Addis Ababa University
አዲስ፡አበባ፡ዩኒቨርሲቲ
SEEK WISDOM, ELEVATE YOUR INTELLECT AND SERVE HUMANITY !

Addis Ababa University

Addis Ababa Institute of Technology

Center for Ethio-Mines Development

Masters in Mineral Engineering

Reverse Flotation as a Method for Beneficiation of Sekota Iron Ore

A project submitted to the Center for Ethiopian Mines Development as partial fulfillment of the requirements for the Master of Engineering in Mineral Engineering degree

By

Temesgen Demissie

Advisor: Dr.Abubeker Yimam

June, 2023

Addis Ababa, Ethiopia

Approval page

Title: Revers Flotation As A Method For Beneficiation of Sekota Iron Ore

Student Name: Temesgen Demissie Signature……………….Date……………

Advisor: Signature………………..Date…………….

Co-advisor: Signature………………..Date…………….

Examiner: Signature………………..Date…………….

Examiner: Signature………………..Date…………….

Center for Ethio-Mines Director

Name: Signature………………Date……………

Table of Contents

List of figure

List of table

Acknowledgements

First of all, I would like to thank **God** for giving me strength and guidance along the way. Then, I would like to thank my advisor, Dr.Abubker Yimam and co-Advisor Mr Basalfew Zenebe, for all their support, guidance, and advice over the past few months. Without them this work would not have been possible. I would also like to thank my project group for all their help and support. I would like to extend my thanks to Addis Ababa University and Geological survey worker for providing materials, advice, and part of the funding for my work. My deepest gratitude goes to my father, Mr Demissie Amlakterda, my Beloved wife Desta webetu, my sisters, my child Barkot and Ms. Emebt webetu, they give full of love and they always believing in me and supporting me throughout this journey. Finally, all my friends give fraction of time contributes.

Abstract

Upgrading low grade Sekota iron ore to reduce the unwanted minerals and improve the quality is necessary to address these issues, in order to produce an acceptable feed for a steel production facility. The primary aim was to use reverse flotation as a beneficiation method for Sekota iron ore, in order to get a last flotation that meets the desired specifications. This process was divided into three stages: crushing, grinding, and flotation. For each of these stages, such as grinding, dosage of collectors, flotation duration, and procedures were determined. In the laboratory, where the samples were obtained, the ore was ground in a size of -0.074mm, using 250 grams of ore, with varying amounts of anionic oleic acid as the collector, 5mg/ton of activator and 5mg/ton of depressant, and floated with 2.0 g/ton of ethanol frother. The slurry was maintained at 10.5 using NaOH throughout the process. Before conducting any optimization tests on the iron ore flotation process, a laboratory procedure was developed to carry out the reverse flotation of the iron ore. The results showed that following these parameters, the flotation process achieved a final concentrate with a grade of 39.16% iron and an iron recovery of 41.29%. In this study, with varying duration of flotation, the iron grade ranged from 40-45% with an iron recovery of approximately 42%.

CHAPTER ONE

1. Introduction

1.1backgraound

Deposits of iron were found on the Marquette Range on September 19, 1844 by William A. Burt, United States, and group who were surveying in the Michigan. Burt was the creator of the solar compass and it was the extraordinary fluctuations in the orientation of the needle that prompted him to instruct his group to search for the cause. Exposures of ore were discovered in large quantities; in truth, a simple strip of grass uncovered the ore.

Due to its extensive industrial use, iron is extremely important and ranks first among all metals in terms of global making and usage (Nakhaei and Irannajad, 2017). Because of its affordability and high strong, it is used only in engineering use such the manufacture of machinery and machine tools, automobiles, the hulls of large ships, and structural components of buildings (Greenwood and Earn Shaw, 2012).

