Journal of Chemical, Biological and Physical Sciences

An International Peer Review E-3 Journal of Sciences

Available online at www.jcbsc.org

Section D: Environmental Sciences

CODEN (USA): JCBPAT Research Article

Physico-Chemical Characteristics of Tailings from Gango Gold Mine

Antonio Y. Asoy [1], Ronnie L. Besagas [2*], Romeo M. Del Rosario [3] and Noel T. Dael [4]

[1] Jacobi Carbons, Villanueva Misamis Oriental, Philippines

[2-4] Department of Science Education/Department of Chemistry, University of Science and Technology of Southern Philippines, Cagayan de Oro City, Philippines

Received: 30 January 2017**; Revised:** 08 February 2017**; Accepted:** 11 February 2017

Abstract: The physico-chemical characteristics of the Gango gold mine tailings and the economic feasibility of reprocessing it was investigated. Characterization was made in two categories of tailings: the surface tailings and the 1m deep tailings. The results showed that both surface and 1m deep tailings are alkaline at pH 9.80 and 8.98, respectively. Ignition at 500˚C resulted in a minimal loss of weight for both surface and 1m deep tailings implying that the tailings contain only a traced amount of volatile substances. The sulfur content of the tailings is at the average of 2.03%. The presence of sulfur may trigger a harmful environmental condition called acid mine drainage. Substantial amount of Fe, Mn, Cr, Cu, Co, Pb, Ag, and Au were assayed in the Gango gold mine tailings. In terms of the economic aspect, the tailings contain substantial amount of gold (7.38 g Au/t) with significant economic value. It is estimated that the tailings pond at Gango Gold Mine contains more than 945 kg of gold. Reprocessing of Gango gold mine tailings to recover the precious gold metal is highly viable.

Keywords: Gold, tailings, gold mine, small-scale gold mining.

INTRODUCTION

Gango Gold Mine is operated by small-scale miners. It is located in barangay Gango municipality of Libona province of Bukidon, Philippines. As of May 1, 2010 Gango has a population of 4,884 [1]. The

soils of Gango have an estimated gold reserve of 1,026,000 metric tons [2]. Because of this enormous gold reserve Gango was declared by the local government and the Department of Environment and Natural Resources—Mines and Geosciences Bureau (DENR-MGB) Region-10 to be a "Minahang Bayan" (People's Mining Area). The mining operation involves the manual breaking of the ore and hauled by mini dump truck from the source of the mill plant. Cyanide leaching is employed and then gold extraction from pregnant solution is achieved in a conventional carbon-in-leached. The processing generates tailings which are disposed in only one tailings pond located at Sitio Manlauyan, Gango, Libona Bukidnon. The tailings pond has an area of about 6,000 square meters with 10 meters depth of tailings. This impoundment site contains an estimated 128,000 tons of tailings.

Tailings are one of the mining wastes produced during mineral processing operation. Specifically, tailings are a mixture of water and finely ground rock that is left over after the valuable metals are completely or incompletely extracted from its host ores [3, 4]. Thus, tailings can contain leftover chemicals and residual minerals from incomplete extraction due to crude or unoptimize method and are usually deposited into tailings pond [5]. The content of the tailings themselves depend on what mineral being mined and technology used to process the ore [3, 6]. To ensure safety of tailings disposal and containment, mining plants must have a "Tailings Management Facility (TMF) or Tailings Storage Facility (TSF)" as a final storage area for tailings. However, the gold mining operations in Gango do not have this kind of storage facility because their tailings are just discharged as slurry through pipe lines into only one tailings pond. The disposal of tailings is commonly identified as the simple most significant source of environmental impact of many mining operations. Providing a safe, permanent storage of tailings is and always has been one of the most important aspects of a mining operation of any size. Yet it is one of the most neglected aspects of many small-scale miners. This is a serious threat to the environment and public health, for it leaves the mines untreated. For example, many hard rock mines extract minerals that are bound up with sulfide compounds. These compounds become part of the mining wastes after the metallurgical extraction and in turn produced sulfuric acid when in contact with air and water, a process that occur at a very low rate in undisturbed rock and at a higher rate in unprotected waste rock and a much higher rate in unprotected mine tailings which have a massive surface area. This phenomenon is an infamous problem affecting the mining industry and is known as "Acid Mine Drainage (AMD)" [4, 7, 8].

