
A REVIEW OF CHARACTERIZATION STUDIES ON THE APPLICATION OF HYDROMETALLURGICAL TREATMENTS IN THE RECOVERY OF LEAD FROM GALENA

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ABSTRACT

In this paper, the characterization investigations of hydrometallurgical methods for extracting high-purity lead metal from galena were reviewed. This study aimed to explore the recovery of lead from galena because hydrometallurgical treatment presents a potentially more energy-efficient alternative to conventional pyrometallurgical methods, which generate hazardous and damaging environmental pollutants and also use a lot of energy. A major source of lead, galena ore (PbS), was crushed, powdered, and sieved to produce small particles for use in chemical and mineralogical analyses employing X-ray fluorescence (XRF), X-ray diffraction (XRD), and scanning electron micrographs (SEM). An X-ray diffractogram (XRD) was used to identify the minerals present in the ore, a scanning electron microscope (SEM) was used to examine the surface morphology, and X-ray fluorescence (XRF) was used to evaluate the chemical composition.

KEYWORDS: Galena; lead; characterization; hydrometallurgy; XRD analysis, SEM analysis.

1.1 INTRODUCTION

Lead glance, or galena (PbS), is the natural mineral form of lead (ii) sulfide. It is the most significant source of silver and the mineral of greatest significance of lead, claim Young, Courtney A. et al. (2008).

Galena is one of the most common and plentiful sulfide minerals. It frequently requires on octahedral shapes while crystallizing in the cubic crystal system. It is often connected with

the minerals fluorite, calcite, pyrite (FeS_2), chalcopyrite (CuFeS_2), and sphalerite (ZnS), (Zarate-Gutierrez, Lapidus, and Morales, 2012).

Historically, pyrometallurgical methods have been used to melt lead sulfide and secondary waste containing lead with the objective to create metallic lead (Okada et al., 2007). However, the traditional pyrometallurgical approach of lead disposal is associated with undesirable emissions of hazardous sulfur oxides and lead vapor or dust into the environment (Ettler et al., 2005; Aydogan et al., 2007; Pan et al., 2013). Because pyrometallurgical operations raise environmental problems, a lot of research has been done recently on hydrometallurgical processes.

The hydrometallurgical process depends on leaching, and adopting the appropriate leaching reagent proves helpful to the process. In lead hydrometallurgical processes, leaching agents frequently incorporate acids, sodium hydroxide, and chloride solutions (Baba and Adekola 2011; Lima and Bernardez 2013; Nagib and Inoue 2000; Liao and Deng 2004; and Qin et al. 2012). Techniques for acidic leaching can be used to remediate minerals that include lead. According to Qin et al. (2007), Feng et al. (2007), Liu et al. (2012), the dissolved lead's combination with other metals such as Fe, Ca, Mg, and SiO_2 results in complicated purification procedures and significant acid usage. A useful and specific reagent is thus required for such ores.

The recovery of lead from oxidized resources by hydrometallurgical techniques is advised due to the rigorous limitations previously stated; therefore this has become a global study issue. In galena, hydrometallurgical processes can be utilized for dealing with complex or low-grade flotation concentrates without producing sulfur dioxide emissions or lead dust. Additionally, less energy is needed to remediate lead-containing oxidized minerals. To date, a number of lixiviants have been investigated for the leaching of galena in order to produce a high-purity leached metal.

