

A Study on the Performance of Sodium Mercaptobenzothiazole (NMBT) Collector on the Flotation of Black Mountain Ore

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Abstract—This paper investigated the performance of Sodium Mercaptobenzothiazole (NMBT) as a collector in the flotation of Black Mountain ore. The ore contains metals such as lead, copper and zinc and the associated minerals of economic importance are chalcopyrite, galena and sphalerite respectively, with traces of silver. The study evaluated the effectiveness of the collector and how pH affects the recovery of minerals in particular copper. The performance of the collector was influenced by mineral surface chemistry. The experimental test work was conducted at varying pH levels using Denver flotation cell in order to investigate the collector performance in a basic medium. The experiments were conducted at two different test runs of slightly basic solutions of pH 8.5 and 9.0. The results of both fresh ore and floated ore samples were analysed using XRF. Although Black mountain ore contains small quantities of copper as compared to other ores, a significant amount was recovered ($\pm 78\%$ of the available copper in the ore), as an indication of the performance of NMBT.

Keywords—Black Mountain ore, copper metal, performance, pH levels, sodium Mercaptobenzothiazole.

I. INTRODUCTION

FLOTATION is a well-known process in mineral separation used to recover valuable minerals from gangue and is a widely used method for the concentration of fine-grained minerals. It is fast becoming a generally accepted processing technique especially with regards to the treatment of low grade and complex ore body which hitherto has been regarded as uneconomic and as waste [1]. As a selective process it can be used to achieve specific separations from complex ores such as copper-zinc, lead-zinc and so on. This technique is unique due to the fact that it is continually being expanded to treat the

sulphides of minerals like nickel, platinum and gold hosting sulphides, also oxidized minerals such as cerussite and malachite. In addition, it can also be used in the treatment of oxides such as haematite and cassiterite, this is a clear deviation from its initial objectives of treating the sulphides of lead, zinc and copper [2]-[4]. In general, it is a way of separating valuable suspended solids from a medium such as a mixture constituted by solids and water by taking advantage of the different physiochemical surface properties of minerals—in particular, their wettability, which can be a natural property or artificially changed by chemical reagents. The process introduces fine air bubbles into the slurry so that the air bubbles attach to the valuable particles, and transport them to the surface [1]. The attachment of valuable minerals to air bubbles and the suspension of gangue in the water are geared towards recovering the majority of the valuable minerals inherent in the sample.

The particles to be floated are rendered hydrophobic by the addition of the appropriate chemicals. By altering the hydrophobic (water-repelling) or hydrophilic (water-attracting) conditions of their surfaces, mineral particles suspended in water can be induced to adhere to air bubbles passing through a flotation cell or to remain in the pulp. The air bubbles pass to the upper surface of the pulp and form froth, together with the attached hydrophobic minerals [1], [5].

A. Flotation reagents

Flotation agents are substances added to the ore pulp to make possible or facilitate the treatment of ores, which enable full applicability of the process. Proper choice of reagents is needed for maximum flotation recovery and selectivity [6]. Examples are collectors, depressants, frothers, modifiers, reagents and activators. The most important of these agents are the collectors, which attach themselves to normally non-floating minerals, thus endowing them with hydrocarbon like surfaces and making them capable of adhering to gas bubbles [7]. Other reagents used in flotation are explained below [8]:

Depressants: These assist in selectivity and minimize displacement of unwanted minerals by forming a polar chemical envelope around the solids particles that enhance hydrophilicity in order to aid in separation.

Activators: Activators may be added to chemically alter the solid surface increasing the interaction with collectors that are ineffective alone. The addition of small amounts of copper

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sulfate to the pulp can however, result in the flotation of black mountain minerals.