Mine wastes require careful management to ensure the long-term stability of storage and disposal facilities, and to prevent or minimize air, water and soil contamination [9]. In particular, the tailings physical and chemical characteristics have to be determined to establish its long term behavior and its potential short- and long-term liabilities and possible environmental impact. Thus, this work focused on characterizing the mine tailings produced by the mining plants in Gango, Libona Bukidnon in terms of some physical and chemical parameters including the mineralogy with respect to the level of some metals it contained. The economic feasibility of reprocessing the tailings to recover the precious gold metal was also evaluated based on the level of residual gold contained in the tailings.

METHODOLOGY

The tailings were taken from the tailings pond of Gango Gold Mine. Enough quantity of tailings had been taken from the site that will suffice for the various analytical determinations. There were 15 sampling spots that were identified in which both surface tailings and tailings within 1 meter deep were obtained. Then the 15 samples for each surface and 1 meter deep tailings were mixed to obtain two composite samples that are representative to the entire tailings pond from the surface up to a depth of 1 meter. The tailings samples were placed in sealed plastic bags. **Figure 1** shows a picture of the tailings pond.

Figure 1: The gold mine tailings pond at Sitio Manlauyan, Gango, Libona, Bukidnon, Philippines.

The tailings were mixed thoroughly to ensure homogeneity of the bulk sample. In obtaining the analytical sample, the tailings undergone the quartering method. Enough representative samples were taken for the physico-chemical characterization. The gold and other metals in tailings were assayed using flame atomic absorption spectroscopy.

RESULTS AND DISCUSSION

Physico-chemical characteristics: The results of physico-chemical tests on the tailings is shown in **Table-1**. The results revealed that there is no significant difference in the specific gravity between the surface tailings and the 1m deep tailings. The specific conductance of tailings, on the other hand, varies significantly with location in the tailings pond. The surface tailings have a higher specific conductance than that of the 1m deep tailings. This probably because the surface are the newly discharged tailings which contains more dissolved ions at ambient temperature than the bottom tailings.

Table-1: Physico-Chemical Characteristics of Tailings.

Parameter	**Tailings**	
	Surface	**1m Deep**
Specific gravity	2.64	2.59
Specific Conductance (µS/cm)	560	452
Loss on Ignition (%)	0.771	0.996
pH	9.80	8.98
Sulfur (%)	2.04	2.01

After ignition at 500°C, there is only a minimal loss on weight for both the surface and 1m deep tailings. This implies that the mine tailings contain only a traced amount of volatile substances. The results further revealed that the tailings are alkaline, which is expected because the leaching process employed is cyanidation. In cyanidation, the cyanide solution is kept strongly alkaline at pH between

9 to 12 by adding lime to prevent the generation of the highly toxic hydrogen gas [10, 11]. Considering that the Gango tailings pond is just an impoundment pond and do not have safety facilities, there is a high risk of instigating undesirable effects on the environment due to the alkaline pH. When the tailings contaminate the soil of the nearby communities it may affect plant growth. The ideal soil pH for plant ranges from 5 to 8 with the optimum pH of 7.5 for a number of crops and pastures [12]. Alkaline soils can lead to stunted plants, poor growth and reduced yields in some crops and pastures [12]. Due to its sulfur content, the tailings pond may also trigger a phenomenon known as acid mine drainage (AMD). AMD is one serious environmental problem affecting the mining industry. This problem occurs when large quantities of sulfides end up going to the tailings, and becomes oxidized as they are exposed to wind, rain and snow as well as temperature changes thereby creating sulfuric acid [4, 7, 13].

Gold and other metals: Table-2 shows the levels of gold and other metals in the tailings. The results revealed that the tailings is loaded with a significant amount of heavy metals. The concentration of particular heavy metals varies with the location in the tailings pond. Both lead and cobalt are more abundant in 1m deep tailings, while copper, chromium, and manganese are more concentrated in the surface tailings. These distributions of metals are affected by a number of factors such as accelerated weathering, mobilization rates of tailings slurry, and the addition of reagents in the extraction of gold from its ore.

Table-2: Gold and Other Metals Assay.

