International Journal of GEOMATE, May 2019, Vol.16, Issue 57, pp.130 - 136
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2019.57.8137
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

APPROACH TO ASSESSMENT OF SOIL AND WATER CONTAMINATION BY MINING ACTIVITIES IN MANDALAY REGION, MYANMAR

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ABSTRACT: In Myanmar, the mining sector is playing an important role in contributing to the country's income. Thus, environmentally and economically sustainable mining activities are essential for the long-term development of the sector. In Myanmar, there were a few research for the contamination of surface soil and groundwater of harmful effects caused by improper mining activities. Most of the research interests are geologically mapping for the potential area and chemical refining effect, not including the point of view about the environmental issue in mining areas. The environmental investigation is required in the near future to determine the detailed situation for surface and groundwater quality and human health. According to the previous study, arsenic concentration of groundwater has been found in some places of Sagaing, Mandalay, and Magway regions are higher than the WHO drinking water guideline value of 10μg/L. Gold and copper mineralization is distributed with sulfide minerals in the Mandalay region, Myanmar. Arsenic and heavy metal can be distributed into the environment naturally from the weathering, oxidation, and erosion of sulfide minerals. In this paper, the authors presented the overview of drinking water standards from four Asian countries they are Indonesia, Japan, Myanmar, and Sri Lanka. As a preliminary study, arsenic and some other heavy metal concentration in soil and rock (ore) samples will study from the Gold and Copper mining site in Mandalay Region, Myanmar by different methods. The analytical method is also very important to approach the assessment of environmental contamination because Myanmar is launching the practice of environmental assessment.

Keywords: Mandalay region, Arsenic, Drinking water standards, Analytical methods

1. INTRODUCTION

At the present time, the crisis of decreasing water resources, rare of safe drinking water and impact of natural environment were facing in a lot of country in the world but the rate of population in the world is gradually increased day by day [1], [2]. Water is not only an essential material for the daily life of all living organism but also a crucial requirement to access the safe water for human health. Therefore, water quality guidelines and drinking water standards are also very important to assessment by waterborne pathogens and chemical to prevent the health of humans [2]-[4]. The means of safe drinking water is "does not represent any significant risk to health over the lifetime of consumption, including different sensitivities that may occur between life stages" which is defined in the WHO Guidelines [4]. In this paper, the authors presented the overview of drinking water standards from four Asian countries they are Indonesia, Japan, Myanmar, and Sri Lanka.

Such as industry and agriculture are the main ways for heavy metals to enter the environment by human activities. Heavy metals produced during the mining process have become one of the primary sources of soil pollution in the mining area. The presence of heavy metals in contaminated soils is of great concern as they are not biodegradable and thus pose a risk for humans and the environment [5], [6]. Among them, arsenic (As) is one of the most common metals in contaminated sites because of its widespread accumulation in air, rock, soils, and water by naturally and industrially [7]. In Myanmar, the mining sector is playing an important role in contributing to the country's income as a country endowed with rich mineral resources and a long history of mining. In some gold mine, they use cyanide and amalgam so it affected the nearest stream or river water [8], [9]. Thus, environment-tally and economically sustainable mining activities are essential for the long-term development of the sector. In Myanmar, there were a few research for the contamination of and surface and groundwater of harmful effects caused by improper mining activities. Most of the research interests are geologically mapping and chemical refining effect, not including the point of view about the environmental issue in mining areas. The environmental investigation is required in the near future to determine the detailed situation surface and groundwater quality and human health. Gold and copper mineralization is abundantly distributed and associated with sulfide minerals in the Mandalay region, Myanmar [10]. Arsenic and heavy metal can be distributed into the environment naturally from the weathering, oxidation, and erosion of sulfide minerals [6], [11]. The main objective of this paper is heavy metal concentration in soil and rock (ore) samples will study from the near area of gold mining site and Copper mining site in Mandalay Region, Myanmar by different methods in this paper as a preliminary study. The analytical method is also very important to approach the assessment of environmental contamination because Myanmar is launching the practice of environmental assessment. Because mining activities may be detrimental to the environment, any negative effects caused by mining activities should be mitigated.

