Effective environmental management system of acid mine drainage at Kyisintaung copper surface mine in Myanmar

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Abstract: Copper products are being utilized in many utilities such as electrical equipment, mechanical, architecture, and military industries. Basically the copper processing begins with the mining of copper ore which causes the environmental and social problems unless proper management systems are being exercised. This study focus on the effects of Acid Mine Drainage (AMD) of Kyisintaung mine, located near the confluence of the Yama Creek and the Chindwin River in Monywa, Sagaing region, Myanmar. To identify the effects, surface and ground water in the vicinity of the mine are sampled and analysed at the certified national laboratory. The study highlights the detailed analysis of the study programme and the results and findings have been discussed thoroughly. It has been observed that the hydrometallurgy method and zero discharging system are utilized at the mine. The results indicates that the effects of AMD around the area are insignificant because the laboratory analysis results of studied pollutants such as pH, temperature, hardness, conductivity, TDS, DO, Cu, Fe, Pb, Mg, \( \text{SO}_4^{2-} \) are within the acceptable range of national environmental quality guideline. Finally, it has been noticed that there are no significant effects of AMD to surface and groundwater around the mine site, no water pollution sources to the environment, no serious environmental damages caused by AMD to near-by areas, and hence the adopted EMS of the mine is considered to be an effective system.

Keywords: Copper Sulphide Ore; Hydrometallurgy; Acid Mine Drainage; Environmental Management System; Water quality

1. Introduction

It has been said that copper is one of the first metals extracted and used by ancient people and is still an important metal nowadays. Everyday our human beings rely on copper products in various ways. It cannot be denied that copper is an integral part of many utilities such as electrical conductors, electronic devices, telecommunication devices, water distribution pipes, automobiles parts, heating and lighting facilities, etc. [1]-[2].

Apart from the recycling of used copper, the copper metals come from the extraction of copper ore from the ground. It is obvious that mining and metallurgical processing of copper cause harmful effects to the environment. There are many examples that mine tailings and Acid Mine Drainages (AMD) from the copper mines cause adverse effects on the surrounding lakes, surface and ground water bodies, forests and agricultural lands [3]. However, the severity of the environmental effects may vary depending on the types of processes and environmental control measures being applied.
This study mainly deals with the study of the AMD effects of Kyisintaung copper mine, located in Monywa district, Sagaing region, Myanmar to the surrounding water bodies. At the Kyisintaung area, the existence of copper mineral has been known for centuries. In the 1970s, the feasibility study for the Kyisintaung area was carried out and production began in the mid-1980s with limited stripping. Currently MYTCL operates the mine with the production rate of 50,000 tons annually.

Copper sulfide ore (Chalcocite-Cu$_2$S and Chalcopyrite-CuFeS$_2$) is found at the Kyisintaung mine, and hydrometallurgy method which is able to process complex and low-grade ore to get marketable copper metal at 99.99% is being utilized[4]. The method is more environmentally friendly and eco-friendly having lower processing cost than other conventional processes [5]-[7].

1.1. The Objective of the Study
The objectives of the study include:
- To study the current Environmental Management Systems of the mine adopted in its operations, and
- To study the AMD effects on the surrounding water body in the area.

1.2. Study area
The Kyisintaung mine is located at the coordinates of 22° 7'21.56"N and 95° 1'58.27"E, Salingyi township, Monywa district, Sagaing region in Myanmar as shown in Figure 1. There are the Yama creek, approximately 1 km north, and the Chindwin river, about 6 km east, of the mine. The surrounding area comprises paddy fields, residential households and an open-pit copper mine called LapadaungTaung.

The area has a semi-arid climate, which is characterized by the very high temperatures (high evaporation levels) and a long dry season. The average temperature ranges from 14°C - 41°C throughout the year. The highest temperature reaches up to 38°C in April while the lowest found 14°C in the winter, January. The annual rainfall ranges from 10 to180 mm and the relative humidity ranges 60-80 % annually [8].

Figure 1. Study area location
2. Methodology
The step-by-step mining operations included mineral extraction, transporting, crushing, heap leaching, solvent extraction and electro-winning and, environmental management systems have been studied during field observation. The total of 21 water sampling points comprising 12 surface water samples and 9 ground water samples were identified in the vicinity of the mine. As presented in Figure 2, the surface water samples were taken along the Yama creek and the Chindwin river while the ground water samples were collected from the tube wells of residential households.