Frothers: Another important component in successful flotation is the frother. Air on its own is not enough to lift minerals and a frother is required to help to transport the valuable minerals. Once the surface is hydrophobic, a solid particle must be able to attach to an air bubble. While it may be possible to initially obtain solid particle attachment to air bubbles in an agitated liquid under aeration alone, these air bubbles are unstable and quickly break down due to collisions with other bubbles, solid particles and the vessel walls. In addition the bubble size may not be sufficient to effectively carry a solid particle to the surface of the liquid. Consequently frothers are added to promote the formation of stable air bubbles under aeration. Frothers like collectors are typically comprised of both polar and non-polar end. The non-polar hydrophobic end orients itself into the air phase.

Modifiers: Modifiers change the physiochemical state of the mineral surface. A modifier or conditioner in flotation is considered to be any reagent that does not work as collector, depressant, or frother. Functions performed by modifiers and conditioners include pH adjustment, mineral surface change, precipitation of soluble salts, and reagent concentration change. Powdered activated carbon is a modifier or conditioner since it is used to improve separation of metals by adsorbing excess depressants and other organic reagents, such as collectors, from the solution or mineral surface. Modifiers control selectivity through preferential adsorption of the collector by the mineral to be floated and prevention of adsorption by other undesired minerals.

Various flotation reagents formed from three elemental group are schematically shown in Fig. 1 [8].

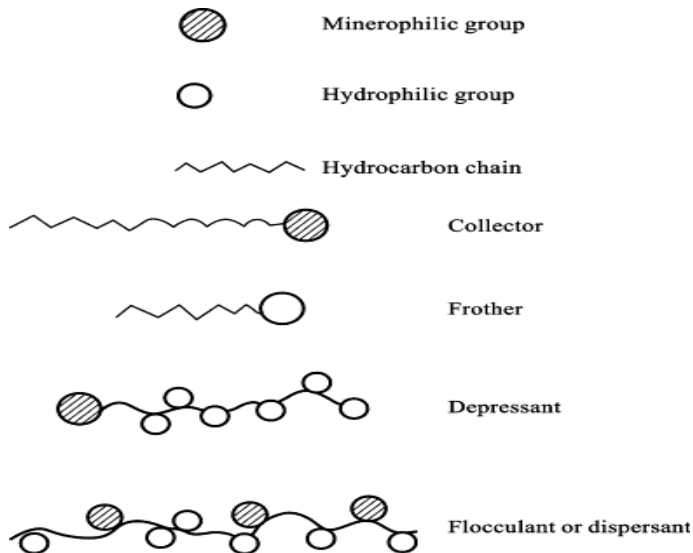


Fig 1: Various flotation reagents formed from three elemental groups (After Somasundaran and Dianzuo [8])

B. Importance of collectors

Collectors form a mono-layer on the particle surface that essentially makes a thin film of non-polar hydrophobic hydrocarbons. They also increase the contact angle so that

bubbles will adhere to the surface [7]. They can be non-ionic, anionic or cationic. The anionic collectors are simple hydrocarbon oils, while the non-ionic and cationic collectors consist of a polar part that selectively attaches to the mineral surfaces, and a non-polar part that projects out into the solution and makes the surface hydrophobic [8]. The classification of collectors is shown in Fig. 2.

Collectors can either bond chemically to the mineral surface (Chermisorption), or be held on the surface by physical forces (Physical adsorption) [9]. Some collectors have frothing characteristics that at first may seem to be advantageous, but are actually quite harmful as they make it quite difficult for the concentration collector to be changed without hindering with the froth. Other collectors have froth stabilizing properties that in some instances, especially for ore bodies with a resistance to froth formation, can be beneficial [7].

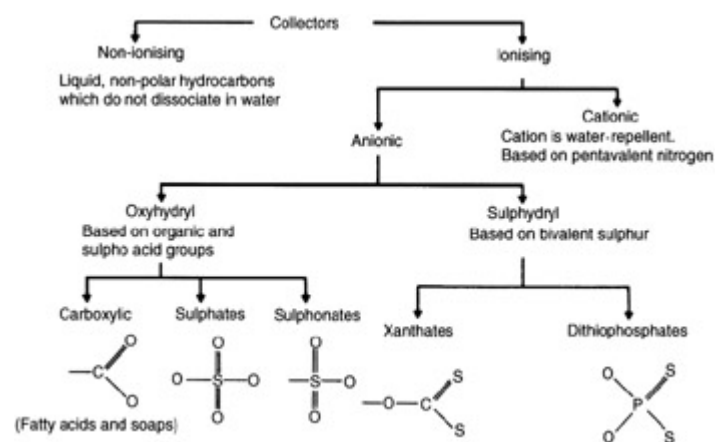


Fig 2. Classification of collectors (After Wills, 2006 [1])