2. THE COMPARISON OF ENVIRONMENTAL STANDARD

There are different indices in each country standards but toxicological index and radioactive index will be expressed in this paper because those indexes were closely related to the mining sector. Although some of the limitations of standard values from each country are same, some are different not only the item (parameters) number but also the standard values when compared (**Table 1**) and it may depend on the situation or technical limitation of the countries [12]-[15]. According to the 2014 Environmental Performance Index Rating, Japan is standing in rank 26 out of 178 countries but it is the first rank of accessibility for drinking water. Myanmar is standing at rank 164 and access to drinking water rank is 125. Ranking 112 and 124 of access to drinking water for Indonesia and Ranking 69 and 95 of access to drinking water for Sri Lanka were respectively standing (**Table 2**) [16]. Water pollution is basically linked with an inadequacy of environmental sanitation [17]. Water contamination in Myanmar, especially in risk is becoming alarming and must be taken into consideration. The potential pollution contributed by runoff water originating from communities, cattle-farming, mining and agricultural drainage system is not under-estimated or ignored. The growth of industrialized development, using the more fertilizers and pesticides to boost the efficiency of farmers and mining with intensive use of the chemical in association with sprawling mine sites the introduction of losing technical systems in the country are all going to significantly contribute to the generation of contamination loads [18]. Hence, such structures should be considered in water pollution control programs. Water Resources Utilization Department (WRUD) and the Department of Development Affairs firstly reported the concentration of arsenic for the national-scale survey supported by some international NGOs. According to that previous survey data, arsenic concentration of groundwater has been found in some places of Sagaing, Mandalay, and Magway regions are higher than the WHO drinking water guideline value of 10μg/L [19].

Table 1 Comparison of Drinking Water Quality Standards from four countries

Chemical & Toxicological Indices						
No.	**Parameters**	**Units**	**Myanmar**	**Japan**	**Sri Lanka**	**Indonesia**
1	Antimony	mg/L	0.02	-	-	0.02
2	Arsenic	mg/L	0.05	0.01	0.01	0.01
3	Barium	mg/L	0.7	-	-	0.7
4	Boron	mg/L	2.4	1.0	-	0.5
5	Cadmium	mg/L	0.003	0.003	0.003	0.003
6	Chromium	mg/L	0.05	0.05	0.05	0.05
7	Copper	mg/L	2	1.0	1	2
8	Cyanide	mg/L	0.07	0.01	0.05	0.07
9	Fluoride	mg/L	1.5	0.8	1	1.5
10	Lead	mg/L	0.01	<0.01	0.01	0.01
11	Manganese	mg/L	0.4	0.05	0.1	0.4
12	Mercury (Total)	mg/L	0.001	0.0005	0.001	0.001
13	Nickel	mg/L	0.07	-	0.02	0.07
14	Nitrate	mg/L	50	10	50	50
15	Nitrite	mg/L	3	0.04	3	3
16	Selenium	mg/L	0.04	0.01	0.01	0.01
17	Uranium	mg/L	0.03	-	-	0.015
Radioactive indices						
No.	Parameters	Units	Myanmar	Japan	Sri Lanka	Indonesia
1	Gross Alpha	Bq/L	0.5	-	-	0.1
2	Gross Beta	Bq/L	1	-	-	1

Save the Children Fund, (UK) conducted as a preliminary study in March-May 2000. In that study, 35% of 145 shallow tube wells in 63 communities those situated in Ayeyarwady region that results showed the arsenic concentration is also excessed the proposed national standard 0.05 mg/L in Myanmar. The further study of UNICEF survey to 1912 wells in Ayeyarwady Region analyzing by Atomic Absorption Spectrometry (AAS) found 21% of test wells with a concentration of arsenic is above 0.05 mg/L and retested in a subsequent survey by AAS and field test kit result in some well too. This concentration is also exceeding the WHO standard and proposed national standard [20]. The concentration of arsenic, manganese, fluoride, iron, and uranium in well water from around Myingyan Township in Mandalay Region, Myanmar are also exceeded the public health concern levels [21]. In some river, sediments are contaminated by mercury and mercury concentration in muddy sediment is higher than 10 µg/g and total mercury level in the hair of miner is 0.6 to 6.9 µg/g [8]. The buffer of Tabaitgine and Sintku in the north of Mandalay Region is the main focus area in that study because there is a major artisanal and small-scale gold mining areas in Myanmar [8].

