times \ldots \ldots \times \mathrm{CF}_n)^{1/n} \quad (4)$$

Where n is the number of metals and CF is the contamination factor.

4. Results and Discussion

The analyzed samples were collected from two different locations. Six soil samples were collected nearby Thitchauk coal mine and another six soil samples were collected from farms, region of Kyaukse Township. The potential environmental impact of heavy metals in nearby Thitchauk coal mine area was related not only to their total concentration and chemical forms, but also to the rate of weathering suffered by the samples. The results of the comparisons of heavy metal concentration in this research work are shown in Table 2. The selected heavy metals concentration results are presented with recommended value of USEPA (1983) and MPL value of WHO/FAO (1992). The regional variations of total concentration of heavy metals (such as Mn, Fe, Cu, Ni, Zn, Sr) and toxic elements (such as Cd, Cr and Pb) in the twelve soil samples were shown in Figure 2. The mean concentration value (373.83 ±148.46 ppm) of chromium (Cr) in nearby coal mine soil was higher than the USEPA, 1983 value 100 ppm. The mean concentration value (991.17±360.06 ppm) of manganese (Mn) was higher than the USEPA, 1983 value 600 ppm. The mean concentration value (103.25±45.70 ppm) of copper (Cu) was higher than the USEPA, 1983 value 30 ppm but slightly higher than the maximum permissible limit (FAO/WHO, 1992) value of 100 ppm . Similarly the mean concentration value (136.83±30.38 ppm) of lead (Pb) was higher than the USEPA, 1983 value 74 ppm and maximum permissible limit (FAO/WHO, 1992) value of 100 ppm. The mean concentration value (270.16±77.59 ppm) of chromium (Cr) in farm soil was higher than the USEPA, 1983 value 100 ppm. The mean concentration value (74.62±21.67 ppm) of copper (Cu) was higher than the USEPA, 1983 value 30 ppm but lower than the maximum permissible limit (FAO/WHO, 1992) value of 100 ppm. Similarly the mean concentration value (87.40±14.33 ppm) of lead (Pb) was slightly higher than the USEPA, 1983 value 74 ppm but lower than the maximum permissible limit (FAO/WHO, 1992) value of 100 ppm. Thus, attention has to be taken in order to control the level because it may result in a dangerous effect for future.

The iron (Fe) was selected as a reference element because of its abundance and is one of the widely used reference elements. The results of EF values presented in Table 3, average EF values gave this order of enrichment of heavy metals present in nearby Thitchauk coal mine soil: Ni > Zn > Cr > Cu > Pb > Mn > Sr and in farm soil: Zn > Sr > Mn > Cr > Cu > Pb > Ni. Ni was the highest contaminated for nearby Thitchauk coal mine soil while nickel was the least contaminated in farm soil. Most of the EF values in farm soil were relatively higher than those in nearby coal mine soil because the normalized value of nearby coal mine soil was much higher than others. The I–geo factor was not readily comparable to the other indices of metal enrichment due to the nature of the I–geo calculation, which involves a log function and a background multiplication of 1.5. On the basis of the mean values of I–geo, soil samples in the research area are rich in metals in the following order of contamination of heavy metals present in nearby Thitchauk coal mine soil: Ni > Fe > Zn > Cr > Cu > Pb > Sr > Mn and in farm soil: Zn > Mn > Fe > Cr > Cu > Sr > Ni > Pb. The contamination factor values were presented in Table 5. The average contamination factor values for different heavy metals in analyzed soil samples are Ni > Fe > Zn > Cr > Mn >Sr > Pb for nearby coal mine soil and Cr >Fe >Mn >Sr >Pb> Zn>Ni for farm soil. Table 5 also shows the values of pollution load index. The mean value of PLI ranges was 3 to 4 in nearby coal mine soil. However, the mean value of PLI range was 2 to 3 in farm soil.

5. Conclusion

In the present study, over the points of view according to the results of heavy elemental concentration values, Chromium (Cr), Lead (Pb), Nickel (Ni), Iron (Fe), Manganese (Mn),Strontium (Sr),Copper (Cu) and Zinc (Zn) were observed in all analyzed soil samples. For nearby coal mine soil, the average concentration values of toxic elements chromium (Cr) and lead (Pb) were larger than the USEPA, 1983 and maximum permissible limit of (WHO/FAO), 1992. Similarly for farm soil, the average concentration value of toxic element chromium (Cr) was larger than the USEPA, 1983. The impact of anthropogenic heavy metal pollution on soil samples was evaluated using Enrichment Factors (EF), geo–accumulation index (I–geo) and contamination factor (CF). The geo–accumulation index (I–geo) were distinctly variable and suggested that in both soil samples range from uncontaminated to moderately contaminated with respect to the analyzed metals. The average results demonstrated that the EF factor for only nickel was relatively high in nearby coal mine soil. Nevertheless EF values of manganese, zinc and strontium are relatively high in farm soil. The mean value of PLI ranges was 3 to 4 which indicated that soil nearby coal mine is strongly polluted. However, the mean value of PLI range was 2 to 3 that reflects farm soil was moderately polluted to strongly polluted in 2018. Therefore, an annual analysis of heavy metals in soil and water should be conducted to reduce the elemental pollution and ecological pollution of coal mine soil and farm soil from Kyaukse Township.