The use of the appropriate collector will determine the effectiveness of valuable mineral recovery. Consequently, investigation of the interaction of collectors with mineral and metal surfaces has been an ongoing area of research, as adsorption of a collector is the key chemical step in the flotation process [10]-[18]. The potential dependent adsorption of an organic collector onto a mineral surface has been utilised in the selective floating of minerals for over a century [17]. pH of a medium is also an important factor that influences flotation. Control of pH is one of the most widely applied methods of modulation of mineral flotation. If possible, flotation is usually carried out under basic conditions because most collectors are stable at higher pH values. pH also determines the ratio of molecule to ion concentrations as well as the solubility of a collector [5]. Flotation depends directly on the nature and properties of mineral-water interface [5]. Two factors are important: (1) the interaction of water molecules with the mineral surface, both in liquid and gaseous environments, and (2) the electrical double layer at the solid-water interface [19]-[20]. Most minerals are naturally hydrophilic, they are water loving substances and

tend to dissolve in water and they need collectors to render them hydrophobic (water hating). Once rendered hydrophobic, there must be a contact between them and gas bubbles so that the bubbles can attach to the surface as shown in Fig. 3. It is only then that flotation can occur.

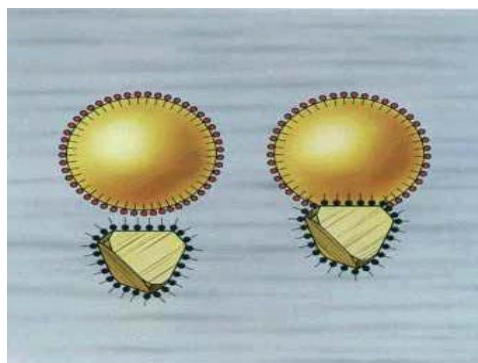


Fig. 3 Action of collector to cause hydrophobicity [20]

Thiol collectors are the most commonly used collectors for sulfide minerals for the recovery of these minerals from their associated gangues by froth flotation in the mining industry [10] & [21]. Common thiolcollectors and their uses are shown in Table 1.

TABLE 1
COMMON THIOCOLLECTORS AND THEIR USES

Collector	pH range	Uses
Xanthates	8-13	Flotation of sulphides, oxidized minerals
Aerofloats	4-12	Selective flotation of copper sulphides from pyrite
Dialkyl dithiocarbamate	5-12	Similar properties to xanthate, but more expensive
Isopropyl thiocarbamate	4-9	Selective flotation of copper sulphides from pyrite
Mercaptobenzothiazole	4-9	Flotation of tarnished or oxidized lead and copper minerals

C. Sodium mercaptobenzothiazole

Sodium mercaptobenzothiazole is classified as an organosulphur compound (chemical formula: $C_7H_4NNaS_2$). It

is widely used in refineries, steam crackers, aromatic extraction and petrochemical manufacturing. Used primarily as a vulcanization accelerator in the production of rubber, to inhibit corrosion of copper and as an ingredient in cutting of oils and petroleum products [22]. However, it can also be used as a collector introduced in flotation process by atomization. It is a very versatile collector and can be used for the flotation of a number of minerals. In the form of its sodium salt, it is adsorbed very rapidly onto mineral surfaces and, therefore, requires a very short conditioning period. It is a very good collector of oxidized and partially oxidized gold ores. Since it does not adsorb on sphalerite, it can be used in differential flotation [20].

D. Black Mountain Ore

Black Mountain Ore is rich in iron and silicon and constitutes small percentage of copper metal. The minerals of economic importance in this ore are chalcopyrite which contains copper, galena with lead, sphalerite with zinc and small traces of silver.

