Mine Slag -Precious Metal Recovery

Created by Bobby Boekhoud/Just Refiners USA, Inc. on 9 May 2017 (Updated 21 January 2019)

Refinery Slag Process Recovery Test Work

Composite samples of typical Mine Refinery Slags were tested for projected recoveries of Gold and Silver when processed onsite, assuming average types and grades.

The Test work on the slag was based upon typical milling and primary leaching operations and anticipated expected recoveries on Heap Leach operations to be even lower.

This slag test work was commissioned to review onsite processing and recovery versus offsite refining of this important and valuable mine by-product commodity.

Some mines process their slag 'inhouse' for convenience and some mines send their slag to external refiners to obtain maximum value and to reduce concerns about operational security and metallurgical accounting.

We carried out experiments in a laboratory environment, where milled slag was subjected to agitation and controlled cyanide residence time. After 12, 24 and 48hrs of leaching the cyanide was evaluated for precious metal content as well as the glass/metal residue.

As shown on an attached test work appendix, overall weighted average recovery for Gold was 43.79% while Silver was 33.51%. These results are slightly variable depending upon slag type, composition, grades, and glass versus metallic content but representative overall demonstrating a significant loss of value when processing the materials onsite.

We also observed from the lab test, the longer the leaching test progressed the slower the dissolution became.

To compliment these findings, there is a paper written by Fathi Habashi, titled Kinetics and Mechanisms of Gold and Silver Dissolution in Cyanide Solutions. Department of Metallurgy, Montana College of Mineral Science and Technology.

Factors effecting the rate of dissolution of gold are:

1) The rate of dissolution depends on the surface of the metal (gold) in contact with the liquid (cyanide) phase.
2) The rate of dissolution depends on the rate of stirring. (No agitation on a mine dump.)
3) The rate of dissolution is only slightly affected by the increase of temperature, the process requiring an activation energy of 2 to 5 Kcal/mole.

Similarly; Factors effecting silver dissolution are as follows:

1) Silver dissolves at half the rate of gold.
2) Dissolution rate increases with oxygen and agitation. (No agitation on mine dumps)

Taking into account the handling/shipping costs and the refining and treatment charges, a mine can assume a 40% increase in Gold revenue and 50% increase in Silver revenue when their slag materials are refined offsite. When taking into account yearly Refinery Slag tonnages estimated additional revenues would be significant and worthwhile.

We would be pleased to confirm each clients or potential clients Refinery Slag by-product material recovery on a case by case basis, but our assumption is that even if larger metallic fractions are being removed much smaller metallic fractions remains in the slag materials, confirmed by historical data and thus the justification for offsite refining.

Environment

With reference to the above, a very important factor, with regards to shipping the slag off the mine site, is the environment legislation.

In accordance, with the Basel Convention or the Control of Transboundary Movements of Recoverable Wastes, Slag generated from precious metal melting operations is classified as a green list waste under Code GB040. (Please refer to Appendix 3 attached.)

The slags materials generated by the gold mines is subject to Green Control Procedures. The definition of the Green Control Procedure is as follows:

Regardless of whether or not wastes are included on this list, they may not be subject to the Green Control procedure if they are contaminated by other materials to an extent which (a) increases the risk associated with the waste sufficiently to render them appropriate for submission to the Amber Control procedure, when taking into account the criteria in Appendix 6, or (b) 'prevents the recovery of the wastes in an environmentally sound manner'.

