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Risk Assessment at Abandoned Tin Mine In Sungai Lembing, Pahang, Malaysia

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ABSTRACT

The Sungai Lembing abandoned tin mining and processing activities 77 years lease to mine the area have resulted in the production of hazardous wastes, which contain high residual concentrations of heavy metals. Heavy metals (As, Pb, Zn, Cu, Cr and Ni) contained in the tailings are mobilised, migrate to the surroundings and cause severe and widespread contamination of soils, surface and ground waters and to river. For the purpose of this study, eight holes were drilled using hand auger, and sampling of contaminated soil was conducted at different depths and collected samples from surface for the tailings. The concentrations of heavy metals in this area exceed the limit allowed by Dutch list and Kelly Indices. Results showed that the concentrations of heavy metals in contaminated soils range between 101.71 mg/kg for Cr and 250311.4 mg/kg for Pb. Meanwhile, the maximum concentration of heavy metals in tailing deposits is 151839.32 mg/kg for Pb near the main potential sources of pollution (i.e. near the abandoned processing structure), and the minimum concentration is 96.04 mg/kg for Cr. The results suggest that there is a vital increase of heavy metal risk in this area. Polluted heavy metals dispersion (for examples from historical and active tailings impoundments and waste rock dumps), are mainly associated, at this site, with water transportation of mine waste through the flowing streams. Control measures of pollution routes and remediation measures at the site are urgently required.

KEYWORDS: heavy metals, abandoned mining, tin mine, tailings, Sungai Lembing

INTRODUCTION

Previous studies such as those of Benvenuti et al. (1997), Asklund (2005), Wang & Mulligan (2005), Navarro et al. (2007), and Schwab et al. (2007) showed that mining is one of the most important sources of heavy metal contamination in the environment. Heavy metals contained in residues coming from mining and metallurgical operations are often dispersed by wind and/or water after their disposal. In addition, the pollution of soil and groundwater by dissolved heavy metals has mainly been associated with Acid Mine Drainage (AMD), one of the most serious environmental hazards of mining industry. The AMD is generated by the oxidation of sulfide-bearing minerals exposed to weathering conditions, resulting in low quality effluents characterized by acidic pH, a high level of dissolved metals (e.g., As, Cd, Cu, Zn), and anions (e.g., sulphates and carbonates) (Razo et al. 2004).

For the abandoned mine, the resultant waste consists of roaster piles, tailings ponds, waste rock piles and acid mine drainage. Percolation from the tailing ponds has contaminated ground water below and down gradient of the ponds. The ground water discharges to a nearby stream and so do the runoff from the roaster, waste piles and acid mine drainage. In particular, the main concentrations of concern are arsenic, iron, copper, lead, manganese, nickel, and zinc that exceed water quality criteria in the stream.

Heavy metals occur naturally as a result of mineral deposition processes. For example, arsenic is usually an unusable byproduct that may introduce into the environment through the natural process of erosion of mineral deposits or through mining and milling of these deposits. Metals or mineral decomposition products may be present in mine water, mine dump rock, mill tailings or nearby soils, or water bodies.

The wastes generated by beneficiation milling operations are collectively known as tailings. Tailings are the waste portions of mined material that are separated from the target mineral(s) during beneficiation. By far the larger proportion of ore mined in most industry sectors ultimately becomes tailings that must be disposed. In the gold industry, for example, only a few hundredths of an ounce of gold may be produced of every ton of dry tailings generated. Similarly, the copper industry typically mines relatively low-grade ores that contain a low percent of metal values; the residue becomes tailings. Thus, tailing disposal is a significant portion of the overall waste management practice at mining and milling operations (EPA 2000).

Tailing fine grained under drier conditions are especially prone to producing dust. Sulfide tailings oxidized by weathering conditions are potential generators of acidic runoff, are discharged into rivers if flow is sufficient, and held behind dams if necessary or placed on land (EPA 2000).