Metals	**Tailings**	
	Surface	**1m Deep**
Gold (ppm or g Au/ton)	7.37	7.38
Silver (ppm)	3.61	2.45
Lead (ppm)	1666	3207
Cobalt (ppm)	50.2	57.1
Copper (ppm)	865	652
Chromium (ppm)	4882	3184
Manganese (ppm)	1696	1122
Iron (%)	3.68	4.15

Heavy metals are known toxic to humans, animals, and other living organisms at elevated levels. Therefore, their presence at significant levels in the tailings pond makes the gold mine tailings in Gango more environmentally hostile and, thereby, may instigate short- and long-term undesirable consequences in the environment and living organisms if it continue to exist unmanaged. Chromium in hexavalent state, for instance, is classified by the USEPA as a Group A, known human carcinogen by the inhalation route of exposure [14]. Long-term inhalation exposure to various Cr (VI) compounds has been shown to result in a high risk of carcinomas of the respiratory organs [15]. Exposure to high lead levels can severely damage the brain and kidneys and ultimately cause death. In pregnant women, high levels of exposure to lead may cause miscarriage. High level exposure in men can damage the organs responsible for sperm production [16].

Furthermore, lead toxic effects may occur in the central and peripheral nervous systems, blood (including inhibition of heme synthesis, which also affects other cells), kidney, and cardiovascular, endocrine and immune systems, gastrointestinal tract, and male reproduction (sperm quality) [17].

Ingestion of a large amount of copper salts causes gastrointestinal disturbances. In severe cases, systemic effects, especially hemolysis, liver, and kidney damage, can occur [18]. To avert further negative impact of the gold mine tailings to the local community and the environment, it is imperative to implement effective tailings management as soon as possible and ensure that the chemical constituents are kept at manageable and predictable levels. Another significant findings revealed of the assay is the high gold content of the tailings with an average of 7.38 g Au/t between the surface and 1m deep tailings. This grade of Au is significantly higher than other gold mine tailings subjected to reprocessing such as the Balatoc gold tailings of Benguet Corporation in the Philippines.

The gold assay of the 10 tailing ponds of Balatoc gold tailings ranged from 0.56 to 0.96 g Au/t with an average of 0.69 g Au/t [19]. Furthermore, in Tasmania, Australia the Hellyer mine tailings which contain about 2.6 g Au/t is viewed as substantially valuable resource [20]. This implies, therefore, that the Gango gold mine tailings are a significant resource of gold which can be reprocessed to recover the precious metal. With an estimated 128,000 tons of tailings, the total residual gold in Gango tailings pond would be equivalent to 945 kg. With the current market price, approximately 1,900 PHP/g (38 USD/g) in the Philippines at the time of writing, this is indeed economically valuable. Alongside the economic gain, the reprocessing of tailings may precede the move of relocating and placing the tailings into a more secure storage facility or tailings management facility, hence, it is also beneficial to the environment.

CONCLUSIONS

Being unmanaged, the Gango gold mine tailings is evidently hostile to the environment as it bears substances detrimental to the health of the environment, humans, animals, and other organisms. The tailings is relatively high in pH, 9.80 at the surface and 8.98 at the depth of 1m, as compared to the natural environment, it contain sulfur which can cause a serious environmental problem associated to mining operations called the acid mine drainage, and it carries a significant amount of heavy metals such as Fe, Pb, Co, Cu, Cr, Mn, Ag, and Au. Placing tailings in a safe and well-managed storage facility is viewed indispensable. In terms of the economic aspect, however, the tailings contain a substantial amount of residual gold (7.38 g Au/t) with significant economic value. The Gango gold mine tailings can be reprocessed to recover the precious gold. Moreover, the reprocessing of tailings may precede the move of placing the tailings into a storage facility.