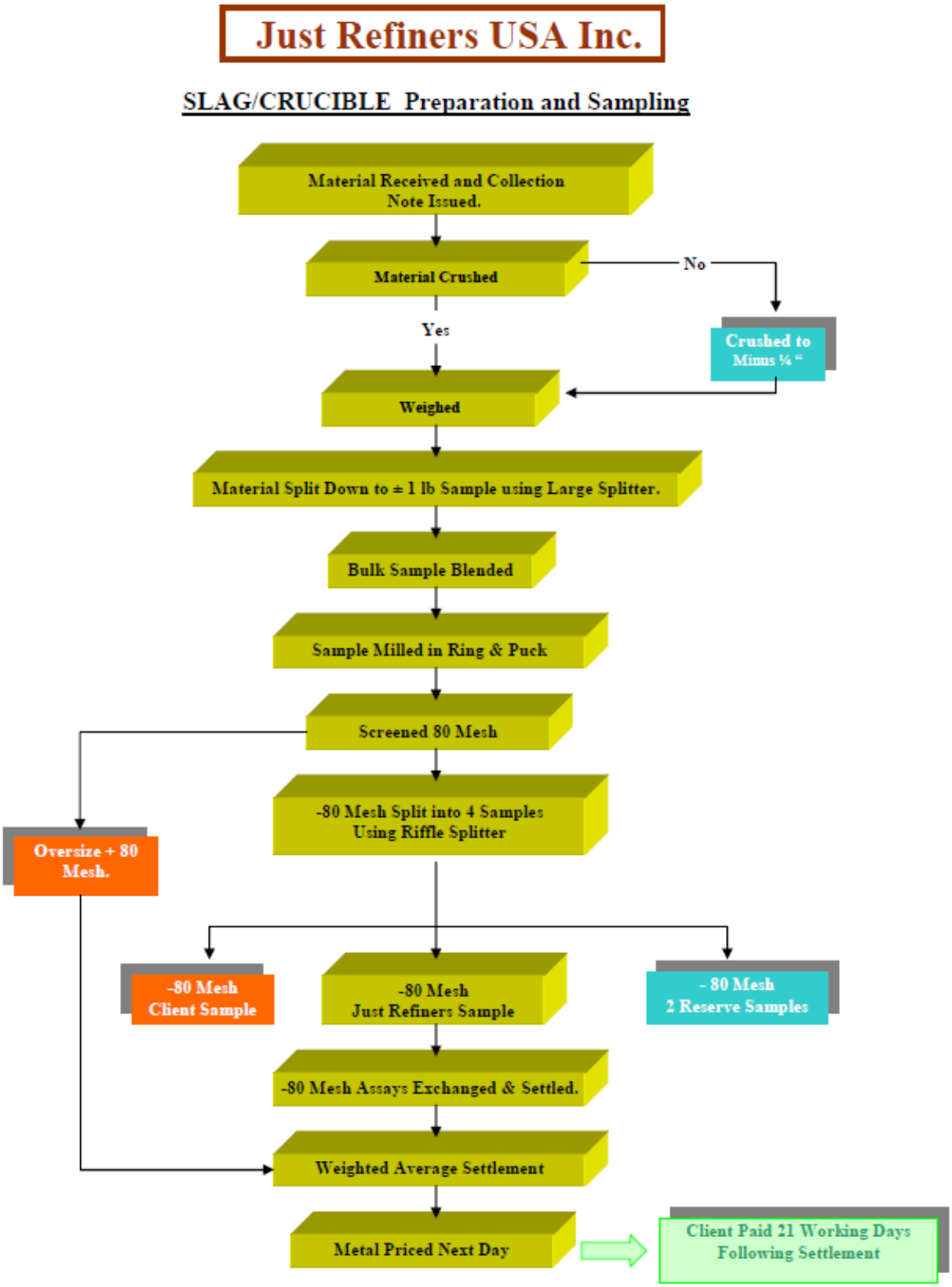
When one reads Appendix 6, it makes reference to Appendix 2 of the Control of Transboundary Movement of Recoverable wastes. (Both Appendix 2 & 6 have been attached for ease of reference.) Both Appendices have relevance to the classification of slag.

None of the Hazardous Characteristics in Appendix 2 of the Basel Convention and the Control of Transboundary Movements of Recoverable Waste: is found in the slag materials generated by the mines. The slag is classified a non-hazardous waste and is correctly categorized as a green list material which is not regulated.

The slag materials are received and processed at Just Refiners. Each material lot is prepared, sampled and evaluated for precious metal content. In addition, a scan is carried out by an independent laboratory to determine the presence of deleterious elements. With each shipment, Just Refiners determines the safest and most economical disposal route possible. All slag, crucible, and furnace lining materials are processed in house.