Study Area

Sungai Lembing (3°54'23"N and 103°2'30"E) is a tin mining town located at 34 km northwest of Kuantan in Pahang (Figure 1). It is an old mining town, which once had the biggest tin mine on earth. It was 100 years ago during the British colonial days when Sungai Lembing was founded. For 80 years of mining activities, it became the largest, longest and deepest underground tin mine in the world. Until the 1970s, Sungai Lembing was a major producer of underground tin. Sungai Lembing town was developed in the 1880's when the British set up the tin mining industry, although the history of mining in this area extends much further back. From 1891, the Pahang Consolidated Company Limited which was under British control, had a 77-year lease to mine the area. The pit mines were closed in 1986 due to high operational costs and low yields, but during their heyday, these mines were among the largest and deepest in the world. The total tunnel length is 322 km with a depth ranging between 610 m and 700 m. Sungai Lembing mine kept its waste material from treatment plant at a predetermined site near the bank of the river Kenau (Fuad 2002).

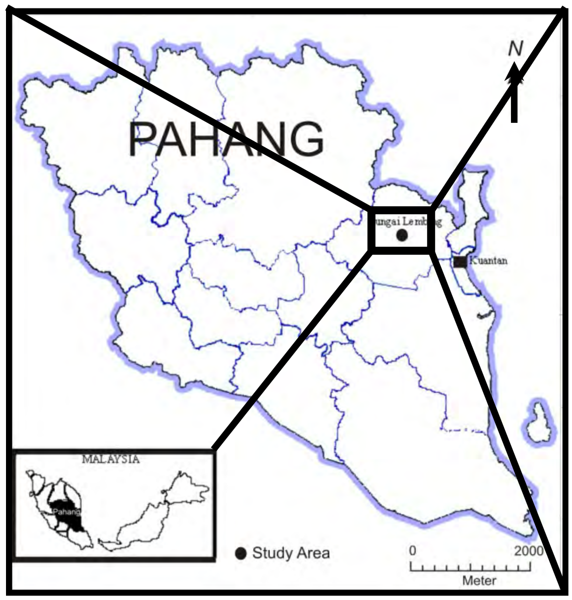

Figure 1: The study location

MATERIALS AND METHODS

In April 2008, contaminated samples were collected from the surface for tailings and at various depths for soil (50, 100, 150 cm intervals) in eight holes drilled using hand auger. Sampling locations are indicated on Figure 2. The symbol of holes is SL from 1 to 8, and that for tailing is T from 1 to 7.

Microwave oven dissolution procedure was used to digest the soil. About 0.1 gram sample was placed in a 250 ml polycarbonate bottle. Then 2.0 ml of concentrated nitric acid (HNO_3) was added to the bottle, followed by 5.0 ml of 7:3 mixture of hydrochloric-hydrofluoric acid (HCL-HF). Samples were then placed into the microwave oven and heated with 400-500 watt with 120˚C for 15 minutes. After cooling 40 ml of 1.5% boric acid (H_3BO_3), solution was added to each bottle. Then the bottles were recapped and returned to the oven and heated again at 400-500 watt for 15 minutes with 130˚C. After cooling to room temperature, the solutions were analyzed for heavy metals using ICP-MS instrument.