2. GALENA'S PHYSICOCHEMICAL AND MINERAL CHARACTERISTICS

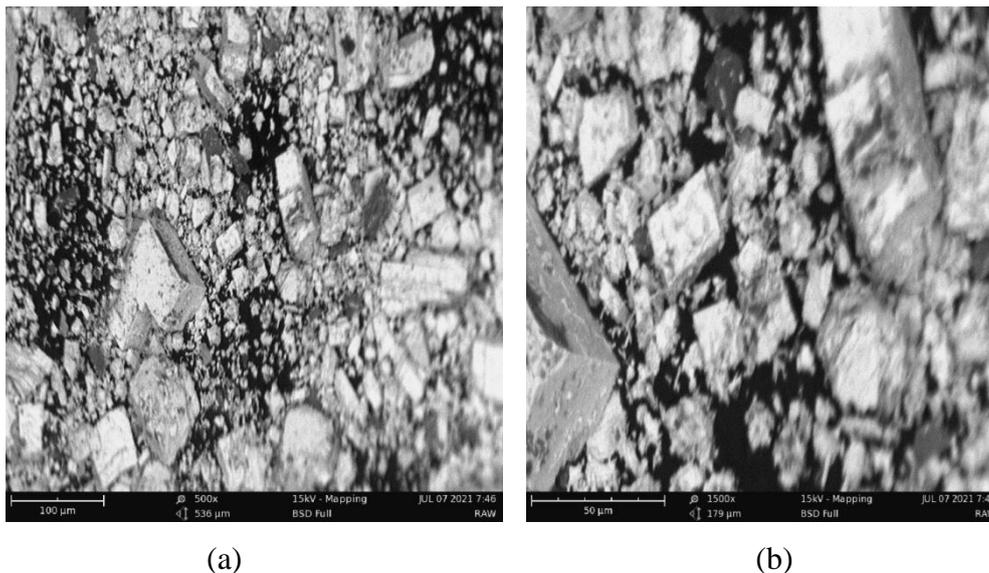
2.1. Crystal composition and structure

In spite of its strong Pb-S bonding and cubic crystal form, galena is relatively insoluble in water at room temperature. According to Nnanwube and Onukwili (2018), it frequently corresponds to the minerals; fluorite, calcite, and sphalerite. Using X-ray diffraction (XRD), scanning electron microscopy (SEM), and X-ray

fluorescence (XRF) to characterize raw galena indicates trace and small impurities like Fe and Zn that impact leaching behavior and justifies the dominance of PbS.

2.2 Morphological and Surface Analysis

The degree of crystallinity and surface shape, which affect reaction kinetics, were discovered by SEM examination. Prior to leaching, sulfur and associated functional groups on the ore surface were also verified by FTIR analysis.



SEM image of galena showing magnifications of 500x (a) and 1500x (b)

3. METHODS OF HYDROMETALLURGY LEACHING

Hydrometallurgy is an essential aspect of the multibillion dollar minerals processing industry. It utilizes aqueous solutions to recover metals from ores, concentrates, and recycled or residual material. Either the selective separation of various metals in solution, or the recoveries of metals from solution through electrochemical reductive processes or salt crystallization are involved, depending on thermodynamic preferences (A. Ghasem, S. Kohramnejadian, 2015). Aqua metallurgical processes such as agglomeration, leaching, solvent extraction/ion exchange, metal recovery, and tailings/waste treatment are among the methods used to recover metals.

Hydrometallurgical processes are crucial at multiple stages in a typical mining recovery and mineral processing circuit, including in situ leaching (where the solution is pumped through rock matrices), heap leaching (of the ROM or crushed ore), tank/autoclave leaching (of the concentrate/matter obtained from floatation), electro-refining (of the blister product from smelting routes), and the treatment of waste tailings/slugs from the aforementioned processes.

Metals are extracted from their ores using modern hydrometallurgical methods, which face many chemical, geology, and engineering-related difficulties.

The geomagnetic position of the ore site, changes in the deposit mineralogy, and declines in ore grade are some of these. This will influence the hydrometallurgical route used. The emergence of technologies that improve throughout the circuit energy efficiency, water and resource use, and waste recovery—particularly acid rock drainage—is also crucial. Both baseline and pilot studies are continuously being conducted to find new solutions to these contemporary problems in order to implement ecologically acceptable methods for the extraction of significant metals.

The following are some instances of leaching agents utilized in hydrometallurgy:

- a. Acid leaching agents: hydrochloric acid, sulfuric acid, and nitric acid serve as typical examples of acidic leaching agents. They dissolve a wide range of metals, including copper, zinc, and nickel.
- b. Basic leaching agents: Potassium hydroxide and sodium hydroxide are two frequently employed basic leaching agents. In accordance with A. Tripathi, M. Kumar, and A. Agrawal (2012), they are good at dissolving metals like gold and aluminum.
- c. Oxidative leaching agents: ferric chloride and sodium hypochlorite are two common oxidative leaching agents. They are effective in dissolving metals such as copper and manganese.

The optimal leaching agent depends on the chemical makeup of the feed material and the metals that need to be eliminated. The impact of the leaching agent on the environment is another factor to consider while selecting a procedure. The flexible leaching technique is a method for recovering metals from a wide range of input materials. Many metals are made with this important hydrometallurgical process, including copper, zinc, nickel, aluminum, and gold.