Iron can produce compounds in both the bivalent and trivalent states, making iron ores the fourth most reactive element in the earth's crust (5.1 mass%). The majority of the iron is discovered in Fe (II) silicate minerals including pyroxenes, amphiboles, biotites, and olivines in the primary (magmatic) rocks of the earth's mantle. Sulfides frequently contain iron. These are igneous or metamorphic, though. Metallic iron may be commercially produced from rocks and minerals. The ores are often containing iron oxides and differ in color from rusty red to dark purple to bright yellow. According to Ramanaidou and Wells (2014), the iron is typically found in the minerals goethite (FeO (OH), hematite ($Fe2O3$, 69.9% Fe), 62.9% Fe), limonite (FeO (OH)•n($H2O$), 55% Fe), siderite ($FeCO3$, 48.2% Fe) and magnetite ($Fe3O4$, 72.4% Fe).

"Unprocessed shipping mineral" refers to minerals that can be directly used in blast furnaces for the making of iron and have iron content of over 60% in the form of magnetite or hematite . Pig iron the main essential materials needed for the production of steel, and it is the raw material necessary for its production. Steel is manufactured using 98% of the iron ore that is extracted (Mineral Information Institute, 17 April 2006).

Industrial iron ores (magnetite, hematite, limonite, and siderite) contain varying amounts of iron, with high-grade ores having iron concentrations above 55% and commercially unviable cut-off grades having iron concentrations below 25%. In addition to affecting the price of the product, the iron grade also impacts the breakeven point for profitability and the differences between suppliers. However, the most significant impact of the iron grade is on the energy consumption during mining rather than the missed opportunities of not using higher grade ore.

Now a day, the sector is getting on all countries, even though the more project manufacturers are obtain in Australia and in South America. The manufacturers in Brazilian have, since the 1980s, increased their market volume in Western Europe. The price iron ore as a totally is declining. The ore is main raw material for metallic iron extraction to make steel. To keep up with the fast growth in crude steel production, there has been a substantial rise in world iron ore making over the past ten years. The production of iron ore globally has witnessed a steady increase from 1.043 billion tons to 2.93 billion tons between 2001 and 2012. China holds the top position as the leading owner of iron ore, accounting for approximately 1.3 billion tons in that year (Holmes, R. J., & Lu, L. (2015). Considering that whole products have an established marketing system, it is reasonable for ore to adopt the same approach. In order to meet the increasing demand for transparent pricing in the market, various financial exchanges and clearing home around the globe have implemented the ore swaps clearing (Source: Index Mundi, Accessed 2022).

Figure 1; World iron ore price (source: index mundi, 2022)

Iron ore is transformed to produce iron or steel through iron ore beneficiation (physical removal of unwanted impurities, control of product size, or combination). Iron ore preparation is the process of utilizing various methods to enhance lower grade ore resources so that they are suitable for iron production. Most iron occurrences and deposit categories, reserve, size, composition and other ore characteristics are not adequately studied, which limits the feasibility analysis for making informed investment decisions. The occurrences can be classified as medium-large deposits and small scale. Ethiopian iron ore has relatively low iron content. The deposits of Shire, Bikilal, Melka Arba and a small part in Kaffa have been extensively examined. The overall verified ore in the nation adds up to roughly 350 million tones, Strategic Evaluation of the Ethiopian Mineral Sector of Ethiopia Mineral Sector Assessment (2014).

Beneficiation methods, which utilize gravity, magnetism, and flotation to obtain iron with high content (often up to 65%), are showing to as screening, crushing, and milling. Between the Tertiary volcanic rocks of the central Ethiopian highlands and Mesozoic rocks, the Sekota region might be thought of as a transitional zone. The transitional character of the area around Sekota encourages the presence of several valuable minerals like hematite (iron ore), dimension stones, zeolite, and gemstones. (Sekota Iron Ore Feasibility Study, 2014)

