Early Step to Prevent Environmental Impacts in Mining Project

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Micro Review

Early Step to Prevent Environmental Impacts in Mining Project
Case Studies: Mine Water Management in Messel Gold Mine, Minahasa, North Sulawesi and Sorowako Lateritic Nickel Mine, Luwu, South Sulawesi, Indonesia

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The purpose of the work is to show that an early data acquisition for environmental impact assessment is very important in mining operation. Study of the mineralogy, hydrochemistry, hydrogeological systems, and groundwater flow modeling, showed that in the abandoned Messel Pit area soils and natural springs have indicated high arsenic content, and the high arsenic content in groundwater was dominantly caused by natural condition. Arsenic in Buyat Village's groundwater is believed originally coming from the oxidation of sulphide minerals (arsenopyrite) in the alluvial deposit. In the case of Sorowako Nickel Mine, high concentration of Cr^{6+} were found at ore stockpiles, open pit areas, and ex-pit ponds. With suitable data preparation and analysis, environmental impacts in mining operation could be managed and minimized. As a conclusion, environmental data acquisition for environmental impact assessment should be started during the early phase of mine development in line with the exploration program.

1. Introduction

Nowadays, to maintain civilization in the planet earth, more and more energy and mineral resources are needed. It means that the extraction of earth resources will never stop. As the consequence the threat to the nature and environment will always potentially occur.

Since mining operation will always generate impacts on the environment, it is an obligation for mining operators to minimize the impacts. Environmental impact management should become an important part of the mining operation.

It was in 1982 when the first environmental law in Indonesia was issued, namely Law Nr. 4/ 1982. This law was revised in 1997 (Law Nr. 23/ 1997), and the final revision was declared in 2009 (Law Nr. 32/ 2009).

According to the law and government regulations on the environment, it is the obligation of every new mine to submit an Environmental Impact Assessment Document to be approved by central or local EIA Committee, before the mining license is granted.

Experiences show that environmental impact assessment is usually conducted separately from other activities of mine development (i.e. exploration and mine design). In many cases data collecting for EIA study was conducted long after exploration work finished. Ideally, it will be better, if the environmental data for EIA were collected since the exploration work. On the other hand, the exploration design should also consider the EIA program.

1.1 Mining and Environment

Mining, particularly large scale surface mining, will cause significant changes to the nature, such as physical components i.e. morphology, surface and groundwater system, water quality, land stability, air quality, biological characteristics, as well as social behavior and local/regional economy.

Without a good practice of EIA, the impact may cause severe disturbance to the nature and human life. With a good EIA practice, a good mining practice can be done, environmental impact management can be better designed, and then, the disturbance to the nature can be minimized.

1.2 Indonesian Experiences

Before 1982, there were no laws or regulations to push industries, including mining companies to protect the environment or to implement environmental friendly practices in their operations. It can be seen, there are some abandoned mine sites became unusable lands (wetlands, lakes, swamps) with undrinkable water.

Since the declaration of the environmental law in 1982, the situation became better, even though some mistakes were occurred, or some practices were not perfect yet.

One of the important thing to be identified for EIA is the original/natural environmental characteristics before the activity (in this case: mining) was started. Long before the engineering design and feasibility study was done, the early stage of mining industry is exploration campaign. Usually, the exploration team is only collecting data which are needed for resource/reserve calculation and mine design, such as geological settings, structural characteristics, mineralogy and grade/quality distribution, depth and size of ore body, etc. In practice, in line with those activities, the exploration team could also collect the environmental data, long before it is disturbed by any other activities.

2. Arsenic Case: Messel Gold Mine, North Sulawesi Province

Messel Gold Mine, which was closed in 2004 after 9 years operation, was located in North Sulawesi Province, Indonesia (Figure 1). Before the closing, it was indicated in the village Buyat, about 2 km south east of the mine, high concentration of arsenic (> 28 ppb) were found in some dug wells[1]. It was thought by the people, that the arsenic content in the water was come from the mine site.

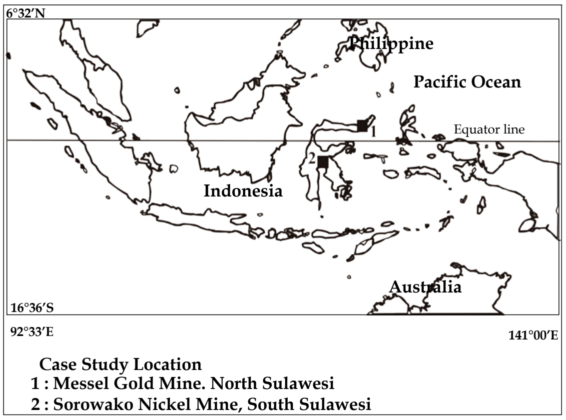

Fig. 1 Case Studies Location[2].