- i. Solid-Liquid Separation: The metal-containing solution must be separated from the solid residue—which incorporates impurities and the unreacted source material—after leaching. On the basis of Ashiq, Kulkarni, and Vithanage, filtration or sedimentation techniques are typically employed to remove the particles from the clear metal-rich solution.
- ii. Metal Recovery Process: Once the metal ions are in solution, they can be recovered selectively using a variety of techniques, depending on the metal and the chemistry of the solution:

- **Precipitation:** Metals may separate as solid compounds when specific chemicals are added to a metal-containing solution. The metals that precipitated can then be removed from the mixture.
- **Solvent Extraction:** This method selectively extracts the metal ions from the aqueous solution and then employs organic solvents to remove them from the organic phase.
- **Electrolysis:** When a high-purity metal is required, this method can be utilized to plate the metal onto electrodes.
- **Cementation:** This method uses a more reactive metal to extract the desired metal ions from the solution. The solid precipitate that the displaced metal forms can be separated.
- **Purification:** Depending on the intended use and desired result of the finished product, additional purification steps may be required. These processes may involve additional chemical treatments or techniques to remove impurities and obtain the necessary metal purity.
- **Final Product:** Following further processing, refining, or casting into ingots, the recovered metal can now be utilized in a range of industrial applications.
- **Hydrometallurgy** has several advantages, including the ability to precisely target certain metals, a reduced environmental impact compared to conventional pyrometallurgical processes, and the potential to handle a range of raw materials. However, careful chemical management, waste disposal, and environmental considerations are required to ensure sustainability and lessen the impact on the environment.

3.2. BIO-HYDRO-METALLURGY

The utilization of microbes to regenerate essential oils and the various natural interactions between esters and minerals are examples of how hydrometallurgy and biology collaborate. The essences are digested by bacteria in an anhydrous environment to study their origin. Microbes are critical to the removal of the essential components of sulfide minerals through a process called biological leaching. For the extraction of essential oils from waste, bioleaching—also known as bio-hydrometallurgy—is the most promising method. Because it extracts valuable essence and can be executed in a straight or circular form, it is frequently employed (H. Veit, A. Moura, et al. 2006).

It is widely believed that microorganisms convert solid essences into forms that dissolve in water through a process known as direct bioleaching. In the waterless phase, for instance, essence values appear while the solid residue is rid of when microbes oxidize Bobby to bobby sulfate. The cyclic bioleaching of sulfide minerals is made possible by the ability of

microorganisms to produce oxidizing oxidants. The amount of required sulfuric acid produced by circular bioleaching can be controlled. Value-containing ores' essential sulfides are oxidized and removed in the form of a dissolving medium during the bioleaching process, often referred to as bio-oxidation.

For example, in the case of arsenicite bioleaching, cyanidation is employed to recover the valuable gold essence that remains after iron and arsenic sulfide are dissolved (Sourav C., Prerna G., Shina G., 2021). Microorganisms that mimic bacteria and archaea are used in a sector of hydrometallurgy called "biohydrometallurgy" to extract the essence from ores and concentrates. By regulating these bacteria's metabolism, this technique dissolves and extracts essences from vibrant raw materials. Bio-hydro-refining is a cost-effective and environmentally responsible substitute for traditional chemical methods of extracting the essence.

4. CONCLUSIONS

By minimizing energy requirements and emissions, hydrometallurgical recovery of lead from galena exhibits substantial potential as a replacement or addition to conventional pyrometallurgical procedures. Improvements in our expertise of leaching mechanisms, process management, and mineral characterization open up the opportunity to more effective Pb recovery systems.

5. CHALLENGES AND RECOMMENDATION

5.1. Challenges

- a. The development of passivation layers that prevent dissolving, such as PbSO_4 .
- b. Chloride/sulfate media corrosion and environmental handling.
- c. Using economical reagents scale up from laboratory to industrial scale.
- d. Reagent regeneration and secondary effluent management.

5.2. Recommendation

Future investigations should concentrate on mechanistic electrochemical studies, techno-economic analysis of commercial hydrometallurgical approaches, characterization of reaction intermediates, and process integration (e.g., integrating chemical and biological leaching).

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