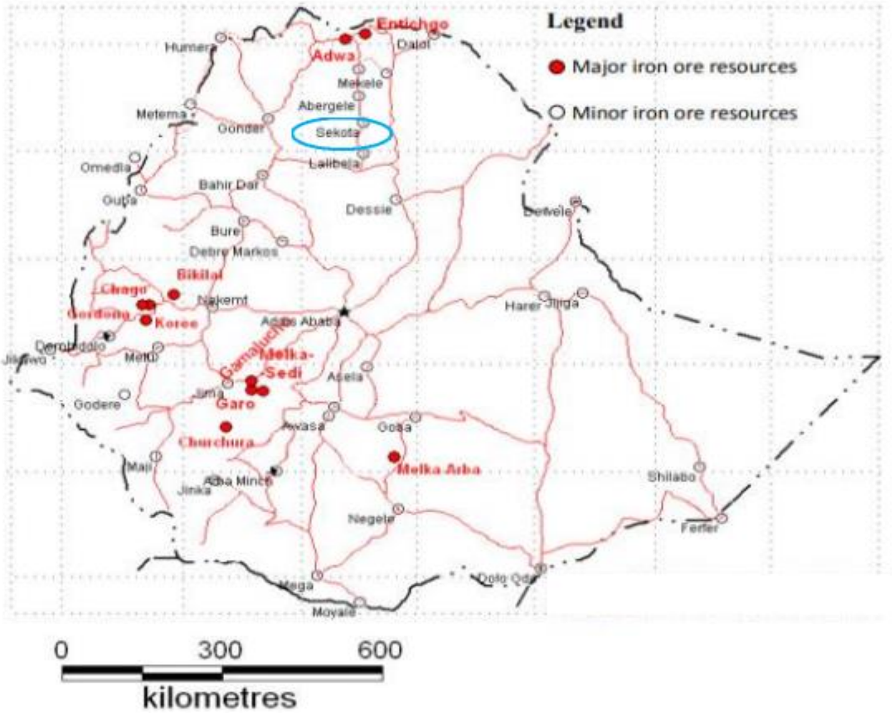


Figure 2: Iron ore location map (source: Geological Survey of Ethiopia, June 2010).

1.2 Statement of the Problem

The demand to extract and convert lower amount in ore into more economically viable products with iron contents above 50% is developing as a result of the rapid remove of high grade iron ore reserves due to the overexploitation of these ore formations. Although reverse flotation was initially used, mineral and gangue hydrophobicity have a distinct separation approach for extracting iron from its waste. Reagent grade, type, and particle size have an impact on greater concentrations of iron recovery.

Sekota contains poor quality hematite iron ore. The inferior quality iron ore makes the smelting process difficult. The presence of silica, however, will require a most relevant of fluxing agent, resulting in a large quantity of slag being produced in the furnace. It is impractical to use this ore to produce iron and steel using the traditional blast furnace technique.

Entrainment can be diminished initially by proceeding to the subsequent step, resulting in an improved sinter product with heightened efficiency and steel quality. Therefore, it is important to upgrade the low grade iron ore in order to reduce the unwanted minerals and enhance the desired grade, in order to address the aforementioned issues and generate a suitable feed for the steel manufacturing facility.

1.3 Objectives

1.3.1 General Objective

Reverse flotation as a method for beneficiation for Sekota iron ore.

1.3.2 Specific objectives

Carried out in the realm of iron ore enhancement and with the areas of study that need further investigation having been pinpointed, the primary aims of the investigation are thus to:

- To collect representative sample the significance to project process.
- To analysis mineralogy issues associated with reverse flotation of iron ore.
- Experimental design require beneficiation root (crush to floatation).
- Optimize flotation of recovery by varying collector and flotation time.
- Identify the best operation condition that is maximizing point.

1.4. Significance of the study

Focus on the development and marketing of mining sector, proper characterization of the deposit will help in exploration and encourage local and foreign investment. The industrialize advantages of this process are significant. So the result of study can be used as a reference to improve the concentrate upgrade of Iron Company in understanding more about flotation method. In academic communities of Universities, the outcome of this study can serve as background for next studies in the area.

1.5. Scope of the study

The scope of this study work involves collecting the sample form the deposit site and characterizing it to know its chemical and mineralogical properties and then determine the liberation size and beneficiating using gravity method. This information will be gathered using the following tools: optical microscopy, silicate analysis. The study is based in a lab set up. Economic viability is not try in pilot scale. The Information search made use of the following databases and web search engines: Science direct, Sci-hub, internet, Google scholar and Yahoo.