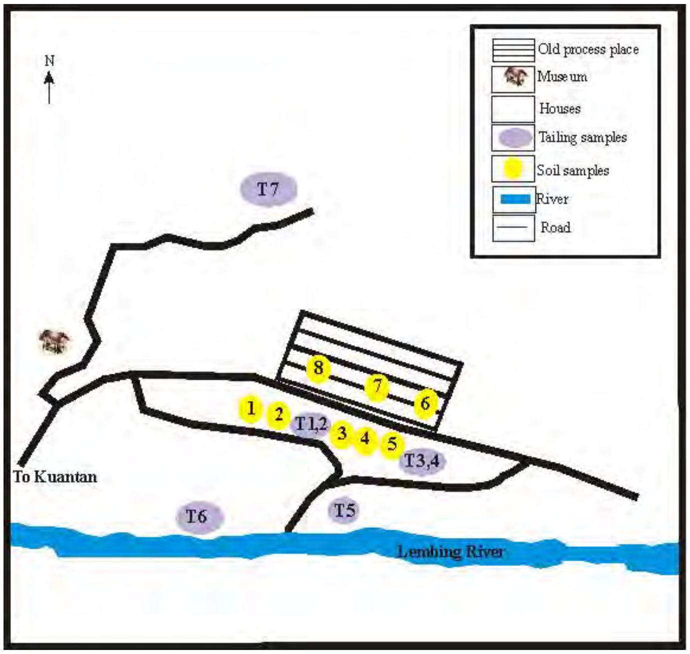

Figure 2: Sampling location at Sungai Lembing

RESULTS AND DISCUSSION

Total contents of heavy metals (As, Cr, Cu, Ni, Pb and Zn) in the contaminated soils and their concentrations in tailing samples are shown in Tables 1 & 2 (Table 1 for soils and Table 2 for tailings). Highest contamination for heavy metals for soils and tailings is found in Pb (250311.3and 151839.32 mg/kg respectively) in the mining operations area. Therefore, the spatial distributions of their total contents in the studied area were investigated. They are provided in Figure 3&4.

The mean values for As is 941.053 - 31680.027 mg/kg. This means exceeds the value for uncontaminated soil according to Dutch list, Kelly Indices and Soil Quality Guidelines (SQG) classification of hazardous waste. Therefore, the study area is contaminated by high concentration As, especially at SL1, SL2, SL3 and SL4 where readings were 13643.64, 31680.027, 13817.44 and 14302.58667 mg/kg, respectively. This is because these areas are tailing waste as observed during the field investigation in view of the topographic depression compared to other locations, SL5, SL6, SL7and SL8, and all tailings. High concentration of As in shallow soil will have an impact on groundwater, and may affect rivers if rainwater drags the waste through the drainage.

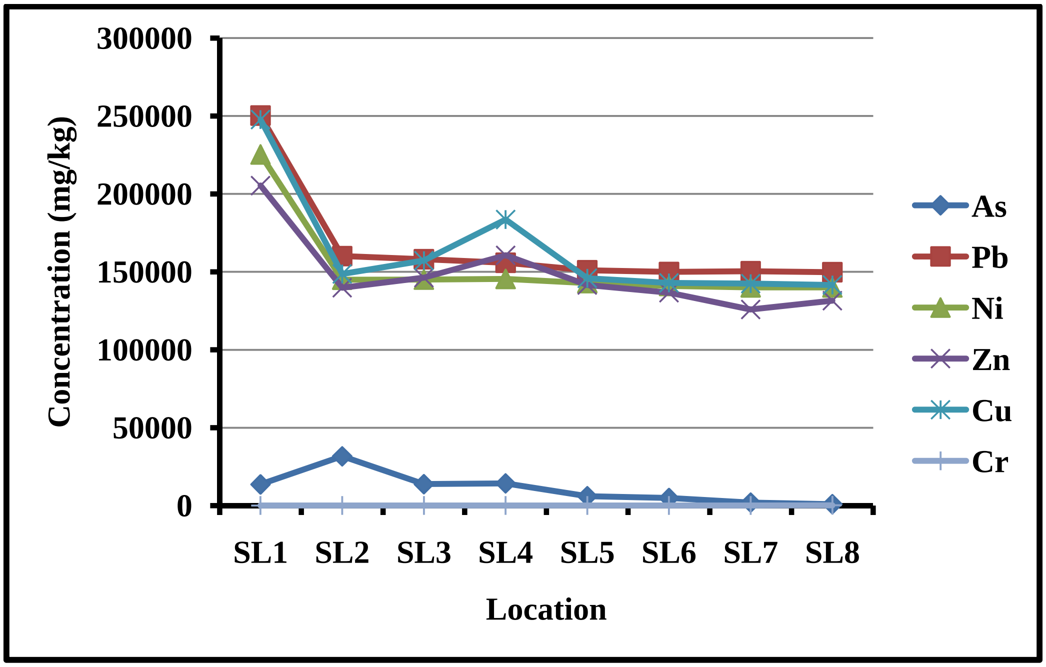

Figure 3: Concentration of heavy metals in soil

Mine tailings contaminated with heavy metals, especially As, are leach out into groundwater and enter the river, resulting the contamination of the surrounding area in sungai Kenau. According to Mogensen et al. (2001), Arsenic concentration in polluted water was observed to range between 0.01 and 0.55 mg/kg, while maximum arsenic levels reach 0.125 mg/kg in sediment and 0.08 mg/kg in plant.

