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Jayanta Bhattacharya
Hony. Chief Editor

MINE AND RETURN™

Green gold extraction may soon be an industrial reality

Cyanidation

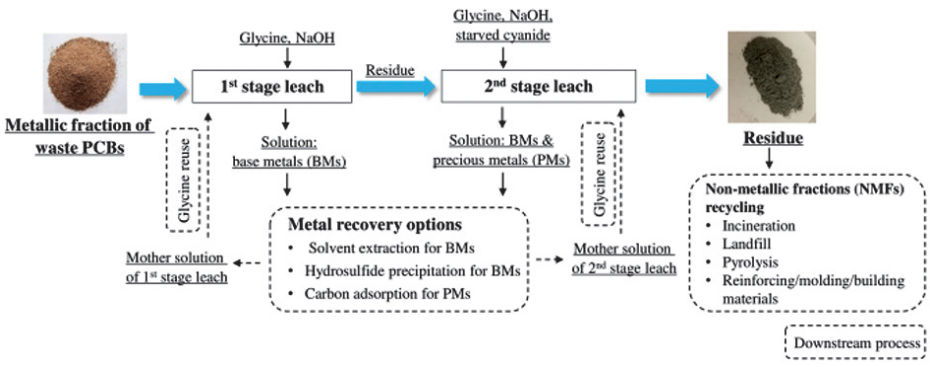
Cyanidation remains the main method for gold extraction in gold mines around the world because of its advantages of being a well-established process, strong adaptability, and easy process control. Nevertheless, the dissolution rate of gold in cyanide solution is very slow; thus, long times are required for gold extraction by cyanidation, especially at low temperatures. In addition, as cyanide is highly toxic, the discharge of cyanide wastewater from the gold leaching process causes environmental pollution, affects domestic water and the ecological balance, and endangers the health of people. With the increasing emphasis on ecological environment protection, many countries and regions have restricted the use of cyanidation. Agencies in Germany, the Czech Republic, Hungary and Costa Rica have already banned the use of cyanide in mining, with multiple Argentinian provinces and the US states of Montana and Wisconsin following suit. As pressures on mining companies to address their impacts on the environment mount, the race to find less harmful gold extraction processes has intensified.

New processes

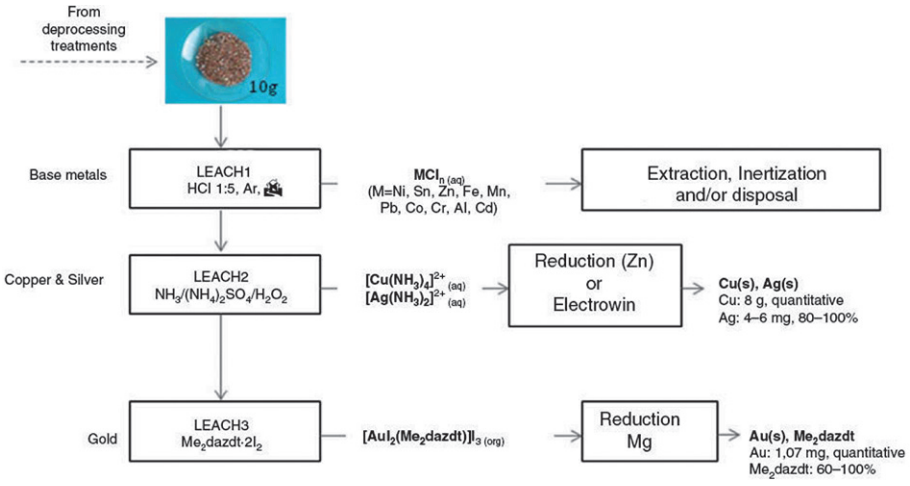
Iodine-iodide leaching is a green non-cyanide gold extraction method. Compared to cyanide, iodine and its compounds are nontoxic, and they are widely used in food and medicine. Moreover, the stability of the gold iodide complex in aqueous solution is higher than that of gold complexes with bromine, chlorine, and thiocyanide, which allows gold extraction from ores with lower gold contents. The large-scale industrial application of the iodine-iodide system to gold extraction is mainly restricted by high costs. If applied to industrial production, a large amount of expensive iodine reagents would be used. Thus, economic considerations indicate that the amount of iodine should be minimized during the gold leaching process. Using cheap oxidants instead of iodine to extract gold is the most direct way to reduce iodine consumption. At present, very little information is available on the application of the non-iodine oxidants to gold extraction from ores in iodide solution. Efforts were made with the dissolution of pure gold using H_2O_2 as the oxidant in the presence of hydrogen iodide, and successful gold dissolution was achieved at 35°C. However, it is disadvantageous to use hydrogen peroxide as an oxidant because it is chemically unstable and is only active for a short time. The electrochemical studies showed that although hypochlorite is a stronger oxidant than iodine, the gold dissolution performance of a hypochlorite-iodide solution was not as good as that of an iodine-iodide solution. Moreover, the gold dissolution rate in the hypochlorite-iodide solution greatly depended on the solution pH. Hypochlorite forms chlorine (aq) under highly acidic conditions (pH<3.5), resulting in the release of toxic chlorine gas from the solution. Moreover, hypochlorite is easily decomposed by light and has strong corrosiveness.