In-situ measurements were carried out for the physical parameter-temperature-and some chemical parameters such as pH, conductivity and dissolved oxygen using HI98194 Multiparameter probe. The other parameters such as Total Suspended Solid (TSS), Total Dissolved Solid (TDS), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Sulfate (SO\(_4^{2-}\)), Calcium (Ca), and Total Hardness (TH) were analysed at the National Health Laboratory of Myanmar.

Water samples were collected with sterilized plastic bottles and the bottles were rinsed three times with the water to be sampled before being filled. After collection, the sample bottles were kept in the container, chilled at about 4°C and then transported to the laboratory [9]-[11].

Figure 2. Surface and ground water sampling points

3. Results and Discussion

3.1. Environmental management systems
It has been observed that the type of ore from Kyisintaung is copper sulfide ore (Chalcocite-Cu\(_2\)S-and Chalcopyrite-CuFeS\(_2\)) with 0.3% - 0.85% copper and the Hydrometallurgy process has been used for copper purification [4]. According to the studies, this process is more environmentally friendly, having lower processing cost than conventional Pyro-metallurgy process. The environmental management systems, that reduce the level of Acid Mine Drainage (AMD) and environmental effects, have been discussed in the following sections.

3.1.1. Heap leaching.
In this stage, the stacked ore is irrigated using a network of pipes and low pressure sprinklers, called wobblers. The diluted sulphuric acid solution is used to extract the copper from the stacked ore. In order to avoid leaching of acidic solution into the soil, the compact clay layer, the impermeable environmentally safe barrier, have been created at the base of each heap. In addition, a 1-mm thick high density polyethylene elastic sheeting (HDPE) is laid down, and in turn covered by another clay liner (350-mm thick) to prevent copper solution losses, as well as to protect the acidic solution from seeping into the ground water system. Each heap is constructed on a slight slope, so that the solution...
containing the dissolved copper percolates down through the heaps to the liner and flows downhill into a series of collection channels (W-Drain) that drain into a system of plastic-lined ponds. The solution containing the highest copper grade is directed into the pregnant leach solution (PLS) pond. The solution with lesser amount of copper concentrates is recirculated back from an intermediate solution pond (ILS) and onto the heap cells to increase the copper concentration. Once contained in the PLS pond, the solution is pumped to the Solvent-Extraction Plant (SX) for further purification [4].

![Figure 3. Heapleaching, SX-EW and acid recirculation](image)

It was also discovered that the company strictly monitors and checks the leakages from heap cells on daily basis and measures are in place to pump out any stray solutions from beneath the HDPE before they have any opportunity to breach the protective clay base barriers. This design methodology not only protects the environment from potential impacts, but also protects the company’s liquid assets of the solution bearing precious copper from being lost [4].

3.1.2. Solvent extraction and electro-winning (SX-EW)

Studies point out that the process SX-EW itself has less environmental impacts since the acidic solution is recirculated and no effluent is being discharged [12]-[14]. In this stage, the valuable copper ion is extracted from the PLS using kerosene (C12H26) and Liquid Ion Exchange (LIX 64N) reagents to produce an enriched electrolyte known as a strong electrolyte. The remaining low-copper aqueous solution from the extraction stage, called raffinate is recycled to the leach cells to recover more copper while the strong electrolyte is sent to the tank house for electro-winning [4].

Electro-winning reduces the copper electrochemically from copper-sulfate in solution to a metallic copper cathode. The cathodes are stripped basically every seven days, with each copper-laden cathode weighing approximately between 48-52 kg as per the London Metal Exchange (LME) market standard. This process consumes higher energy consumption at 8 Mj/kg whereas electro-refining does 1.5Mj/kg. However, the overall SX-EW consumes 2-3 times lower than the conventional process called smelting and refining [15].
3.2. Water quality

The analyzed results of surface and ground water samples were presented in Table A.1 and Table A.2. It was observed that the pH level of samples appeared within the acceptable range, 7-8 and no acidic condition was observed according to the laboratory analysis. It indicates that acid leakage was not happened and acid recirculation system was effective during the study period.