CHAPTER TWO

2. Literature Review

2.1. Mineralogy of Iron Ores

Iron found mostly an oxide ore these are

I. Magnetite Ores

One of the primary iron ores is magnetite, a mineral having the formula Fe_2O_4. It is ferromagnetic and may be magnetized to become a permanent magnet by itself (Jacobsen S.D , Reichmann, H.J., Kantor, A and Spetzler, H.A (2005)). Magnetite is an attractive of all naturally occurring minerals on Earth, with the exclusion of extremely scarce native iron deposits (Harrison,et al., 2002). Ancient peoples initially learned about magnetism through the property of lodestone, which is naturally magnetic bits of magnetite that would draw tiny pieces of iron (Du Trémolet de Lacheisserie, et al., 2005).

Magnetite is a dark or brownish-dark mineral in lustrous, metallic appearance. The hardness is 5-6 on the Mohs scale and leaves a dark streak. Tiny magnetite particles are commonly found in altered and volcanic rocks (W. Edwin Sharp; Edward Salisbury Dana (1998), (Nesse, William D. (2000)). The typical threshold at which a magnetite layered iron deposit becomes economically viable is around quarter iron content. This usually results in a recovery rate of 33% to 40% by mass, producing a concentrate with a grade of over 64% iron.

The standard iron ore concentrate in magnetite contains phosphorus, silica, and aluminum less than 0.1%, 3-7% and 3% respectively. Brazil is currently a major producer of magnetite bearing layered iron deposits, exporting low quantities to Asia. Additionally, Australia has a growing and significant magnetite ore industry (Troll, Valentine R.et.al (2019)).

II. Hematite ore

Hematite is frequently composed of direct shipping iron ore reserves are presently exploited on the world exclude Antarctica, with the biggest manufacturer in Australia, Asia, and South America. The most extensive the ore reserves are derived from altered banded iron formations (BIF) and occasionally volcanic accumulations. Export quality irons are generally in the 62–64% iron range. It’s a most common iron oxide compound with the formula, Fe_2O_3 and is largely obtain in soils and rocks (Muwanguzi and Abraham J. B.et.al (2012)).

Hematite minerals be in the rhombohedra lattice system which is apointed the alpha polymorph of Fe_2O_3.It is only softer than pure iron, but also strong brittle (Cornell, Rochelle M.; Schwartzman and Udo (1996).It found in nature like black, red colors , brown to reddish-brown and silver-gray. It is electrically conductive (Wiley 2018). Hematite can also occur in the absence of water, usually as the result of volcanic activity (Morgenthau, Mengo L (1923)).

III. Goethite

It is a ferric iron-containing compound composed of iron oxy-hydroxide. It has Primary of iron ore constituent of corrosion and marsh. Goethite's toughness ranges from 4.9 to 5.5 the Mohs' scale, and its density differ from 3.2 to 4.3. The mineral forms elongated needle shaped structures (Hurlbut, Cornelius S Klein, Cornelis (1985)) but is typically found in massive form (Barthelmy and David (2012), Anthony, John W. Bideaux and Richard et.al 2022). Goethite has various polymorphs that form under highpressure and high-temperature conditions, which perhaps importance to the conditions within the Earth. It include ε-FeOOH, which possesses an orthorhombic mineral structure, cubic pyrite-type polymorph with or without losing hydrogen (Suzuki, Akio (2010).An ultra-dense hexagonal structure (Nishi, Masayuki, Kuwayama and Yasuhiro et.al (2017)).

Goethite possesses the identical crystal arrangement, the corresponding aluminum oxidehydroxide mineral. Hexagonal shape of oxygen and hydroxide ions is close-packed arrangement, between iron ions occupying octahedral positions. The positions occupied by iron ions create interconnected chains that extend throughout the crystal, with the couple chains in each pair linked by hydroxide ions (Zhang, Li Yuan, Hongsheng, Meng, Yue, Mao and Ho-kwang (2017).

IV. Siderite

It is a valuable mineral which composed of iron carbonate (Fe(II) CO_3), as it contains 48% iron and does not contain sulfur, phosphorus, zinc, and manganese. Magnesium often substitute for the iron, resulting in the formation of siderite-smithsonite (www.mindat.org, Retrieved 2022-11-30). In sedimentary rocks, siderite frequently develops at shallow depths and its elemental makeup is often linked to the depositional setting of the surrounding sediments (Mozley, P.S., (1989).