Compared to other traditional oxidants, persulfate has the advantages of being nontoxic, more stable, easy to store, inexpensive, and easy to control as well as having a wider pH operating range. In industry, persulfate is produced by an electrolysis method using dilute ammonium sulfate as a raw material. The production process is simple, low-cost, and low polluting. At room temperature, the oxidation rate of persulfate is very slow. However, under proper activation conditions, including transition metals, heat, microwave irradiation, visible light, and alkaline conditions, persulfate produces sulfate radicals ($\bullet SO_4^-$) as an active substance, which accelerates the oxidation reaction rate. Sulfate radicals, which have a lone pair of electrons, have a strong ability to accept electrons and strong oxidizing properties. As a result, the oxidizing ability of sulfate radicals is stronger than that of persulfate. In recent years, persulfate has shown great potential for the oxidative degradation of organic pollutants in wastewater and the remediation of pesticide-contaminated soil and polluted groundwater. However, the application of persulfate for gold extraction from refractory ores in iodide solutions has not been reported.

A great new interest is being generated in the areas of



The likely method (not verified) (Text and figure reference: Elsayed A. Oraby, Huan Li and Jacobus J. EksteenWaste and Biomass Valorization volume 11, pages 3897-3909 (2020)" An alkaline glycine-based leach process of base and precious metals from powdered waste printed circuit boards"



Angela Serpe, Flavia Artizzu, DavideEspa, AmericoRigoldi, Maria Laura Mercuri and Paola Deplano, "From trash to resource: a green approach to noble-metals dissolution and recovery". From the journal Green Processing and Synthesis, Volume 3, Issue 2, March 11, 2014

waste to wealth recovery streams for electronic and other waste that are constituted of precious metals. Waste printed circuit boards (WPCBs) constitute a hazardous material with up to 40 different metals, including numerous many heavy metals and environmentally harmful metals. Most hydrometallurgical processing approaches use high concentrations of toxic reagents and generate significant amounts of harmful effluents. A new research investigates the use of cyanide-starved glycine solution containing no free cyanide in the leachate to extract precious metals from WPCBs, with most of copper and base metals pre-removed by upstream glycine-only leaching. Under the optimised conditions, 90.1% Au, 89.4% Ag and 70.1% Pd were extracted together with 81.0% Cu and 15.0% Zn. The extraction of other base metals remained low at 8.3% for Al and <5% for Pb, Ni, Co, Fe and Sn, indicating a fairly good selectivity of the leaching system. By comparing with stoichiometric and intensive cyanidation, the cyanide-starved glycine system showed comparable or better performance on precious metals extraction, but cyanide use was reduced by >70% whereas the glycine can be reused.

Industry adoption

A private company clean mining, part of the Singapore-based consultant clean earth technologies group, is also tackling this issue and seeking to eventually commercialise its non-toxic gold recovery solution. The company recently announced a partnership with NuFortune Gold, through which it hopes to coin itself as Australia's first clean gold producer. The companies have previously collaborated to develop non-toxic gold extraction methods with Australia's national science agency CSIRO. The companies said the new method had been demonstrated at a pilot plant. Based on what the companies said was a success on multiple levels, including recovery at scale and cost enhancement, Clean mining and NuFortune gold signed a commercial agreement.

NuFortune has now laid plans to use this gold recovery solution during its production scheduled for 2022 as it works to process 500,000 tonnes of ore per annum. Clean Mining said it has been "inundated" since the 2019 launch of its solution, which aims to dissolves gold in a non-toxic re-agent to eliminate toxic slurry typically left over in cyanide extraction. Clean Earth Technologies Chief Executive Officer Kevin Fell said the partnership marked the first step towards large-scale clean gold production.

The company estimates it has completed 150 tests on a "wide range" of ore types and believes its technology is suitable for all gold mining operations. "The results have been extremely positive and showed that we have a genuine solution to replace toxic practices within the gold mining industry with our analysis to-date highlighting that we are more cost effective over the full life cycle of a mine," Mr Fell explained. "Clean Mining is looking forward to further progress and announcements from its clients in South America, Europe, and the Middle East."

NuFortune Gold has submitted its application to list on the Australian Stock Exchange (ASX0 for its IPO in 2022.