Messel Gold Mine was located in an active volcanic belt (Lembeyan Volcanic Ridge), where the North Sulawesi's faults trending NE-SW and NW-SE was developed[3]. Other structural evidences (small faults) are interpreted from shaded DEM data[4]. The area is overlaid by plutonic-volcanic rocks of Palaeogene to Quaternary ages, and by sedimentary rock of Mesozoic and Cenozoic ages.

There are 3 possibilities of arsenic source in the area[5]: seepage through fault and other structures (fault zone) below the mineralization zones act as channels of hydrothermal water to the surface; seepage from the mine site (abandoned mine pits, processing plant, and waste dumps); and oxidation of arsenic bearing minerals which found in the mine site, such as arsenopyrite (FeAsS), arsenian pyrite ($FeAs_xS_{2x}$), orpiment (As_2S_3), and realgar (AsS). Alteration of As-rich pyrite will release arsenic into water system and precipitate secondary minerals such as goethite/ FeO(OH) and jarosite/ (K,Na)Fe_3.$(SO_4)_2$.(OH).

One thing to be considered is the potency of dissolving arsenic from secondary mineral jarosite, which is stable at low pH value, but unstable at neutral pH value. Rain water or surface water of neutral pH could infiltrate the weathered zone, and jarosite will release its arsenic ions to form goethite. This process may occur not only in the mine area, but in all mineralized zones[5].

According to Iskandar et al (2011), the most possible process that caused high arsenic concentration in groundwater, in Messel area, was from the first process. The second and third processes are small comparing to the first process[5]. It means, the natural process of hydrothermal seepage through hot springs was more dominant, especially to the deep/ confined groundwater system. The conceptual model of the arsenic distribution can be seen in Figure 2[4].

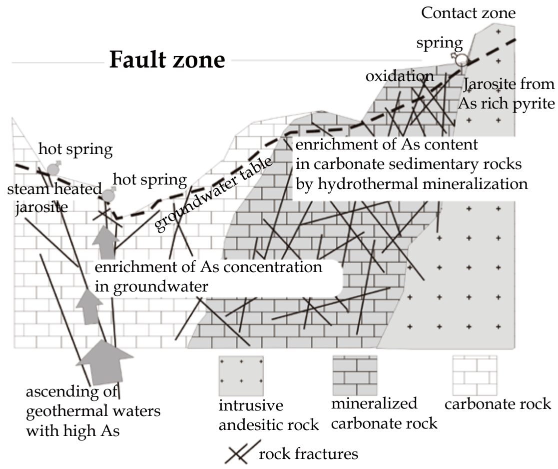

Fig. 2 Conceptual model of the arsenic distribution in Messel Mine area.

On the other hand, the alteration products seem to be one of the important arsenic sources to shallow/ unconfined groundwater system in the mineralized area.

Detail groundwater mapping, drilling and sampling, and water chemical analysis were conducted to understand the high arsenic concentration in dug wells in Buyat Village. A cross section showing the hydro stratigraphy/ hydrogeological system of the area can be seen in Figure 3[1].

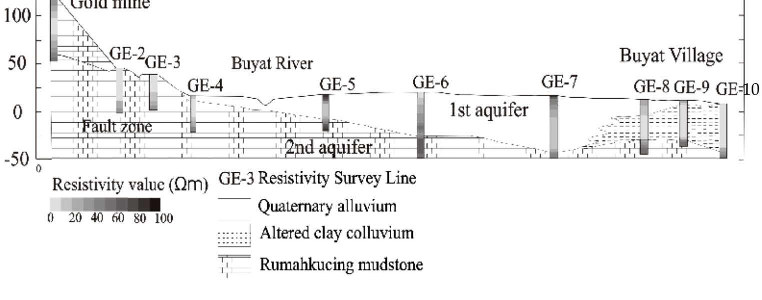

Fig. 3 NW-SE Hydrogeological Cross Section of Messel Gold Mine Area.

The above NW-SE hydrogeological cross section was constructed from bore holes, dug wells, and resistivity data. In general, the groundwater flows from mine site to Buyat Village. But according to rainfall and hydrogeological system of Buyat Village area, during dry season the Buyat River is a gaining stream. Only in rainy season the elevation of Buyat River is higher than shallow groundwater surface in the village and become a losing stream.