For Pb, the readings were ranging from 149740.33 - 250311.33 mg/kg in soil while the concentrations in tailings were ranging between 141555.76 - 151839.32 mg/kg. These results showed that the Pb is the largest polluter**. A**ccording to Niragu (1978) measure of the soil is uncontaminated when the concentration of Pb less than 20 mg/kg. Roussel et al (2000), Lee et al. (2001), and Asklund & Eldvall (2005) discovered that the Pb resides in large quantities with the remnants of mining activities, and the result is an extension of what other studies reported on the subject. One of the reasons that created Pb with high concentration in the soil and tailings is Pb availability in a large amount in tin as well as the possibility of its being shot through the production of tin (Rana 2006). In addition, there was no substantial difference in the contents of Pb between the soils and tailings.

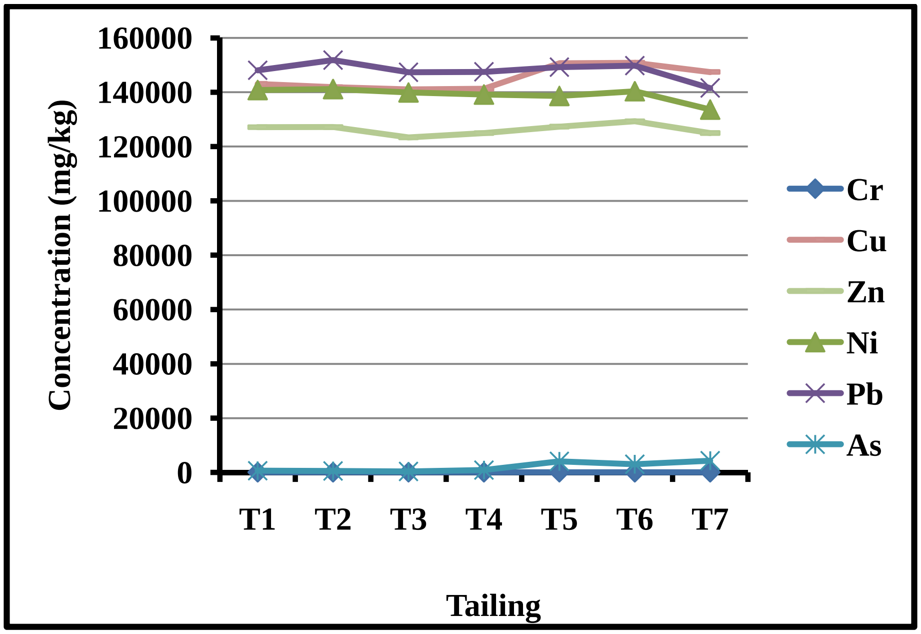

Figure 4: Concentration of heavy metals in Tailings

Table1: Heavy Metal Concentration in soils

Location	*Heavy Metals Concentration (mg/kg)*					
	As	Pb	Ni	Zn	Cu	Cr
SL1	13643.6	250311.3	225351.3	205396	247720.6	101.71
SL2	31680.03	160073.2	144991.7	139839.1	148669.1	142.8
SL3	13817.4	158107.6	145130.2	146285.6	157207.1	104.4
SL4	14302.6	155837.1	145521.7	160672.5	183539.13	104.1
SL5	6096.2	150997.9	142814.9	141578.1	145840.3	108.9
SL6	4906.9	149928.8	141019.9	136688.3	142879.8	102.7
SL7	2009.6	150354.9	140097.3	125886.5	142420	110.5
SL8	941.1	149740.3	140059.9	131537.4	141545.3	205.5
Dutch list	55	530	210	720	190	380
Kelly Indices	50	500	50	500	200	200
SQG	12	70	50	200	63	64

While Ni concentration, in this area, ranges between 140059 - 225351 mg/kg in soil and 133627 – 138652 mg/kg in tailings, and according to Rana (2006), Ni contaminates the soil when the concentration of Ni is higher than the 40mg/kg. Results value for soil and tailings are higher than this is show that soil and tailings have heavy contaminated by Ni. Yaron (1996) mentions that the highest concentration of Ni was noticed in the layer of the soil that is rich in organic matter or with relatively high content of clay.