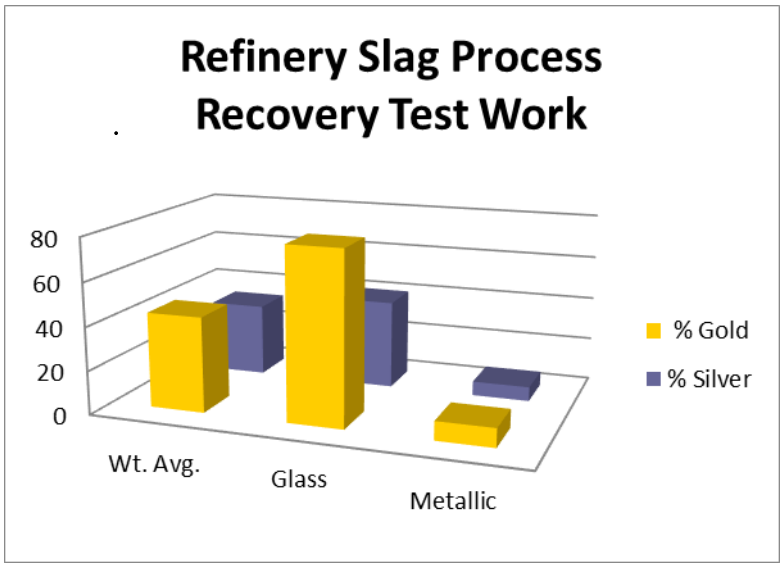
Since the opening of JRI in 1993, JRI has never experienced an environmental violation.

JRI SLAG/CRUCIBLE PREPRATION AND SAMPLING FLOWCHART



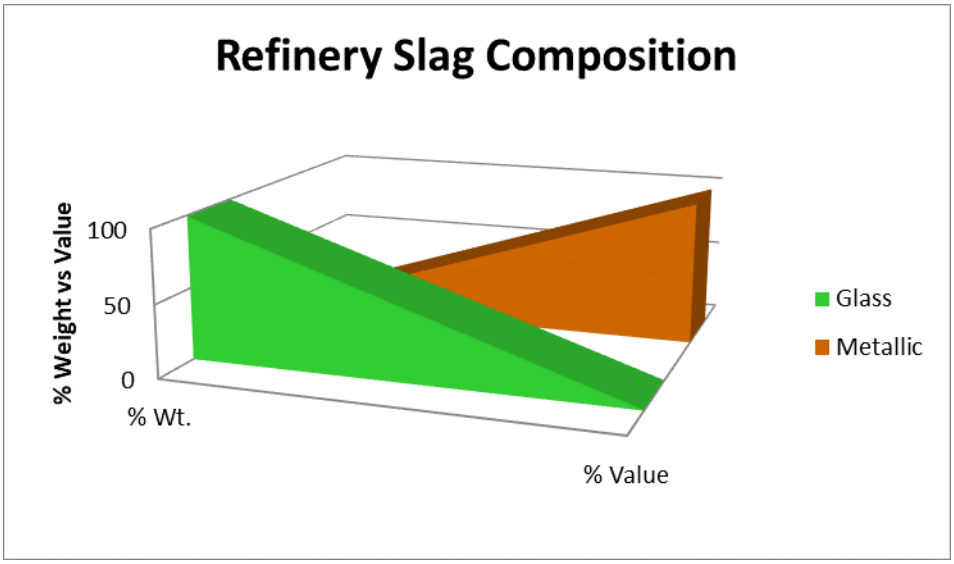
Refinery Slag Recovery Test Work

Metal Recovery	Overall Wt. Avg.	Glass	Metallic
% Gold	43.79	78.98	8.68
% Silver	33.51	40.78	6.58



Refinery Slag Recovery Test Work

Metal Contained	% Wt.	% Value
Glass	99.26	0.54
Metallic	0.74	99.46



4. Green control procedure

Since the wastes subject to the Green control procedure are deemed to pose negligible risks for human health and the environment during their transboundary movement for recovery within the OECD area, they are not controlled under the OECD Decision. However. the OECD Decision imposes a general requirement that all wastes, including those subjects to the Green control procedure, shall be destined for recovery operations within a recovery facility which will recover them in an environmentally sound manner according to national laws, regulations and practices[3].