In addition, the results compared to the National Environmental Quality Guidelines (NEQG) are illustrated in Table A.1 and Table A.2. For the surface water quality, the TSS concentrations of all samples, except SW11 and SW12, significantly exceed the guideline value at 50 mg/l while the results of remaining parameters were below the guideline limits. This is because the samples were collected during the rainy season (August 2018) where the higher flow rate carries more particles and larger-sized sediment leading to higher concentration of TSS [16].

Regarding the results of ground water samples, it has been found that all the concentrations of studied parameters were within the acceptable limit of NEQG values. However, the TSS values appear to be higher than in GW07 and GW08 at 110 mg/l and 99 mg/l respectively, while the other points were lower than NEQG limit. The total hardness concentrations of all samples appear to 2-3 times higher than the guidelines values. It was also found that the concentration of sulfate in GW08 and GW09 were higher than the guidelines values since it is assumed that these sampling points were located very close to the heap leaching area and the remaining points were within the guidelines value limits.

4. Conclusion

The results and findings of this study can be summarized as follows:

- The adopted hydrometallurgy process for copper purification has been found to be environmentally friendly and the environmental management systems of the mine are effective the study period.
- The comparison of water quality (surface and groundwater) between the laboratory analysis and the NEQG standards indicates that the results have been within the acceptable range of guideline limits and this means that there are no serious environmental damages caused by AMD.
- Regarding the surface water quality testing, it has been observed that the TSS concentration of all samples except SW11 and SW12, significantly exceed the guideline value at 50 mg/l while the remaining parameters were below the range of guideline limits. This is because of the collected water samples, which were collected during the rainy season where the higher flow rate of water carries more particles and larger-sized sediments leading to higher concentration of TSS.
- Regarding the ground water testing, it was observed that the concentration of all studied parameters were found to be within the acceptable limit of NEQG limit except the TSS concentration of GW07 and GW08 at 110 mg/l and 99 mg/l were appeared to be higher than the guideline limits. The total hardness concentrations of all samples were also appeared 2-3 times higher than the guidelines values. It was also found that the values of concentration of sulfate in GW08 and GW09 were higher than the guideline limits since it is assumed that these sampling points were located very close to the heap leaching area while the remaining points were observed within the guideline limits.

5. Recommendations

5.1. Application of this research results

The following recommendations have been made:

- The environmental management systems of the Kyisintaung mine can be adopted to similar copper mine to reduce Acid Mine Drainage (AMD) problems;
- The methodologies used in surface and ground water sampling can be applied in the future water sampling; and
The analysed results of water samples from the study can be utilized as the baseline data for future water quality studies.

5.2. Recommendation for further study

The recommendations to undertake further studies include:

- This study only focused on water quality in the vicinity of the Kyisintaung mine, it is recommended that the soil analysis should also be studied to estimate the effects of AMD.
- The effects of AMD for Latpadaungtaung Copper Mine, which is about 4 miles south-east from this Kyisintaung Mine, should also be studied to identify and estimate the cumulative effects.