Table 2 Country Ranking of 2014 Environmental Performance Index Rating

No.	Country	Rank	Rank of accessibility for drinking water
1	Japan	26	1
2	Sri Lanka	69	95
3	Indonesia	112	124
4	Myanmar	164	125

3. MATERIAL AND METHODS

3.1 Study Area

Soil samples were collected from near area of Mo Di - Mo Mi gold mine which is located in Yamethin Township, Mandalay Region and, Rock (ore) samples were collected from Zabutalu copper mine which is located in Sabe Taung area, Kyaukse Township, Mandalay Region. **Figure 1**. shows the location map of sampling sites, Mandalay Region, in Myanmar.

3.2 Sample Preparation

Soil samples were air dried for Japan, Ministry of Environment (MoE) Announcement 46 and 19 and dried in an oven at 105º C until 2 hours but it may depend on the moisture of sample for acid digestion method. And soil samples were separated grain sizes and grind the soil mass and agglomerates except for small and medium gravels. After grinding, samples were sieved through a non-metallic 2 mm eye sieve. Preparation for analysis involved crushing is made approximately 20 g of samples. Rock (ore) samples were dried in an oven at 105º C for 24 hours. After drying the samples were made the powder by manually grind and using the 200 mesh sieve for all methods.

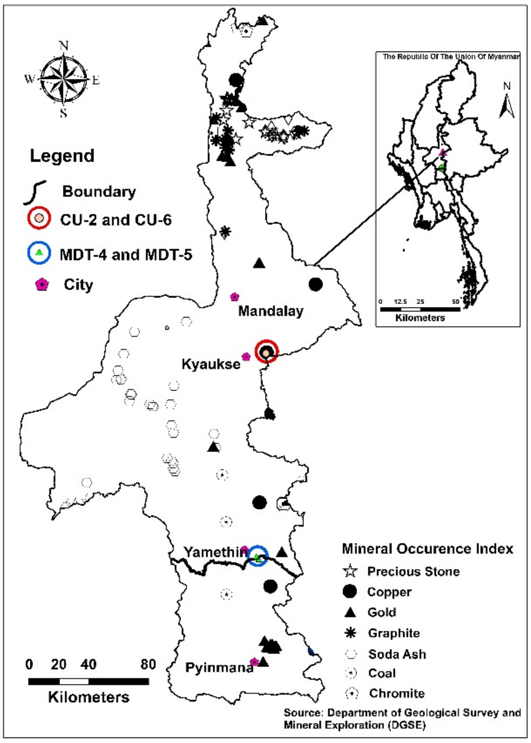

Fig.1 Map of sampling locations

3.3 Japan, Ministry of Environment (MoE) Announcement 46

A sample (unit g) and a solvent (hydrochloric acid is added to pure water so that the hydrogen ion concentration index is (5.8 to 6.3 or less) are mixed at a weight ratio of 10%. Make sure that the mixture is 500 ml or more. The prepared sample solution was shaken at room temperature (roughly 20 ° C) at atmospheric pressure (roughly 1 atm), (the shaking frequency was adjusted to about 200 times per minute and the shaking width was adjusted to 4 - 5 cm) and continuously shake for 6 hours. The sample solution obtained by carrying out the procedures was allowed to stand for about 10 to 30 minutes. After that, centrifuged at about 3,000 rpm for 20 minutes and the supernatant was filtered with a membrane filter with a pore size of 0.45 µm, weigh the amount necessary for quantification accurately and use it as a test solution. Only 3 g sample powder was used and followed by the procedure in this experiment because the sample amount which is expressed in the announcement is much. These samples were dilute with 1% HNO_3 prepared for analyzing because the sample solution will be reliable with a standard solution.