Furthermore, it is required by the OECD Decision that all persons involved in any contracts or arrangements for such transboundary movements should have the appropriate legal status, in accordance with domestic legislation and regulations. Those movements shall also be subject to applicable international transport agreement (see Annex E) and other existing controls normally applied in commercial transactions.

It should also be noted that some member countries may impose specific requirements for the transboundary movements of wastes subject to the Green control procedure by their domestic legislation. For example, the European Community legislation requires that certain information, signed by the holder of wastes subject to the Green control procedure, accompanies each shipment of such waste, in order to assist the tracking of these shipments.

5. Amber control procedure

Main features of Case 1 and Case 2 control procedures

Within the OECD area, all transboundary movements of waste subject to the Amber control procedure can take place only upon prior written notification to the competent authorities of countries of export, import and transit (if any) and upon tacit or written consent from these authorities to the notified movement of waste. Furthermore, each shipment of waste shall be accompanied by a movement document from the point at which the transboundary movement begins to the point of recovery. These two elements of the Amber control procedure are hereinafter referred to as *the notification procedure and tracking procedure, respectively*.

Two cases exist within the Amber control procedure according to the type of facility to which wastes are destined. Actually, two types of facilities exist: most of the recovery facilities are "usual" recovery facilities, i.e. not subject to any particular procedure, requirement, or rule due to a special feature in relation to their activity. The other type of recovery facility is the so-called "pre-consented" facility. These facilities are less numerous and benefit from a specific provision due to the type of waste they recover and the frequency of their imports of the same waste. This specific provision, the "pre-consent", is granted to the facility by the competent authority of its jurisdiction. To a large extent, these two cases are identical, but they differ at a few stages of the notification procedure.

[3] An OECD Council Recommendation has been adopted by member countries for this purpose in 2004 [C(2004)100], which recommends a number of measures to be taken at the government level and at the facility level to ensure that waste is managed in an environmentally sound manner.

APPENDIX 2:
LIST OF HAZARDOUS CHARACTERISTICS[4]

Code[5] - Characteristics

B1: Explosive

An explosive substance or waste is a solid or liquid substance or waste (or mixture of substances or wastes) which is in itself capable by chemical reaction of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings.

H3: Flammable liquids

The word "flammable" has the same meaning as "inflammable". Flammable liquids are liquids, or mixtures of liquids, or liquids containing solids in solution or suspension (for example, paints, varnishes, lacquers, etc. but not including substances or wastes otherwise classified on account of their dangerous characteristics) which give off a flammable vapors at temperatures of not more than 60.50 C, open-cup test, or not more than 65.60 C, open-cup test. (Since the results of open-cup tests and of closed-cup tests are not strictly comparable and even individual results by the same test are often variable, regulations varying from the above figures to make allowance for such differences would be within the spirit of this definition).

H4.1: Flammable solids

Solids, or waste solids, other than those classed as explosives, which under conditions encountered in transport are readily combustible, or may cause or contribute to fire through friction.

H4.2: Substances or wastes liable to spontaneous combustion

Substances or wastes which are liable to spontaneous heating under normal conditions encountered in transport, or to heating up in contact with air, and being liable to catch fire.

H4.3: Substances or wastes which, in contact with water, emit flammable gases

Substances or wastes which, by interaction with water, are liable to become spontaneously flammable or to give off flammable gases in dangerous quantities.

HS.1: Oxidizing

Substances or wastes which, while in themselves not necessarily combustible, may, generally by yielding oxygen cause, or contribute to, the combustion of other materials.

[4] Codes and hazardous characteristics are identical to those in Annex D of the Basel Convention.

[5] Corresponds to hazard classification system included in the United Nations Recommendations on the Transport of Dangerous Goods (14th Revised Edition, UN, New York, 2005) for HJ through H9; omission of H2, H7 and H9 are deliberate. Codes H10-H13 correspond to UN class 9.

HS.2: Organic peroxides

Organic substances or wastes that contain the bivalent-0-0-structure are thermally unstable substances which may undergo exothermic self-accelerating decomposition.

H6.1: Poisonous (Acute)

Substances or wastes liable either to cause death or serious injury or to harm human health if swallowed or inhaled or by skin contact.

H6.2: Infectious substances

Substances or wastes containing viable micro-organisms or their toxins which are known or suspected to cause disease in animals or humans.