It is frequently discovered in fissure of hydrothermal deposits, and is connected with fluorite, galena, barite and additional minerals. It is also a prevalent digenetic mineral in shale and sandstones, where it occasionally creates concretions, which can envelop fossils that are preserved in three dimensions (Russell Garwood, Jason A. Dunlop & Mark D. Sutton (2009)). It has a toughness of 3-4 on the Mohs scale, 3.96 is a specific gravity, and a vitreous or pearly luster and it exhibits anti-ferromagnetic properties below its temperature of 37 K (Frederichs, T et.al (January 2003)).

V. Limonite

It is a type of iron ore composed of a mixture of with water iron (III) oxide-hydroxides in different compositions. The general formula is often written as $FeO(OH)\cdot nH_2O$, but this is not completely accurate as the proportion of hydroxide to oxide can vary greatly. Limonite is one of the three main iron ores, along with hematite and magnetite, and has been extracted for iron production (MacEachern, Scott (1996) Diop-Maes and Louise Marie (1996)).

Limonite is comparatively massive with a specific gravity that ranges from 2.6 to 4.3 (Northrop and Stuart A. (1959)). It typically has a medium to dark yellowish brown color. The toughness varies significantly, ranging from less than 5. In thin sections, it occurs as red, yellow and brown and has a high refractive index between 2 - 2.4. Limonite minerals exhibit strong birefringence, although the grain sizes are often too small to be detectable (Nesse, William D. (2000))

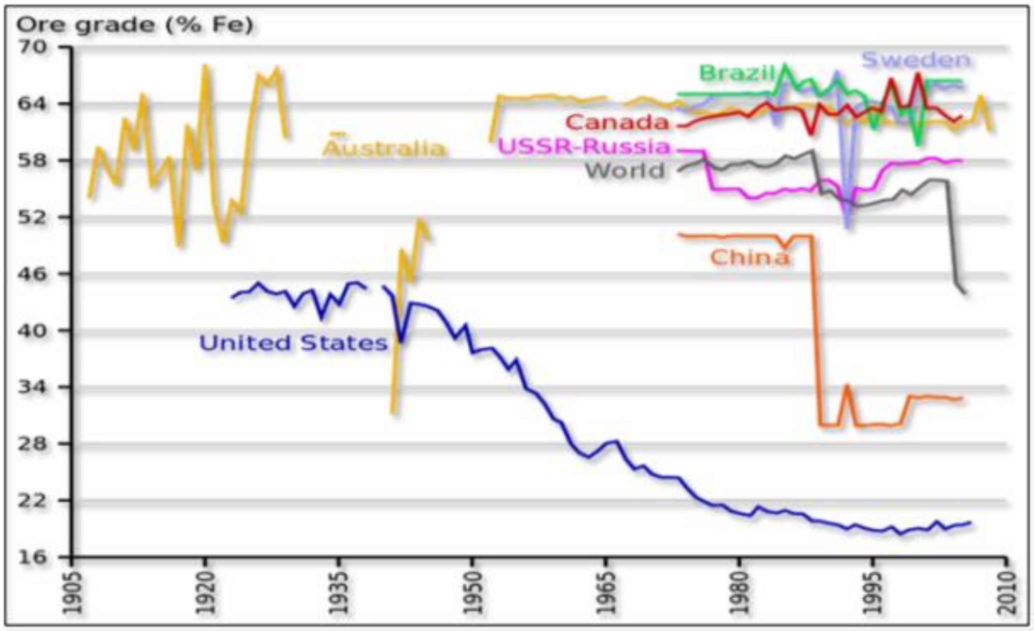


Figure 3: World ore grade and its consumption (source: Gavin M.Mudd, 2010)

2.1. Beneficiation of iron

Most iron ore operations that require improvement of run of mine ore to make solid, fine, and pelletizing concentrate iron ore products will sack a sludge fraction to final waste. This fraction can vary in particle size from –200 µm down to –10 µm. The common understanding is that this portion is of inferior quality in regards to the iron ore mineral content and includes a notable amount of substances that are detrimental to iron ore such as silica, sulphur, alumina, phosphorus, and so on. Nevertheless, one must exercise great care when evaluating the retrieval of fine iron ore, as it is crucial to verify the accuracy of this belief, or else valuable chances will be overlooked (Williams, P.J et.al).