3.4 Japan, Ministry of Environment (MoE) Announcement 19

Weigh 6 g or more of the sample and mix the solvent (hydrochloric acid added to pure water so that the concentration of hydrochloric acid is 1 mol/l) (unit ml) at a ratio by weight of 3%). The prepared solution was shaken at room temperature (roughly 25º C) at atmospheric pressure (roughly 1 atm), (the shaking frequency was adjusted to about 200 times per minute and the shaking width was adjusted to 4 – 5 cm) and shake for 2 hours. A shaker container is a polyethylene container or a container which does not adsorb or dissolve substances to be measured and has a volume of 1.5 times or more the solvent. Leave the sample solution obtained by shaking for about 10 to 30 minutes. Centrifuge the sample solution if necessary and filter the supernatant with a membrane filter with a pore size of 0.45µm and weigh the amount necessary for quantification accurately and use it as a test solution. 1 g sample powder was used followed by the procedure in this experiment although expressed to use 6 g or more sample to use in announcement procedure because the sample amount which is expressed in the announcement is much. These samples were dilute with 1% HNO_3 prepared for analyzing because the sample solution will be reliable with a standard solution.

3.5 Acid Digestion Method (Department of Geological Survey and Mineral Exploration, Ministry of Natural Resources and Environmental Conservation, Myanmar)

Dry sample powder 1 g were weight and separately placed in 60 ml Pyrex beakers and then slowly add 10 ml of HCl and digest to nearly dryness on a hotplate at over 150 º C. After nearly dryness, cool down that and add 10 ml of HNO_3 and digest to nearly dryness on a hotplate at over 150 º C again. After that, 10 ml of HNO_3 and 5 ml de-ionized water were added into these beakers and boil for 10 minutes on the hot plate and covered with a watch glass for every step. The digested samples were settled down and filtered into 100 ml volumetric flask using Millipore Millex-GP 0.45µm and the volume made up to the marks with de-ionized water.

4. RESULT AND DISCUSSION

In order to determine the concentration of B, As, Se, Cd, and Pb in soil and rock, three methods were used: Japan, Ministry of Environment Announcement No. 46, 19 and acid digestion method which is using in Department of Geological Survey and Mineral Exploration, Ministry of Natural Resources and Environmental Conservation, Myanmar. Inductively coupled plasma/mass spectrometer (ICP-MS) was used to analyze element concentration. Results were expressed as the means of three replicates ± standard deviation (SD). The obtained results mean value in samples of B, As, Se, Cd, and Pb with standard deviation for each method are shown in **Table 3**. These results are pointed to methodological differences between the three different methods as shown in **Table 4**. Two types of acids such as HNO_3 and HCl were used and heating on a hot plate and it takes about 7 hours in acid digestion method. Only Deionized Water (pH 5.8 – 6.3) were used and it takes about 6 hours in Japan, Ministry of Environment (MoE) Announcement 46 method. Only HCl was used and it takes about 2 hours only in Japan, Ministry of Environment (MoE) Announcement 19 method. B, As, Se, and Pb concentrated as the most abundant of heavy metal in the sample CU-2 and CU-6. Those are mining rock (ore) from the copper mining site. Lead-zinc and barite veins associated with copper in carbonates were distributed in that area by geologically [10]. Copper-bearing minerals are chalcopyrite, tetrahedrite, bornite, chalcocite, pyrite, malachite and azurite and often associated with minor gold [10]. Oxidation of sulfide minerals such as pyrite, arsenopyrite, galena, chalcopyrite and sphalerite can release the arsenic and heavy metals [22]. That’s why, the result shows a high concentration of B, As, Se, and Pb. Pb was only rich in sample MDT-4 and MDT-5. Those samples are soil sample from the near area of the gold mining site. According to the result, that area can be assumed that the other 4 elements did not leach that area although near the mining site. Cd concentration can only be seen in sample CU-6 but in sample MDT-4, MDT-5 and CU-2 was undetected with three methods. This might be due to the fact that Cd is present under detectable amount in these samples. This study investigates in the mining area and presents analytical data on heavy metal distribution may be the first time because it is not included for B, As, Se, Cd and Pb although Kyi Tun (2014) [9] and T. Osawa and Y. Hatsukawa (2015) [8] investigated the valuable data on the state of mining in Myanmar. And, most of the other researchers are also mainly focus on the wells in public area for arsenic in groundwater contamination, not for mining area.