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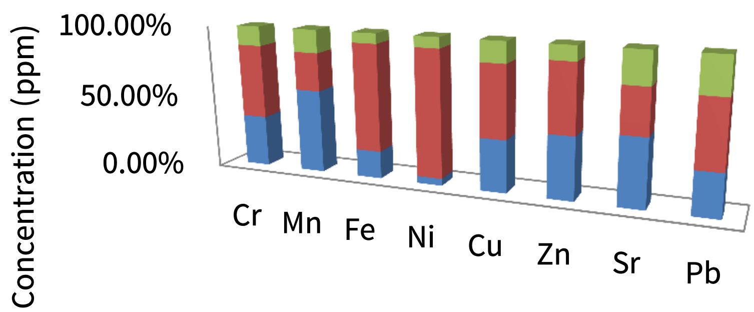
Table 2 Heavy Metal Analysis result of the Samples (ppm)

	Code	Cr	Mn	Fe	Ni	Cu	Zn	Sr	Pb
Nearby Thitchauk coal mine Soil	TCS–1	348	622	387000	514	115	350	317	161
	TCS–2	330	855	394000	321	163	138	238	154
	TCS–3	176	1520	468000	441	–	313	202	169
	TCS–4	538	877	373000	697	–	211	286	127
	TCS–5	560	723	361000	342	68	136	368	122
	TCS–6	291	1350	377000	498	67	256	275	88
	Mean	**373.83**	**991.17**	**393333**	**469**	**103.25**	**234.00**	**281.00**	**136.83**
	SD	148.46	360.06	38318	137.2	45.7	88.92	58.34	30.38
Farm Soil	FS–7	254	1853	105765	26	97	230	273	101
	FS–8	233	1939	96909	24	76	200	343	85
	FS–9	202	2830	97455	27	38	167	767	64
	FS–10	256	2256	97075	26	82	225	416	91
	FS–11	403	1740	111032	26	77	235	312	94
	FS–12	207	2280	96159	24	78	220	413	90
	Mean	259.18	2149.73	100733	25.57	74.64	212.77	420.73	87.51
	SD	74.02	397.86	6181.57	1.13	19.57	25.48	178.70	12.66
USEPA – 1983	BKG	**100**	**600**	**37400**	**40**	**30**	**50**	**200**	**74.8**
MPL (WHO/FAO) 1992		**–**	**–**	**–**	**50**	**100**	**300**	**–**	**100**



	Cr	Mn	Fe	Ni	Cu	Zn	Sr	Pb
USEPA	100	600	37400	40	30	50	200	74.8
TCS	373.83	991.17	393333.	469	103.25	234	281	136.83
FS	259.18	2149.73	100732.	25.57	74.64	212.77	420.73	87.51

Figure 2 Comparison of heavy metals mean concentrations in TCS soil and FS soil samples

Table 3 Enrichment Factor Analysis result of the Samples

	Factor	Cr	Mn	Ni	Cu	Zn	Sr	Pb
Nearby Thitchauk coal mine soil	EF–1	0.336	0.1	1.242	0.37	0.676	0.153	0.208
	EF–2	0.313	0.135	0.762	0.516	0.262	0.113	0.195
	EF–3	0.141	0.202	0.881		0.5	0.081	0.181
	EF–4	0.539	0.147	1.75		0.423	0.143	0.17
	EF–5	0.58	0.125	0.886	0.235	0.282	0.191	0.169
	EF–6	0.289	0.223	1.235	0.222	0.508	0.136	0.117
	Mean	**0.366**	**0.155**	**1.126**	**0.336**	**0.442**	**0.136**	**0.173**
	SD	0.165	0.047	0.365	0.138	0.156	0.037	0.032
Farm Soil	EF–7	0.9	1.09	0.23	1.15	1.63	0.82	0.48
	EF–8	0.9	1.25	0.23	0.99	1.55	1.12	0.44
	EF–9	0.78	1.81	0.26	0.5	1.29	2.49	0.33
	EF–10	0.99	1.45	0.26	1.06	1.74	1.36	0.47
	EF–11	1.36	0.98	0.22	0.87	1.58	0.89	0.42
	EF–12	0.81	1.48	0.24	1.01	1.71	1.36	0.47
	Mean	**0.956**	**1.343**	**0.240**	**0.930**	**1.583**	**1.340**	**0.435**
	SD	0.212	0.301	0.017	0.230	0.161	0.607	0.056