Gravity, magnetic, and flotation separation method are the most accepted technologies for beneficiate fine iron ore particles but the processes lead to iron concentrates with significant quantities of extremely small and/or intertwined gangue particles (Sandvik and Rein, 1997). Magnetic separation is commonly employed to separate natural magnetic iron ore (magnetite) from a range of less magnetic or nonmagnetic substances. Throughout the process of magnetic separation, a significant portion of the iron units being processed are lost to tailings due to the weak magnetic properties of hematite. Magnetic separation can be conducted in either a dry or wet environment, with wet systems being more prevalent. The magnetic separation of iron ores can be divided into low or high intensity methods.

The gravity concentration is largely being utilized in the upgrading of hematite iron ores. These methods are employed to suspend and transport lighter gangue away from the heavier valuable mineral. These separation processes are primarily based on disparities in the specific gravities of the materials and the size of the particles being segregated. Impurities can be eliminated together with the waste material (tailings) even if there are differences in density, as long as the sizes of the particles differ.

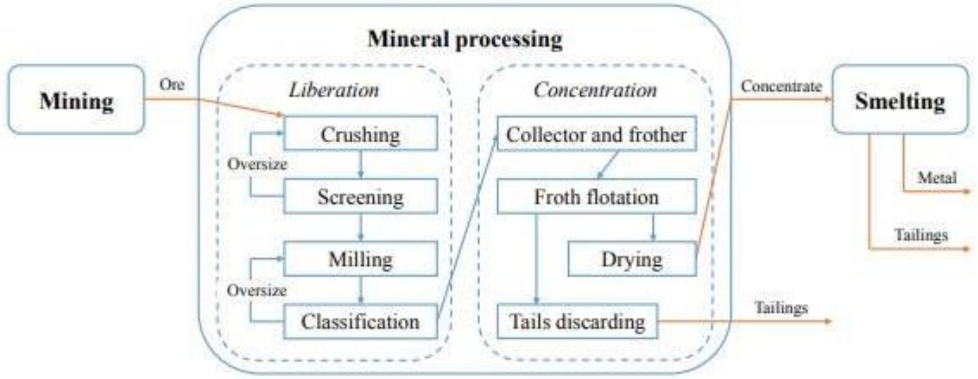


Figure 4: mineral processing scheme (source: Williams, P.J ,et.al)

2.1.1. The Flotation Method

Flotation is largely utilized as the primary beneficiation technique for non-magnetic iron ores, and is frequently employed for further upgrading magnetic iron ores as well (Araujo, Viana and Peres 2005, Nakhaei and Irannajad 2018). Reverse flotation has been utilized for over a century; its development has had a significant impact on the mineral industry (Fuerstenau et al., 2007). Furthermore, flotation has been implemented in other domains such as de-inking of recycled paper and wastewater treatment. Flotation can be categorized into two general pathways: direct flotation and reverse flotation. The primary distinction between these two pathways is the manner in which the valuable product is retrieved. In direct flotation, the valuable iron material is retrieved in the froth product whereas in reverse flotation, it is retrieved in the sinks or underflow product.

2.1.3 Hydrophobicity

The basis of foam flotation is the variation in wettability of distinct minerals. Particles range from those that are easily contactable by water (hydrophilic) to those that are water-repellent (hydrophobic). If a mixture of water-repellent and water-loving particles are suspended in water, and air is bubbled through the suspension, then the water-repellent particles will tend to attach to the air bubbles and rise to the surface. The foam layer that forms on the surface will then be heavily loaded with the water-repellent mineral, and can be extracted as a separate product. The water-loving particles will have a much lower tendency to adhere to air bubbles, and therefore they will remain in suspension and be washed away (Whelan and Brown, 1956).