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### Appendix A

#### Table A.1. Results of surface water samples

| Analysis                        | NEQG/Composite Guideline | SW01 | SW02 | SW03 | SW04 | SW05 | SW06 | SW07 | SW08 | SW09 | SW10 | SW11 | SW12 |
|---------------------------------|--------------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| **pH**                          |                          | 6-9  | 7.8  | 7.6  | 7.3  | 8.1  | 7.7  | 8.1  | 7.9  | 7.9  | 8.0  | 8.1  | 7.8  | 8    |
| **Temperature**                 |                          | -    | 29.1 | 28.6 | 29.3 | 28.1 | 28.9 | 27.1 | 28.2 | 30.3 | 25.7 | 26.5 | 31.4 | 28.6 |
| **Dissolved Oxygen**            |                          | -    | 3.71 | 4.71 | 5.02 | 4.79 | 5.17 | 5.14 | 4.36 | 5.05 | 4.91 | 4.04 | 4.32 | 6.28 |
| **Conductivity @ 24.5°C**       |                          | -    | 106  | 103  | 108  | 521  | 109  | 106  | 521  | 102  | 123  | 169  | 1054 | 628  |
| **Total Suspended Solids**      | 50 mg/l                  | 687  | 892  | 608  | 233  | 788  | 750  | 292  | 763  | 86   | 63   | 29   | 19   |
| **Total Dissolved Solids**      | 1500 mg/l                | 533.2| 523.3| 536.9| 746.9| 547.3| 504.1| 738.1| 517.4| 525.1| 558.2| 1071.1|846.2 |
| **Cu (dissolved)**              | 0.30 mg/l                | <0.01| 0.01 | <0.01| <0.01| <0.01| <0.01| <0.01| <0.01| <0.01| <0.01| <0.01| <0.01|     |
| **Fe (dissolved)**              | 3.5 mg/l                 | 2.10 | 1.39 | 0.77 | <0.01| 0.73 | 0.47 | <0.01| 0.90 | <0.01| <0.01| <0.01| <0.01|     |
| **Lead**                        | 0.10 mg/l                | <0.01| <0.01| <0.01| <0.01| <0.01| <0.01| <0.01| <0.01| <0.01| <0.01| <0.01| <0.01|     |
| **Sulphate**                    | 400 mg/l                 | 14   | 13   | 16   | 68   | 15   | 15   | 66   | 14   | 14   | 17   | 154  | 79   |
| **Calcium**                     | 200 mg/l                 | 13   | 11   | 9    | 31   | 10   | 9    | 31   | 16   | 15   | 18   | 21   | 26   |
| **Magnesium**                   | 150 mg/l                 | 5    | 5    | 5    | 17   | 5    | 4    | 17   | 5    | 5    | 6    | 28   | 21   |
| **Total Hardness**              | 180 mg/l                 | 51   | 47   | 41   | 146  | 44   | 40   | 145  | 61   | 57   | 70   | 167  | 150  |
| **Acid**                        | 0.50 mg/l                | Nil  | Nil  | Nil  | Nil  | Nil  | Nil  | Nil  | Nil  | Nil  | Nil  | Nil  | Nil  |
### Table A. 2. Results of ground water samples

| Analysis                  | NEQG/ Composite Guideline | GW01 | GW02 | GW03 | GW04 | GW05 | GW06 | GW07 | GW08 | GW09 |
|---------------------------|----------------------------|------|------|------|------|------|------|------|------|------|
| pH                        | 6-9.                       | 7.2  | 7.6  | 7.7  | 7.5  | 7.6  | 7.6  | 7.2  | 7.2  | 7.5  |
| Temperature               | -                          | 30.3 | 30.5 | 30.4 | 31   | 27.8 | 30.6 | 28.3 | 30.7 | 28.3 |
| Dissolved Oxygen          | -                          | 1.54 | 2.24 | 3.06 | 0.87 | 2.13 | 2.23 | 1.04 | 1.42 | 2.77 |
| Total Suspended Solids    | 50 mg/l                    | 52   | 14   | 15   | 92   | 50   | 10   | 110  | 99   | 19   |
| Total Dissolved Solids    | 1500mg/l                   | 573  | 534  | 645  | 618  | 3165 | 781  | 1543 | 3807 | 2557 |
| Cu (dissolved)            | 0.30 mg/l                  | <0.01| <0.01| <0.01| <0.01| 0.04 | 0.01 | 0.01 | 0.02 | 0.01 |
| Fe (dissolved)            | 3.5 mg/l                   | <0.01| <0.01| <0.01| <0.01| 0.01 | <0.01| 0.01 | <0.01| <0.01|
| Lead                     | 0.10 mg/l                  | <0.01| 0.01 | <0.01| <0.01| 0.03 | <0.01| 0.01 | 0.05 | 0.03 |
| Manganese                | 0.1 mg/l                   | <0.01| <0.01| <0.01| <0.01| <0.01| <0.01| <0.01| <0.01| <0.01|
| Sulphate                  | 400 mg/l                   | 146  | 122  | 196  | 182  | 910  | 194  | 234  | 1000 | 1280 |
| Calcium                   | 200 mg/l                   | 111  | 96   | 81   | 116  | 7    | 54   | 11   | 67   | 24   |
| Magnesium                | 150 mg/l                   | 43   | 40   | 38   | 52   | 90   | 54   | 142  | 106  | 116  |
| Total Hardness            | 180 mg/l                   | 454  | 404  | 359  | 504  | 387  | 356  | 613  | 604  | 538  |
| Acid                     | 0.50 mg/l                  | Nil  | Nil  | Nil  | Nil  | Nil  | Nil  | Nil  | Nil  | Nil  |
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