5. CONCLUSIONS

Japan, Ministry of Environment (MoE) Announcement 19 method was the most efficient method in terms of the recovery of As, Se, and Pb than others and did not take a long time. But Acid digestion method is more recoverable for B than the other two methods except in sample CU-6. Cd is also more recoverable for sample CU-6 in acid digestion method. In summary, Japan, Ministry of Environment (MoE) Announcement19 method is recommended as a method for the analysis of As, Se, and Pb. Acid digestion method is recommended as a method for the analysis of B and Cd. Japan, Ministry of Environment Announcement No. 46 method is not recommended for the analysis of the metal concentration because of its low recovery and it takes a long time. It should be used for the human risk evaluation from drinking groundwater which located that the downstream basin residential area from the mining site. Even though the data obtained in this study may not represent all the mining activities, the results from this research evidence that the environment of mining area could be contaminated with arsenic and some other heavy metals. Further detail investigation of environmental contamination in mining areas, Myanmar is necessary because of the lack of previous data. Moreover, Environmental remediation plans should also be considered to recover the contamination of surface soil and groundwater of harmful effects caused by mining activities. Authors collected the specific plant that is the hyperaccumulation of the arsenic and will start the cultivation test with this sample such as *Pteris vittata* from Myanmar.

Table 3 Concentration of different metals (μg/g) in samples using different methods

Sample	Methods	Elements				
		B	As	Se	Cd	Pb
MDT - 4	(MoE) announcement 46	0.25 ±0.09	0.03 ±0.04	0.01 ±0.00	0.00 ±0.00	0.08 ±0.04
	(MoE) Announcement 19	0.33 ±0.19	2.47 ±0.39	0.43 ±0.15	0.00 ±0.00	13.57 ±2.17
	Acid Digestion Method	2.27 ±0.58	0.71 ±0.30	0.55 ±0.21	0.00 ±0.00	12.07 ±2.28
MDT - 5	(MoE) announcement 46	0.18 ±0.02	0.00 ±0.00	0.01 ±0.00	0.00 ±0.00	0.08 ±0.03
	(MoE) Announcement 19	0.00 ±0.00	1.89 ±0.25	0.45 ±0.15	0.00 ±0.00	24.36 ±1.38
	Acid Digestion Method	3.43 ±1.40	0.65 ±0.17	0.86 ±0.23	0.00 ±0.00	15.56 ±3.21
CU – 2	(MoE) announcement 46	0.34 ±0.04	0.17 ±0.03	0.01 ±0.00	0.00 ±0.00	0.05 ±0.02
	(MoE) Announcement 19	0.00 ±0.00	0.87 ±0.19	21.99 ±7.57	0.00 ±0.00	22.55 ±1.86
	Acid Digestion Method	2.49 ±0.60	2.33 ±0.93	1.72 ±0.59	0.00 ±0.00	1.97 ±0.11
CU – 6	(MoE) announcement 46	0.71 ±0.00	0.14 ±0.04	0.01 ±0.01	0.00 ±0.00	0.02 ±0.01
	(MoE) Announcement 19	5.67 ±3.27	483.39 ±30.47	6.88 ±6.42	2.64 ±0.24	17.63 ±5.57
	Acid Digestion Method	3.80 ±2.48	13.83 ±5.79	1.31 ±0.43	43.66 ±9.89	21.16 ±5.77

Table 4 Comparison table of three chemical methods in this research

Requirements	(MoE) Announcement No. 46	(MoE) Announcement NO. 19	Acid Digestion Method
Sample amount	3 g	1 g	1 g
Reagents	Deionized Water (pH 5.8 – 6.3)	HCl	HCl, HNO_3 and Deionized Water
Reaction	Shaking (200 times per minute)	Shaking (200 times per minute)	Heating on Hot Plate
Total Reaction Time	6 hours	2 hours	About 7 hours

6. ACKNOWLEDGMENTS

The authors wish to their gratitude to U Kyaw Zaw Tun from Department of Mines who help to collect samples, Daw Myat Kay Thi from Department of Geological Survey and Mineral Exploration, Ministry of Natural Resources and Environmental Conservation, Myanmar who explained for the digestion/analytical method and all people who was supported for this studied. This study was financially supported by MEXT, Japanese Government.