REFERENCES

1. NSO,Census of Population and Housing. *National Statistics Office, Philippine Statistics Authority*. Retrieved from https://web0.psa.gov.ph/sites/ default/files/attachments/ hsd/pressrelease/Northern%20Mindanao.pdf,2010,
2. ZNEXT Mining (n.d.). Initial Feasibility Study: Gango Gold Rush Project. *ZNEXT (PEARL) Mining Corporation, Inc*.
3. K.A. Hudson-Edwards, H.E. Jamieson and B.G. Lottermoser. Mine Waste: Past, Present, Future. Retrieved from: http://facstaff.uww.edu/bhattacj/mine_waste_ overview.pdf. 2011.
4. Northern Dynasty Mines Inc. (n.d.). Pebble Poject Bacgrounder: Tailings and Tailings Management. Retrieved from http://www.northerndynastyminerals.com /i/pdf/NDM_ Backgrounder_Sep05.pdf

5. DENR-MGB; MGB Initiates Research on Residual Gold Recovery from Mill Tailings. Department of Environment and Natural Reosurces—Mines and Geosciences Bureau, Metallurgical Technology Division. Retrieved from http://www.mgb.gov.ph/2015-05-13-02-02-11/mgb-news/34-mgb-initiates-research-on-residual-gold-recovery-from-mill-tailings,2015.

6. G. Gavett. Tailings Dams: Where Mining Wastes is Stored Forever. Retrieved from http://www.pbs.org/wgbh/frontline/article/tailings-dams-where-mining-waste-is-stored-forever/2012.

7. T. Chingosho, O. Johnson, M. Mashingaidze. Factors Affecting Gold Recovery from Secondary Ore. *Proceedings of the World Congress on Engineering.* 2014, **2**.

8. G.M. Ritcey. Tailings Management in Gold Plants. *Hydrometallurgy*. 2005, **78** (1-2): 3- 20.

9. W.J. Rankin. Minerals, Metals and Sustainability: Meeting Future Material needs. *Collingwood, Vic.: CSIRO Pub*. 2011.

10. Emerson Process Management. (2013). Measuring pH in Cyanide Leaching. *Emerson Process Management, Rosemount Analytical Inc.*2400 Barranca Parkway Irvine, CA 92606 USA. Retrieved from http://www2.emersonprocess. com/ siteadmincenter/PM%20Rosemount%20,Analytical%20,Documents/Liq_ADS_ 3300 -08.pdf

11. W.W.L. Eugene and A. Mujumbar. Gold Extraction and Recovery Processes. Minerals, Metals and Materials Technology Center, National University of Singapore. Retrieved from http://www.eng.nus.edu.sg/m3tc/M3TC_Technical _Reports/Gold% 20Extraction%20and%20Recovery%20Processes.pdf. 2009.

12. B. Lake. Understanding Soil pH. *NSW Agriculture and Acid Soil Action*. Retrieved from http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/167187/soil-ph.pdf. 2000.

13. J.G. Skousen, A. Sestone and P.F. Ziemkiewicz. Acid Mine Drainage Control and Treatment. American Society of Agronomy and American Society for Surface Mining and Reclamation. Reclamation of Drastically Disturbed Lands. Chapter 6 2000, 131-168.

14. USEPA, Chromium Compounds. *U. S. Environmental Protection Agency*. Retrieved from http://www.epa.gov/ttn/atw/hlthef/chromium.html, 2000.

15. S. Langard and M. Costa. Chromium. *Handbook on the Toxicology of Metals, 3rd Edition*. Chapter, 2007, 24, 2007, 487-510.

16. S. Martin and W. Griswold. Human Health Effects of Heavy Metals. *Center for Hazardous Substance Research. Kansas State University*. Retrieved from http://www.engg.ksu.edu/CHSR/outreach/docs/15/HumanHealthEffectofHeavyMetals.pdf. 2009.

17. S. Skerfving and I. Bergdahl. Lead. *Handbook on the Toxicology of Metals, 3rd Edition*. Chapter, 2007, 31, 599-643.

18. D. Ellingsen, N. Horn and J. Aaseth. Copper. *Handbook on the Toxicology of Metals*, 3rd Edition.2007, Chapter 26, 529-546.

19. Benguet Corp. (n.d.). Balatoc Gold Tailings Project. *Balatoc Corporation, Philipppines*

20. M. Campbell, V. Absolon, J. King and M. Campbell. Precious Metal Resources of the Hellyer Mine Tailings. *I2M Asociates*, Houston, Texas – Adelaide, South Australia – Seattle, Washington. Version 1.8. 2015.

***Corresponding author: Ronnie L. Besagas;** Department of Science Education/Department of Chemistry, University of Science and Technology of Southern Philippines, Cagayan de Oro City, Philippines,

On line publication Date: 11.02.2017

.