E. Flotation of copper from chalcopyrite

Chalcopyrite is the most common ore of copper, though the percentage of copper in it is low. Therefore, there is a need to upgrade the copper concentration (beneficiated) before refining; this can be done by flotation. Chalcopyrite can be found in volcanogenic massive sulfide ore deposits and sedimentary exhalative deposits, formed by deposition of copper during hydrothermal circulation.

F. Objectives

The performance of sodium mercaptobenzothiazole collector (NMBT) in recovering copper from the flotation of Black mountain ore at two different pHs was investigated in this study. Most of the minerals found in black mountain ore (Galena, Spalerite and Chalcopyrite) are said to be sulphide minerals as shown by their chemical formulae: PbS , $(Zn,Fe)S$ and $CuFeS_2$. This study focused on the recovery of copper from Chalcopyrite under slightly basic conditions.

II. METHODOLOGY

A. Samples Milling

3 kg of coarse Black Mountain ore was divided into sizes of 1 kg; each 1 kg sample was then taken to the rod mill with 13 rods, and milled for 4 h, to give a fine texture of about 106 μm , with 80% pass.

B. Sieve Screening

Milled ore samples were weighed and losses during milling were observed. Sieves of sizes 106, 75, 53 and 38 μm were used on the mechanical sieve shaker, and stacks of sieves were used in such a way that the smallest sieve was placed at the bottom. The ore was then sieved for 30 min on the shaker. In this study, particles with a sieve size of 75 μm and below

were used.

C. Flotation Procedure

After the required size fraction of 75 μm and below was obtained by screening after milling, 1 kg (per batch) of ore was put into the flotation cell and mixed with 2 L tap water by means of an agitator which was slowly immersed into the cell. The agitator was started after closing the valve and agitation was performed for 5 min. The initial pH of the solution was measured with a calibrated pH meter prior to addition of any reagents. The initial pH was found to be around 7.8 and 0.05g of CaO (lime) was added to adjust the pH to the desired value (8.5). The solution was then conditioned for 5 min, thereafter, other reagents: activator (CuSO_4), collector (NMBT) and lastly frother (Senfroth XP 200) were each added at intervals of 5 min (conditioning time). Flotation was started by opening air valve. The froth was then collected using a plastic scraper, into the concentrate pans for a period of 15 min until all the concentrate was collected. Once the flotation was completed, both the concentrate and the tailings were filtered and put in an oven to dry for 2 h. The same procedure was followed for a pH of 9.5

D. Post Flotation Sample Preparation

The dry caked samples of both concentrates and tailings were removed from the pans and crushed (pulverised) using a porcelain mortar and pestle while avoiding any contamination of fine material. The concentrate and tailings were weighed for dry mass determination subsequent to flotation. The samples were then placed in marked, separate plastic containers/bags which were then sealed to minimise any surface contamination, or oxidation caused by air. Quantitative determination of the major elements present in the samples was achieved through XRF analysis.

III. RESULT AND DISCUSSION

A. Composition of Black Mountain Ore

Iron minerals are often associated with copper minerals in most ores. The Black mountain ore is rich in iron and silicon as shown in Table 2. Copper is available in small quantities, hence the amount of copper recovered was the lowest. In the flotation of Black Mountain ore, other metals such as iron, silicon, lead, and zinc were highly recovered in terms of both recovery value and grade.

TABLE 2
COMPOSITION OF BLACK MOUNTAIN ORE

Components	%
Cu	0.341
Fe	28.237
Pb	3.559
Si	11.439
Zn	3.106
Fe_2O_3	40.371

SiO_2

24.471

B. Performance of sodium mercaptobenzothiazole collector (NMBT) on concentrates at pH 8.5 and 9.5.

The recovery of copper metal in concentrates using NMBT collector at both pH 8.5 and 9.5 is shown in Fig. 1. The results show that copper recovery was higher at a pH of 8.5, this was found to be 1.313% as compared to 0.499% for a higher pH of 9.5. This shows that as pH increases the recovery of copper decreases. Due to the presence of pyrite in the ore, this reduction in recovery could be due to the formation of precipitates at higher pH values which causes high mineral coverage during flotation. It has also been found that a decrease in recovery at higher pH values is as a result of the increase in the proportion of surface iron specie covering the hydrophobic specie [23].

