Modeling Metal Recovery from Very Low-Grade Ore Materials

Grades: 9-12

Objectives

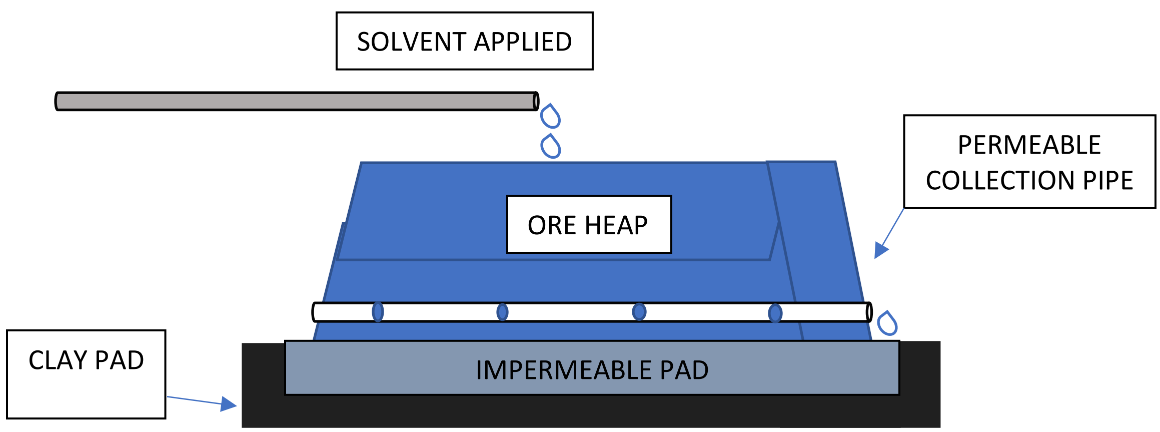
Students will model metal recovery from low-grade ores. Low-grade ores have a smaller amount of valuable material per unit of ore than a high-grade ore, requiring different processing techniques. They will model the process of heap leaching, which includes the use of a solvent, the importance of surface area in a chemical reaction, and the chemistry of reactions that free metal from a solution.

Description and Background

Many metal mines work high-grade ore bodies (ore containing a high amount of valuable metal). They process the extracted rock by crushing, grinding, and physically separating the ore (the metal-containing rock) from the rest of the host rock. This produces a concentrate of metal ore from which the metal itself is refined through additional processes. In low-grade ore bodies, the amount of metal in the ore is too small for that type of expensive processing. After being mined from the ground, this low-grade ore is often crushed and then subjected to a chemical solution process called **heap leaching** to recover the small amount of metal from the ore.

This heap leaching process in the minerals industry involves the following steps:

1. A slightly concave pad is prepared with clays and compacted to a maximum density with minimum permeability (slow movement of water through the clays, such as 1×10^{-6} centimeters per second).
2. This slightly concave pad is then lined with a synthetic liner made of fused sheets of polymer that is resistant to the solvent that will be used. The liner ensures that the results of the reaction are safely contained.
3. Next, a liquid collection system (perforated pipes that will transfer the liquid to a holding tank) is installed over this pad and the crushed, low-grade ore is piled or "heaped" on top of this liquid collection system.
4. A solvent is then applied to the top of the heap to percolate though the heap and dissolve the metal from its ore.



An example of this process is the recovery of copper from a low-grade copper oxide ore with the use of dilute sulfuric acid. The resulting copper sulfate solution is transferred from the collection system and the copper is recovered by electrolysis (separation of charges) or chemical replacement reactions using another metal. The surrounding land and groundwater are protected by the underlying pad. There are monitoring wells around the facility to ensure the ongoing effectiveness of that protection. This work is conducted under an approved permit from the appropriate regulatory agencies. A plan to reclaim the site after mining (secondary use land plan) must be submitted and approved for the permit prior to breaking ground.

This student laboratory activity is intended to model a leaching and recovery process. A mixture of salt and sand is used to represent the low-grade ore material. The salt represents the metal in the ore and the sand represents the host rock and non-valuable minerals of the ore body. Water is the solvent. The salt is dissolved in the “leaching” process and is then recovered by evaporating the water from the leached solution, recovering the salt (representing the metal that was in the sand/salt “ore body”) and leaving only the sand.

