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FLOTATION OF ORES AND WASTE WATERS

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World generally requires a very high standard of pollution control, and mining companies pride their organisations as being examples of excellence in this field.
Hydrometallurgical mining processes decrease the production of gas and solid pollutants into the atmosphere and maximize the recirculation of solvents at every level of waste waters treatment. The extra electrowinning of metal using the circular hydrometallurgical process ensures that the maximum amount of mined metal is recovered. Reducing pollution helps to improve company profitability.

Key words: ore, mine, flotation, waste, waters

INTRODUCTION

The need to minimize pollution through waste water production is recognized world wide. Mining and mineral processing companies all over the world acknowledge this and aim to provide best practice in waste water pollution control.

Mining and mineral processing industries have been considered to be environmental polluters for a long time [1, 2]. The latest developments, in line with many Universities and Mining industries world wide are aimed at the minimization of the negative environmental impact of mining and mineral processing operations [3]. This report reviews current practices that can be deploy in metal ore mining, coal mining and mineral processing operations to reduce pollution from waste water.

Coal and metal mining operations interfere with the natural circulation of water. At a number of mines, ground water accumulates and must be pumped to prevent flooding.

The composition and temperature of effluents depend on the geological composition of soils, the depth at which mining operations take place, and the type of ore being mined.

TYPES OF MINE EFFLUENTS

Generally, the following two types of mine effluents persist: [1, 4-5]

1. Effluents originating from deep mines, which are neutral or mildly alkaline, and systematically segregated according to salt content. Effluents possessing low concentrations of salt are utilized as industrial water, whilst those with high salt content are collected separately and disposed of in an orderly, and planned, manner.
2. Effluent originating from open cut operations. Sulphur often persists within these discharges in the form of pyrites. During leaching and extraction, the following chemical reactions take place:

$$2FeS_2 + 7O_2 + H_2O = 2Fe^{2+} + 4SO_4^{2-} + 4H^+ \; 4Fe^{2+} +$$
$$+O_2 + 4H^+ = 4Fe^{3+} + 2H_2O$$
$$FeS_2 + 14Fe^{3+} + 8H_2O = 15Fe^{2+} + 2SO_4^{2-} + 16H^+$$

The reaction velocity of the oxidation process depends on pH, concentration of oxygen, concentration of FeS_2, and the presence of chemoautotrophic microorganisms oxidising Fe^{2+} to Fe^{3+}. Typical concentrations (in grams per litre) of ions in mine effluent are listed in Table 1.

Table 1 **Typical concentrations of ions in mine effluents**

	Deep mining effluents	Open cut\ Mining effluents
Fe^{2+}		0,5-10
Al^{3+}		0,0-2
$SO4^{2+}$		1,0-20
Total solub. substances	1-50	5,0-50
pH	7,5-10	2,0-4,5

Discharges of acidic mine effluents can be minimized by redirecting rain water into drainage basins and beyond the immediate mine and catchment area, or by segregating ground and surface waters. The chemical composition of acidic mine effluent can be regulated by minimizing its contact with oxidized sulphur compounds, by permanently pumping seepage water and by decommissioning exhausted sections of the mine. Before disposing of effluent into water

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courses, acidic mine effluents must be treated to adjust pH, remove iron and heavy metals, and reduce SO_4^{2-} content. Most frequently, such effluents are neutralised by calcium hydroxide, or using a combination of calcium carbonate (limestone) and calcium hydroxide (slaked lime) [6,7].

The reaction time in the neutralisation reactor usually lasts between 1 and 2 min. During neutralisation, a substantial proportion of heavy metal ions is precipitated. This process is supplement by aerating the mixture for (15–30) min in a vessel situated between the neutralisation reactor and the sedimentation tank, where Fe^{2+} is oxidized to Fe^{3+} and precipitated as a hydrated oxide. The concentration of SO_4^{2-} ions is reduced during neutralisation with calcium compounds to concentrations equal to the solubility of $CaSO_4$.