B8: Corrosives

Substances or wastes that, by chemical action, will cause severe damage when in contact with living tissue, or, in the case of leakage, will materially damage, or even destroy, other goods or the means of transport; they may also cause other hazards.

H1O: Liberation of toxic gases in contact with air or water

Substances or wastes which, by interaction with air or water, are liable to give off toxic gases in dangerous quantities.

HU: Toxic (delayed or chronic)

Substances or wastes which, if they are inhaled or ingested or if they penetrate the skin, may involve delayed or chronic effects, including carcinogenicity.

H12: Ecotoxic

Substances or wastes which if released present or may present immediate or delayed adverse impacts to the environment by means of bioaccumulation and/or toxic effects upon biotic systems.

H13: Capable, by any means, after disposal, of yielding another material, e.g. leachate, which possesses any of the characteristics listed above.

TESTS

The potential hazards posed by certain types of wastes are not yet fully documented; objective tests to define quantitatively these hazards do not exist. Further research is necessary in order to develop means to characterize potential hazards posed to man and/or the environment by these wastes. Standardized tests have been derived with respect to pure substances and materials. Many member countries have developed tests which can be applied to mate1ials destined for disposal or recovery by means of operations listed in Appendices 5.A or 5.B in order to decide if these materials exhibit any of the characteristics listed in this Appendix.

APPENDIX 6:
CRITERIA FOR IBE OECD RISK-BASED APPROACH

A) Properties

1) Does the waste normally exhibit any of the hazardous characteristics listed in Appendix 2 to this Decision? Furthermore, it is useful to know if the waste is legally defined as or considered to be a hazardous waste in one or more-member countries.

2) Is the waste typically contaminated?

3) What is the physical state of the waste?

4) What is the degree of difficulty of cleanup in the case of accidental spillage or mismanagement?

5) What is the economic value of the waste bearing in mind historical price fluctuations?

B) Management

6) Does the technological capability to recover the waste exist?

7) Is there a history of adverse environmental incidents arising from transboundary movements of the waste or associated recovery operations?

8) Is the waste routinely traded through established channels and is that evidenced by commercial classification?

9) ls the waste usually moved internationally under the terms of a valid contract or chain of contracts?

10) What is the extent of reuse and recovery of the waste and how is any portion separated from the waste but not subject to recovery managed?

11) What are the overall environmental benefits arising from the recovery operations?

APPENDIX 3:
LIST OF WASTES SUBJECT TO THE GREEN CONTROL PROCEDURE

Regardless of whether or not wastes are included on this list, they may not be subject to the Green control procedure if they are contaminated by other materials to an extent which (a) increases the risks associated with the wastes sufficiently to render them appropriate for submission to the Amber control procedure, when taking into account the criteria in Appendix 6, or (b) prevents the recovery of the ·wastes in an environmentally sound manner.

Part I:
Wastes listed in Annex IX of the Basel Convention. For the purposes of this Decision:

(a) Any reference to list A in Annex IX of the Basel Convention shall be understood as a reference to Appendix 4 of this Decision;

(b) In Basel entry B1020 the term "bulk finished form" includes all metallic non-dispersible[6] forms of the scrap listed therein;

(c) Pending approval by the Basel Convention, Basel entry B1030 shall read: "Residues containing refractory metals";

(d) The part of Basel entry Bl 100 that refers to "Slags from copper processing" etc. does not apply and OECD entry GB040 in Part II applies instead;

(e) Basel entry Bll 10 does not apply and OECD entries GCOIO and GC020 in Part II apply instead;

(f) Basel entry B2050 does not apply and OECD entry GG040 in Part Il applies instead;

(g) The reference in Basel entry B3010 to fluorinated polymer wastes shall be deemed to include polymers and co-polymers of fluorinated ethylene (PTFE).

Part II:
The following wastes will also be subject to the Green control procedure:
Metal Bearing Wastes Arising from Melting. Smelting and Refining of Metals

{Slag Waste}
GB040 7112 Slags from precious metals and copper processing for further refining
262030
262090

[6] "Non-dispersible" does not include any wastes in the form of powder, sludge, dust or solid items containing encased hazardous waste liquids.