Materials and Equipment Needed

1. Half liter of clean sand (approximately 800 grams or 2 pounds)–from a hardware/landscape supply store or from your local ready-mix concrete plant
2. Sieve such as a kitchen colander (or sieve)
3. Filter paper such as a large coffee filter (or paper towel)
4. Three or four tablespoons of table salt
5. Tap water (approx. 1 liter)
6. A deep-sided cookie sheet or baking pan
7. Balance (weigh scale)
8. Container to transfer and apply water

Procedure

a. Acquire at least one-half liter of clean sand, and wash and **dry** if necessary to clean the sand by removing fine particles and dust from the sand.
b. Using the balance, determine the mass of the three to four tablespoons of table salt (halite or NaCl) and record this mass.

    ________________ ***starting salt mass***

c. Add the salt to the clean, dry sand and mix well. This becomes the low-grade ore body.
d. Using a kitchen colander lined with a large coffee filter or other filter paper to allow a space to place the low-grade ore, carefully pour the low-grade ore into the filter in the colander keeping all low-grade ore on the filter. This simulates the slightly concave heap leach pad loaded with low-grade ore.
e. Place this colander on a deep-sided cookie sheet or baking pan of sufficient capacity to hold the solvent water that you plan to apply to the heap. You are ready to leach the ore.

The cookie sheet or baking pan represents the liquid collection system. Very slowly sprinkle a liter of water over the top of the "low-grade ore" for about 5 -10 minutes in order to dissolve the salt from the low-grade ore body. Capture all the liquid from this leaching of the low-grade ore heap in the cookie sheet or baking pan.

f. Set the cookie sheet or baking pan containing the leached liquid in a quiet, well ventilated, and protected place for the solvent, the water, to evaporate. Set the spent heap of low-grade ore aside.

g. After the solvent has fully evaporated leaving the crystallized salt behind, carefully remove the salt crystals and determine the mass of salt recovered.

____________ recovered salt mass

h. Compare this to the mass of salt placed in the sand to evaluate the efficiency of your solution recovery process with the following equation:

$$\frac{\textbf{Ending Salt Mass}\ \_\_\_\_\_\_\_\_\_\_\_\_ \times 100\%}{\textbf{Starting Salt Mass}\ \_\_\_\_\_\_\_\_\_\_\_\_} = \_\_\_\_\_\_\_\_\_\_\_\_\_\ \textbf{\% Recovered}$$

i. Examine the spent heap of low-grade ore for evidence of success at removal of the salt.

Finishing

Write a description of this activity and summarize the chemical and physical processes used.

Explain why the low-grade ore is crushed to facilitate the leaching process in the heap.

Research what metals are recovered by the heap leaching process and subsequent production from the liquid leached from the heap. Make a list of solvents used and describe how any extra solvent is recovered. Research similar processes used for other products such as in the food and pharmacy industry, and the solvents used in those processes.

Discuss how you use metals that are sometimes obtained through heap leaching (i.e., copper, gold, and silver) in your everyday life.

- Copper, gold and silver are all important in electronics. These electronics are found in homes and other buildings with electricity, and in electronic items such as mobile phones, TVs, game consoles, cars, batteries, refrigerators, microwaves, laundry machines, wind turbines, solar panels, etc.

- Copper:
  In addition to electronic uses, copper is used in plumbing, heating and air conditioning; roofing and other construction applications; coatings for nickel, chrome, zinc, etc.; automotive and

machine parts; coins, and other miscellaneous applications. Copper is an essential micronutrient used in animal feeds and fertilizers.
MineralsEducationCoalition.org/minerals-database/copper/
MineralsEducationCoalition.org/education-database/copper-in-our-electrical-world-video/
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- Gold:
  In addition to electronic uses, gold is used to make jewelry and other art items. It is also used in dentistry and medicine including cancer and rheumatoid arthritis treatments. It is used in medallions and coins and in ingots as a monetary system standard. Its special properties make it useful for scientific and electronic instruments, and in the electroplating industry and for specialized glass coating, including for space helmet glass and on spacecraft.
  MineralsEducationCoalition.org/minerals-database/gold/
  MineralsEducationCoalition.org/elements/gold/

- Silver:
  In addition to electronic uses, it is used in coins and jewelry. Because silver is antimicrobial it is valuable for use in medical equipment.
  MineralsEducationCoalition.org/minerals-database/silver/
  MineralsEducationCoalition.org/elements/silver/