The facts that the distribution of arsenic concentration in the dug wells is random and the evidence of oxidized arsenopyrite mineral in the alluvial deposit, the dissolved arsenic in the village's shallow groundwater is likely on site. The source of sulphides minerals in Buyat alluvial deposit was predicted from the mineralized zone in the north.

The arsenic content in the deeper confined groundwater was studied from hydrothermal water seepage through fault zone.

From the study, it was known that:

1) the occurrence of arsenic in Messel Gold Mine and its surrounding area was mainly caused by hydrothermal water up flow through fault zone, seepage from abandoned mine site, and weathering process of arsenic rich sulphide minerals
2) knowing the mineralogical occurrence, weathering process, hydrochemistry, and hydrogeological system of a mine site from the beginning would be very useful for Environmental Impact Assessment

3. Hexavalent Chrome (Cr^{6+}): Sorowako Nickel Mine, South Sulawesi Province

Sorowako lateritic nickel mine, owned by PT Inco (now PT Valeinco), and is located in South Sulawesi Province, Indonesia (Figure 1). along its operation there was no indication of hexavalent chrome pollution, but in 2005, the management decided to investigate the possibility of hexavalent chrome generation at the mine.

In a nickel lateritic mine, there is always a potential of hexavalent chrome generation. Quite high concentrations of hexavalent chrome were found at ore stockpiles, abandoned pit ponds, and at much lower concentration in the active pits[6)].

Geologically, the mine area was ultrabasic rock: peridotite and hazburgite. The oxidation process of the minerals let the occurrence of residual lateritic clay with high Ni-content. The main secondary mineral of the lateritic deposit is limonite, containing Ni-silicates (garnierite, chrysoprase) with Ni-content up to about 2.5 %. There are also some oxide primary minerals such as magnetite and chromite (trivalent chrome).

In neutral condition, chromite (Cr_2O_3) is a stable in water, but in acid condition chromite will be readily decomposed to form chrome hydroxide and dissolved Cr^{3+} ion in water.

$$Cr^{+3} + 2\,H_2O \rightarrow \mathbf{Cr(OH)^{2+}} + 2H^+$$

$$Cr_2O_3 + 2\,H^+ + H_2O \rightarrow \mathbf{2Cr(OH)^{2+}}$$

Water in the abandoned ponds or moist water/puddles in stockpiles containing $Cr(OH)^{2+}$-ion, will easily oxidized to form chromate (CrO_4^{2-}) when exposed to the sun rays. It means the hexavalent chrome was generated[6)].

$$Cr(OH)^{2+} + 2\,H_2O \rightarrow \mathbf{CrO_4^{2-}} + 6H^+ + 3^{e-}$$

To understand the hydrogeological system of the area and the possible distribution of Cr^{6+} in the groundwater system, some bore holes were drilled, and water samples from stockpile areas (screen stations), collecting ponds, bore holes, and Lamoare River were taken. The result of water analysis show that there are some places with high Cr^{6+} content (screen station, bore hole 11, and Kockum pond). All of them are exposed to the sun rays, except bore hole 11 (Table 1)[6)].

The aquifer system of Sorowako area can be seen in Figure 4 (cross section) and shallow water flow system in Figure 5 (flow net)[6)].

Simulation model to predict the distribution of Cr^{+6} in shallow groundwater system was done, with an assumption that Harapan and Pongsesa Pond's water are infiltrated into the jointed bedrock (blue zone). The result of the simulation can be seen in Figure 6.a (after 1 year) and Figure 6.b (after 10 years)[6)]; shows that the infiltration of pond's water could spread the Cr^{+6} with the help of groundwater flow to wider area.

From the study, it can be concluded that:

1) the possibility of Cr^{6+}-generation in a nickel lateritic mine is always there, especially at stockpiles area and abandoned ponds
2) storing ore in a roofed and shaded place may minimize the generation of Cr^{6+}
3) in this case, the distribution of Cr^{6+} in shallow groundwater system is likely limited
4) if re-injecting mine water from collecting pond into the jointed bed rock (deeper groundwater system) were done, it could distribute the Cr^{6+} contaminant to more wider area

To minimize the Cr^{6+} in discharged water from the mining area, a chemical treatment plant (using sodium bisulfite/ sodium metabisulfite) was built.

Table 1 Cr^{6+}content in shallow groundwater in Sorowako area[6)].