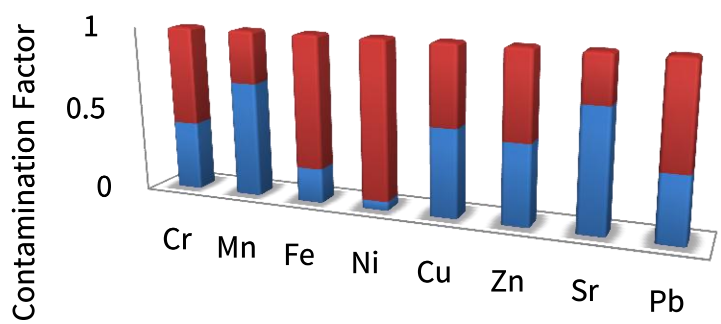
Table 4 Geo–accumulation Analysis result of the Samples

	Factor	Cr	Mn	Fe	Ni	Cu	Zn	Sr	Pb
Nearby Thitchauk coal Mine Soil	Igeo–1	1.214	–0.533	2.786	3.099	1.354	2.222	0.08	0.521
	Igeo–2	1.138	–0.074	2.812	2.42	1.857	0.88	–0.334	0.457
	Igeo–3	0.231	0.756	3.06	2.878	–	2.061	–0.571	0.591
	Igeo–4	1.843	–0.037	2.733	3.54	–	1.492	–0.069	0.179
	Igeo–5	1.9	–0.316	2.686	2.511	0.596	0.859	0.295	0.121
	Igeo–6	0.956	0.585	2.748	3.053	0.574	1.771	–0.126	–0.35
	Mean	**1.214**	**0.063**	**2.804**	**2.917**	**1.095**	**1.548**	**–0.121**	**0.253**
	SD	0.617	0.506	0.133	0.413	0.624	0.582	0.304	0.351
	Igeo–7	0.77	1.04	0.91	–1.18	1.12	1.62	0.63	–0.14
	Igeo–8	0.64	1.11	0.79	–1.31	0.77	1.42	0.19	–0.4
	Igeo–9	0.43	1.65	0.8	–1.14	–0.21	1.16	1.35	–0.81

Farm Soil	Igeo–10	0.77	1.33	0.79	–1.16	0.88	1.59	0.47	–0.29
	Igeo–11	1.43	0.95	0.98	–1.17	0.78	1.65	0.06	–0.25
	Igeo–12	0.47	1.34	0.78	–1.30	0.79	1.55	0.46	–0.32
	Mean	0.751	1.237	0.841	–1.209	0.689	1.498	0.527	–0.368
	SD	0.363	0.256	0.084	0.074	0.459	0.184	0.453	0.233

Table 5 Contamination factor and pollution load index

Element	Nearby Thitchauk coal mine soil						Farm soil					
	CF–1	CF–2	CF–3	CF–4	CF–5	CF–6	CF–7	CF–8	CF–9	CF–10	CF–11	CF–12
Cr	3.48	3.30	1.76	5.38	5.60	2.91	2.55	2.34	2.07	2.02	2.56	4.03
Mn	1.04	1.43	2.53	1.46	1.21	2.25	3.09	3.23	3.80	4.72	3.76	2.90
Fe	10.35	10.53	12.51	9.97	9.65	10.08	2.83	2.59	2.57	2.61	2.60	2.97
Ni	12.85	8.03	11.03	17.45	8.55	12.45	0.66	0.61	0.61	0.68	0.67	0.66
Cu	3.83	5.43	0.00	0.00	2.27	2.23	3.25	2.55	2.60	1.30	2.76	2.58
Zn	7.00	2.76	6.26	4.22	2.72	5.12	4.62	4.02	4.39	3.36	4.51	4.70
Sr	1.59	1.19	1.01	1.43	1.84	1.38	2.31	2.91	3.50	6.50	3.53	2.65
Pb	2.15	2.06	2.26	1.70	1.63	1.18	1.36	1.14	1.20	0.86	1.23	1.26
PLI	3.80	3.32	3.66	3.91	3.17	3.33	2.27	2.12	2.22	2.12	2.34	2.35
PLI_{avg}	**3.53**						**2.24**					



	Cr	Mn	Fe	Ni	Cu	Zn	Sr	Pb
CF(TCS)	3.74	1.65	10.52	11.73	2.29	4.68	1.40	1.83
CF(FS)	2.60	3.58	2.69	0.65	2.51	4.27	3.57	1.17

Figure 3 Comparison of contamination factor for TCS soil samples and FS soil samples

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