Zn is present in the soil ranging between 125886 – 205396 mg/kg while, in tailings, it ranges between 123358 - 129326 mg/kg. These results demonstrate the contaminated soil and tailings when concentration of Zn compared with Rana (2006) and measured for contaminated soils, the concentration of Zn exceed 200,500 and 720 mg/kg for SQG, Kelly Indices and Dutch list standard Respectively. It is likely that high concentration of Zn due to organic matter and sulfides in the soil can be oxidized to release Zn if the dissolved oxygen is abundant as indicated by Zhang *et al.* (2003).

Cu has high concentration that ranges from 141545 to 247720 mg/kg in soil while concentrations in tailings range from 141050 to 150878 mg/kg. Alloway (1995) found that if soil has Cu concentration greater than 20 mg/kg, it is considered contaminated soil. This is in conformity with the results of that analysis of soil and tailings at the site that is found to be contaminated by Cu.

The results of the study showed that the concentration of Cr is low in the study area, and compared to Rana (2006) study that soils and tailings are uncontaminated with the element Cr. The readings were between 101 and 205 mg/kg for soil while it was 96 and 110 mg/kg for tailings. However, the soil contaminated waste contained a higher concentration of 380, 200 and 64 mg/kg according to standard Dutch list, Kelly indices and SQG, which means that Cr has a low concentration in soil and tailings.

Table 2: Heavy Metals Concentration in Tailings

Location	*Heavy Metals Concentration (mg/kg)*					
	As	Pb	Ni	Zn	Cu	Cr
T1	627.88	148083.9	140835	127137.3	143081.7	106.4
T2	531.8	151839.3	141204	127177.8	141866.4	110.08
T3	354.2	147363.3	139934	123358.4	141050.6	106
T4	880.04	147515.5	139170	124929.1	141265.1	101.8
T5	4086.2	149233.2	138652	127344.8	150710.1	96.04
T6	3020.24	149784.6	140387	129326.7	150878.3	103.52
T7	4332.12	141555.8	133627	124981.1	147459.4	106.84

Comparing with the Dutch list, Kelly indices and SQG the results show that the whole of the Sungai Lembing abandoned mining area is contaminated by As, Pb, Zn, Cu, and Ni.

Several studies related to environmental impact assessment in mining sites have reported evidence of tailings transport through streams carrying the material several kilometers downstream (Leblanc et al., 2000; Lee et al., 2001; Jung, 2001; Marques et al., 2001).

The study revealed by Zuhairi et al. (2007) that mine waste or tailings at abandoned mine of Sungai Lembing that were left exposed to air and water has produced acidic water and has increased the level of heavy metals in surface water and soils.

CONCLUSION

In this study, it is found that all heavy metals measured, As, Pb, Cu, Zn, and Ni have high concentrations ranging between 354.2 and 250311.3 mg/kg, whereas Cr has low concentration between 96.04 - 205.52 mg/kg. According to the data, the abandoned tin mine of Sungai Lembing is contaminated with Pb> Cu> Ni> Zn > As> Cr by comparing with Comparing with the Dutch list, Kelly indices and SQG.

The amount of pollution varies from one location to another based on the topography and elevation of site for soils, whereas the results of the tailings are convergent.

Tin mining activities are usually carried out in previously depopulated areas like Sungai Lembing. They make living in such areas unhealthy. The main problems caused by mining are namely formation of wasteland, damage to natural drainage, pollution and the destruction of natural habitats. In this case, of great concern of Sungai Lembing ex-mining site and immediate study and care must be carried out as soon as possible.

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