7. REFERENCES

[1] World Health Organization, “Drinking water quality in the South-East Asia Region,” *Print. India*, 2010.
[2] Khin Sein Kyi, “Water Quality monitoring program and activities in Myanmar,” http://www.unescokyotosympo2015.org/abstracts/Kyi - Water Quality monitoring program and activities in Myanmar.pdf.
[3] H. Utsumi and Y. Tsuchiya, “Water Quality and Standards,” vol. I.
[4] World Health Organization (WHO). “Guidelines for Drinking-water Quality, 4th ed, 2011”.
[5] A. Boularbah, C. Schwartz, G. Bitton, W. Aboudrar, A. Ouhammou, and J. L. Morel, “Heavy metal contamination from mining sites in South Morocco: 2. Assessment of metal accumulation and toxicity in plants,” *Chemosphere*, vol. 63, no. 5, 2006, pp. 811–817.
[6] F. Html, “Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation,” 2017, pp. 1–17.
[7] Society for Mining, Metallurgy & Exploration (SME), “The Role of Arsenic in the Mining Industry April 2012”. http://me.smenet.org/docs/Publications/ME/Issue/TheRoleofArsenicintheMiningIndustry.pdf
[8] T. Osawa and Y. Hatsukawa, “Artisanal and small-scale gold mining in Myanmar : Preliminary research for environmental mercury contamination,” no. 25, 2015, pp. 221–230.
[9] K. Htun, “Sustainable Mining in Myanmar,” vol. 36, no. 1, 2014, pp. 25–35.
[10] K. Zaw, Y. M. Swe, T. A. Myint, and J. Knight, “Copper deposits of Myanmar,” 2017, pp. 573–588.
[11] B. Keshavarzi, F. Moore, F. Rastmanesh, and M. Kermani, “Arsenic in the Muteh gold mining district, Isfahan, Iran,” *Environ. Earth Sci.*, vol. 67, no. 4, 2012, pp. 959–970.
[12] M. of Health, “Proposed National Drinking Water Quality Standards of Myanmar.” 2014.
[13] H. Wakayama, “Revision of Drinking Water Quality Standards in Japan,” 2015, pp. 74–88.
[14] Sri Lanka Standard, “SPECIFICATION FOR POTABLE WATER” First Revision – SLS 614, 2013).
[15] “Peraturan Menteri Kesehatan Republik Indonesia NOMOR 492/MENKES/PER/IV/2010, Tentang Persyaratan Kualitas Air Minum”, “Minister of Health Regulation of the Republic of Indonesia No. 492/MENKES/PER/IV/2010, About Drinking Water Quality Requirements”.
[16] Hsu, A., J. Emerson, M. Levy, A. de Sherbinin, L. Johnson, O. Malik, J. Schwartz, and M. Jaiteh. (2014). The 2014 Environmental Performance Index. New Haven, CT: Yale Center for Environmental Law & Policy. http://archive.epi.yale.edu/epi/country-rankings
[17] International Institute for Environment and Development, “Environment, Water and Sanitation,” *Irish Aid Keysheet No.11*, 2008, p. 12.
[18] J. H. Kim, “Surface Water Pollution in Myanmar (Burma),” in *TU Delft Weblog*, 2016. https://myanmarsurfacewater.weblog.tudelft.nl/2016/09/19/surface-water-pollution-in-myanmar-burma/.
[19] IWMI - International Water Management Institute. (IWMI Research Report 164). doi: 10.5337/2015.216, Integrated Assessment of Groundwater Use for Improving Livelihoods in the Dry Zone of Myanmar, 2015.
[20] T. N. Tun, “Arsenic contamination of water

sources in rural Myanmar," 2003, pp. 219–221.
[21] T. Bacquart, S. Frisbie, E. Mitchell, L. Grigg, C. Cole, C. Small and B, Sarkar, "Multiple inorganic toxic substances contaminating the groundwater of Myingyan Township, Myanmar: Arsenic, manganese, fluoride, iron, and uranium," *Sci. Total Environ.*, vol. 517, 2015, pp. 232–245.
[22] M. Lim, G. C. Han, J. W. Ahn, K. S. You, and H. S. Kim, "Leachability of arsenic and heavy metals from mine tailings of abandoned metal mines," *Int. J. Environ. Res. Public Health*, vol. 6, no. 11, 2009, pp. 2865–2879.