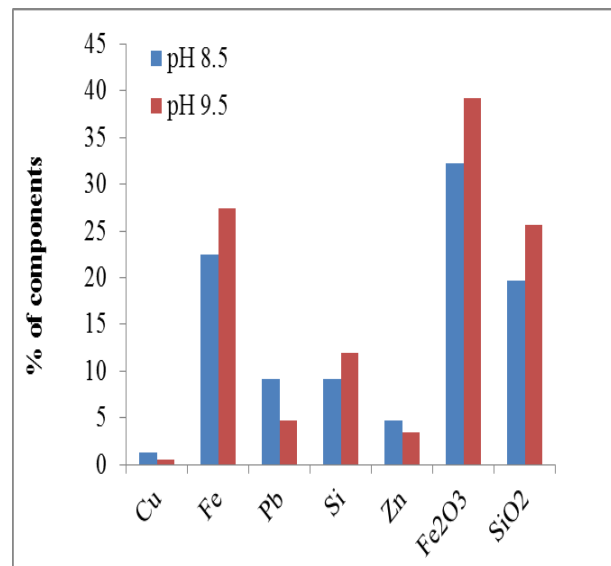


Fig. 1 Performance of sodium mercaptobenzothiazole collector (NMBT) on concentrates at pH 8.5 and 9.5

C. Performance of sodium mercaptobenzothiazole collector (NMBT) on tailings at pH 8.5 and 9.5.

Tailings have less metals compared to the concentrate, most of the metals in the tailing are recovered as shown in Fig. 2. Copper content in the tailings was insignificant compared to other metals. Iron minerals, particularly pyrite, are often associated with copper sulphide minerals in ores. During grinding and conditioning, a variety of surface reactions can take place. For example, activation of pyrite (iron) can occur as a result of dissolution of copper species from chalcopyrite. These copper species form hydrophobic species on the pyrite surface with sulphide and collector, and therefore promote pyrite flotation, which subsequently lowers the overall copper grade in the float.

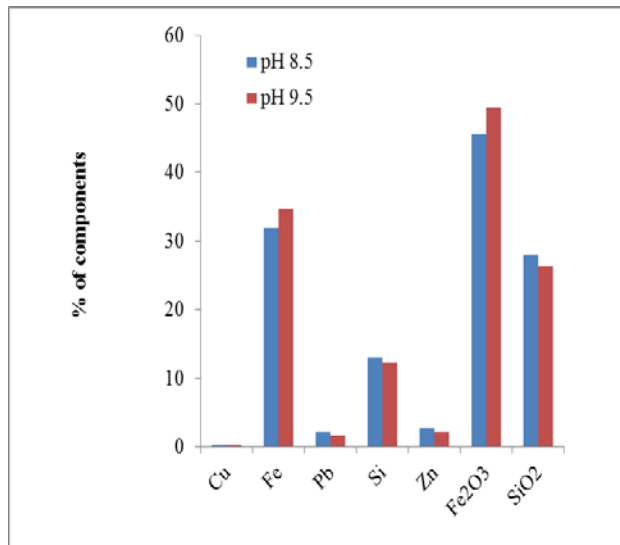


Fig. 2 Performance of sodium mercaptobenzothiazole collector (NMBT) on tailings at pH 8.5 and 9.5

IV. CONCLUSION

This study has shown that pH has a huge effect on the flotation recovery of mineral/meta. Sodium Mercaptobenzothiazole (NMBT) is an effective collector in a slightly basic solution (lower pH values) as higher pH causes mineral coverage, thus reducing the recovery of valuable metal (copper). Most of the copper was recovered at the pH of 8.5 which was the initial pH of Black mountain ore solution, without any additions of pH modifiers.

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