Neutralisation processes using solely grounded limestone are used exclusively on effluent with low SO_4^{2-} contents, although fluidisation processes must still be deployed to prevent the passing of limestone grains. Under these circumstances, the concentration of Fe^{2+} must not exceed 100 mg/L. [3-5]

Desalination of mine effluents is considered in those areas, where there is a shortage of other sources of water. Depending on the composition of the effluents discharged, the availability of relevant technologies and power, ion exchange or membrane separation procedure are employed, in particular reverse osmosis and electrodialysis.

TYPES OF METAL ORES

According to their chemical composition, metal ores are: [7,8]

- Ores with an elementary (pure) metal (e.g. silver, gold and platinum).
- Metal oxide ores. These are metal ores where the metal has formed a compound with oxygen to become a metal oxide. This is the most frequently occurring type of metal ore.
- Pyrite ores (metal ion in a compound with sulphur. Frequently, also arsenic and antimony are present to form a compound substance with the metal).

Waste mine rock usually contains as its main component silicates, Al_2O_3, $CaCO_3$ and Fe_2O_3.

OBTAINING OF METAL CONCENTRATES

In order to obtain a metal concentrate, ore is separated from waste rock by comminution, gravity or magnetic processes, and flotation. These processes are carried out in water, the consumption of which is typically between 3 and 15 cm^3 per one metric tonne of ore. However, if water separation (recirculation) methods are used, the consumption of water can be less than 1 cm^3 per one metric tonne of ore.

WASTE WATERS TREATMENT MEASURES

Waste waters deriving from ore processing plants are contaminated with: [8]

- Insoluble substances, predominantly waste sludge (finely ground waste rock). The concentrations of these solids are usually within the range of 20–300 g/L
- Soluble substances, which are extracted from the ore (heavy metals, sulphates)
- Chemical used in the flotation process.

Froth flotation is a process based on surface chemistry, where particles of metallic sulfides are collected by air bubbles to become the concentrate while gangue minerals remaining in the pulp become the tailings (Figure 1).

Froth flotation agents of phenolic composition were used in the past, causing substantial contamination of