No	Samples	Cr^{6+} (ppb)
1	Bore hole 1	< 10.0
2	Bore hole 2	< 10.0
3	Bore hole 3	< 10.0
4	Bore hole 4	< 10.0
5	Bore hole 5	< 10.0
6	Bore hole 6	16.0
7	Bore hole 7	18.0
8	Bore hole 8	< 10.0
9	Bore hole 9	< 10.0
10	Bore hole 10	< 10.0
11	**Bore hole 11**	**60.0**
12	**Kockum pond**	**136.0**
13	River Lamoare estuary	< 10.0
14	**Screen Station-2 (stockpile)**	**92.0**
15	**Screen Station-5 (stockpile)**	**61.0**

WHO standard for drinking water = 10.0 ppb

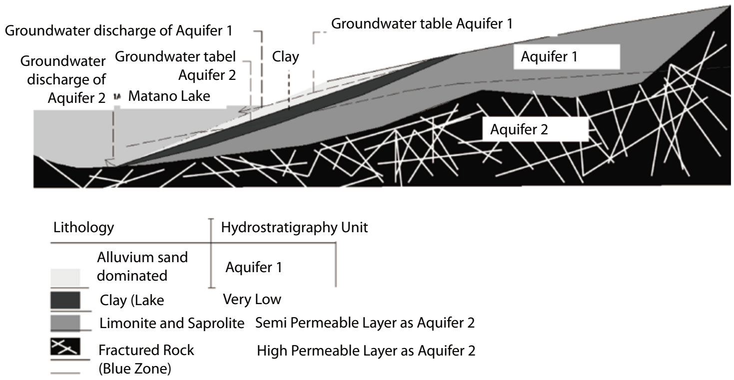

Fig. 4 N-S cross section of hydro-stratigraphy and groundwater system of Sorowako area[6].

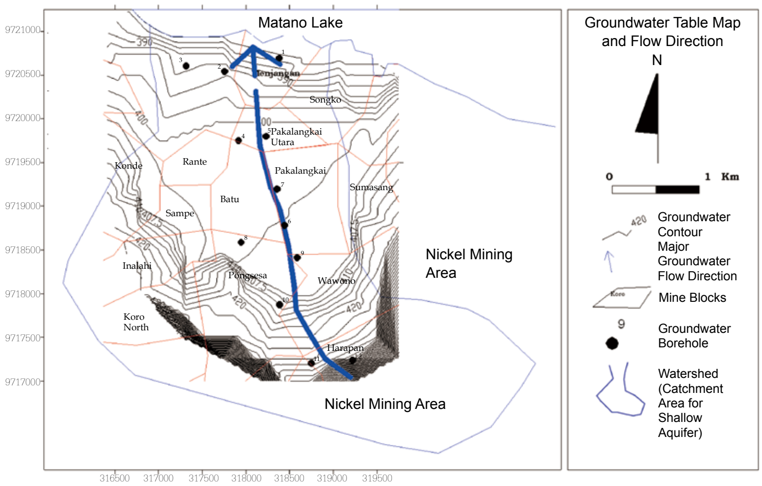

Fig. 5 Shallow groundwater flow net of Sorowako area.

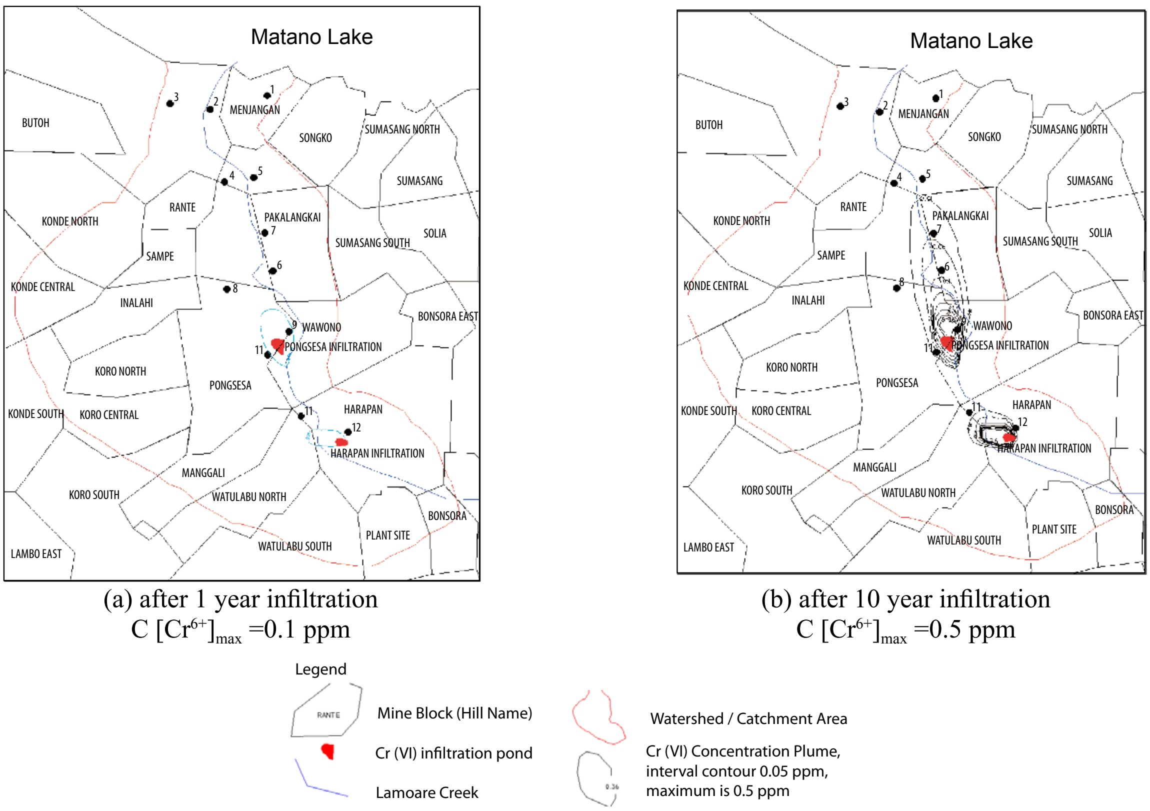

Fig. 6 2-D simulation of Cr^{6+} distribution in groundwater, in Sorowako area.

4. Discussion

In conjunction with the environmental impact assessment of mining operation, particularly the possibility of water and groundwater contamination by toxic materials, heavy metals, acid water, and hydrocarbon, etc., some studies should be conducted, such as the potency of contaminant generation caused by chemical change of the exposed minerals (stockpiles, pits, waste dumps), and the use of chemicals in the process (washing plants/ processing plants).

Ideally, the environmental impacts due to mining operation should be predicted and managed successfully. Impact prediction, especially from mineralogical and chemical point of view (mineralogy and water chemistry), could be done if the preparation of the data was done perfectly. Exploration, as the most beginning of mining industry, have a task not only to make sure that the deposit is real and economically worth, but should also prepare and make sure that the mining operation is environmental friendly.

Those data are mineralogy, weathering/ alteration products, natural water/ groundwater system and its qualities (surface water, springs, and wells). The natural water chemistry data, which had been taken before mining operation, is an important standard value to check and make sure whether contamination occurred during the mining operation or not.

In the case of arsenic in Messel Gold Mine, the study was done after the mine was closed. During the operation, monitoring activities were done continually, but the location of dug wells with high arsenic content was not the monitoring points. The same thing happened in Sorowako, where no monitoring point was set at ore stockpiles, active pits, and abandoned pits.

Both cases show that an early and perfect action in Environmental Impact Assessment, including data preparation, impact analysis, impact management, and monitoring design will reduce such problems during and after the mining operation, and of course save the money and company image.

5. Conclusion

1)Environmental impact assessment is very important to predict the potency of impacts to protect the environment.
2)Exploration activity should be also used to collect environmental data; especially the natural condition before mine was opened.
3)Environmental Impact Assessment should predict all impact possibilities that may disturb the environment: the source, the process, the place, and the distribution of the impacts.
4)Early action in Environmental Impact Assessment will save the environment better, and also save the company's money and reputation/ image.

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References

1) PT NMR - ITB, *Hydrogeological System at Buyat Village North Sulawesi*, Unpublished report (in Bahasa Indonesia) (2005).
2) Indonesia Tourism.com <http://www.indonesia-tourism.com/>
3) W. B. Hamilton, *Tectonics of the Indonesian region*, Geological Survey Professional Paper 1078, U.S. Govt. Print. Off. (1979).
4) I. Iskandar, K. Koike, and P. Sendjajam, *Environmental Earth Sciences*, in press.
5) I. Iskandar and K. Koike, *Environmental Earth Sciences*, **63**(3), 595 (2011).
6) PT Inco – Lapi ITB Mineralogy and Hydrogeology Study at Nickel Mine, Sorowako, a Final Report (2005).