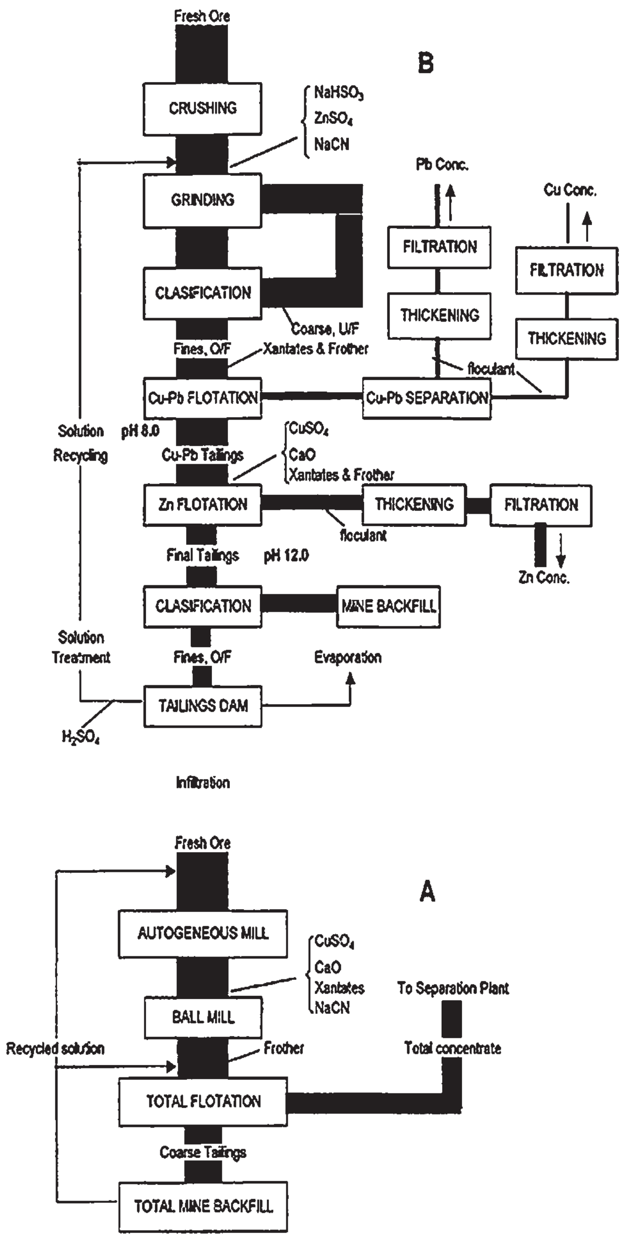

Figure 1 Principal regimes of flotation: A – total flotation, B – selective flotation. [1,5,7,8]

recirculated water. Currently, flotation processes feature ethylxanthogenates, which, despite being toxic, are subjected to hydrolytic decomposition whilst standing within the tailings dam. Other chemical used in froth flotation processes include cyanides, the salts of heavy metals, slacked lime and sulphuric acid. The basic strategy used for treating waste waters from mineral processing is the tailings dam itself, where waste rocks are separated by sedimentation.

Waste water treatment after mineral processing employing a froth flotation process also uses:

- Precipitation (where the metal is heavier than water and sinks to the bottom of the container)
- Oxidation (where oxygen is used in the mineral processing)
- Hydrolytic (where water is used) reactions [6].

The use of these processes enables there to be a significantly reduced concentration of contaminants in the water. The velocity (rate of motion) of this chemical reaction determines the rate at which the water circulates in the process.

METAL ORES AND METALLURGICAL PROCESSES

Metal ores are further subjected to various metallurgical processes, particularly, pyrometallurgy (at high temperatures) and hydrometallurgy (processes in the aqueous media). Hydrometallurgy is being used more and more frequently, since it facilitates metal–winning from the lowest graded ores, and from poly–metallic ores. The main stages of hydrometallurgy processes include leaching (extraction), separation of leach liquids, their purification, and finally, metal–winning. Leaching (extraction) processes use various solvents (water, acids, alkalis, salts, organic solvents or extractants), and metal–winning itself requires electrolysis, and reduction using hydrogen, another agent or by precipitation. [1,2,5,7,8]

Compared with pyrometallurgical processes, hydrometallurgy is much more environmentally friendly. The volume of gaseous pollutants liberated into the atmosphere is only a fraction of what would be generated during pyrometallurgical processes, and emissions of sold particles are comparatively non–existent. Since hydrometallurgical processes are carried out in an aqueous media (or aqueous phase), there is, however, greater potential for contamination of large volumes of water. Waste water from hydrometallurgical processes contain soluble metal compounds, chelating compounds and organic solvents.

CONCLUSIONS

The central issue with waste water treatment is the maximization of water recirculation in all circuits. This is supplemented with technologies suitable for the removal of metal ions, such as precipitation, ion exchange, electrochemical processes or solvent extraction.

Mining companies must be generally proactive in aiming for cleaner production. In some cases, this is forced on the companies through the need to meet safety and environmental legal requirements. World generally requires a very high standard of pollution control, and mining companies pride their organisations as being examples of excellence in this field.

As a summary, it has been found in practise that using hydrometallurgical mining processes instead of pyrometallurgical methods reduces pollution and minimizes the negative environmental impact that mining and mineral processing can cause. Hydrometallurgical mining processes decrease the production of gas and solid pollutants into the atmosphere and maximize the recirculation of solvents at every level of waste waters treatment. The extra electrowinning of metal using the circular hydrometallurgical process ensures that the maximum amount of mined metal is recovered. Reducing pollution helps to improve company profitability.

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