2.2. Reagents

characteristics of unprocessed mineral combinations held in clear water are seldom appropriate for flotation. Substances are necessary to regulate the process in reverse flotation, where appropriate agents cause the valuable minerals to become attracted to water and the worthless minerals to become repelled by water. Aeration is introduced through spargers positioned at the base of the flotation tank, both to disperse the particles and to uphold the suitable froth properties. Consequently, there are numerous diverse substances engaged in the reverse flotation procedure, with the choice of agents relying on the particular mineral combinations being processed.

A. Collectors

collectors are such a type of organic or inorganic chemical that selectively attaches to the surface of the minerals and water repelling nature to the particles, a very effective factor for the adhesion of mineral particles to the air bubble. There are three type of collector; nonionic, anionic and cationic.

Non-Ionic collectors: These are used to increase the hate of natural water of those minerals which have smaller strength faom such as coal. These are hydrocarbon oils which done by selective adsorption of oils by the minerals.

Anionic collectors: These collectors conten of a non-polar and an ionic portion in the anionic part of the compound while the cationic has no significant function enhancement of hydrophobic nature.Those anionic collectors be used for the separation of ores of alkali metals and alkaline earth metals like, magnesium, barium, calcium, strontium etc.

Cationic collectors: these collectors, the cationic portion of the compound plays a very relevant task in increasing the surface properties of the mineral. The ionic part is generally the nitrogen of the compound amines. They undergo physisorption and get bonded to the mineral through electrostatic force of attraction. Due to this reason these cationic collectors have low adhesive force.

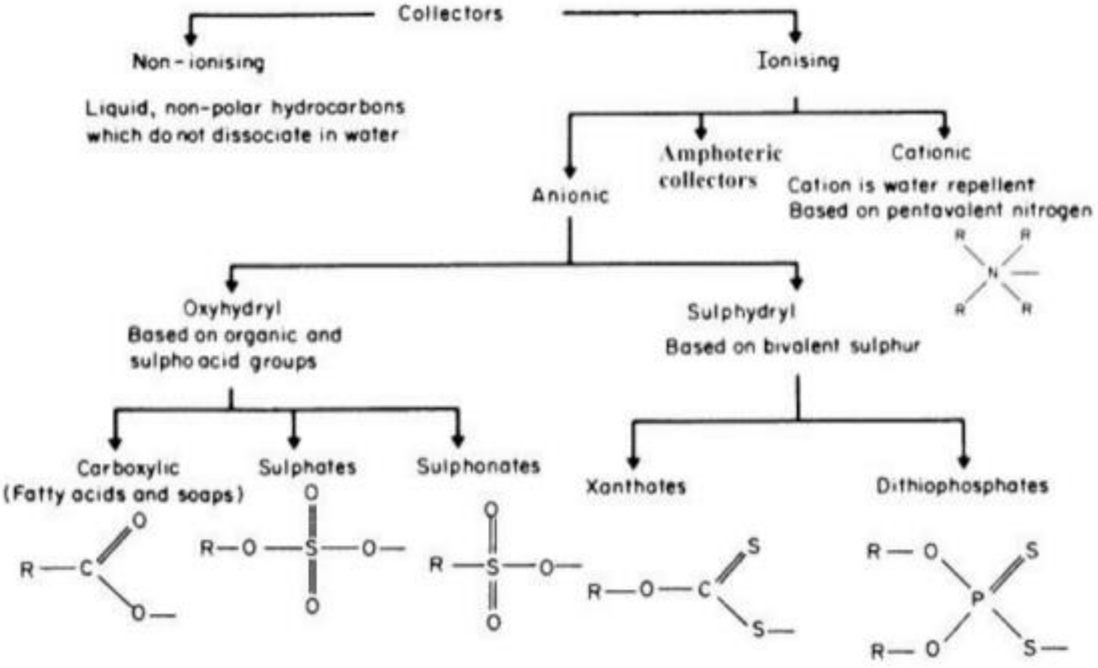


Figure 5 : ionizing and non-ionizing collector (source: Williams and P.J ,et.al)

B. Frother

These are the set of substances that aid in the stabilization of the foam. In addition to stabilizing the bubbles, they also assist in the efficient elimination of foam and segregation of waste materials. The preferred characteristics of a commonly frother which it should have the ability to generate foam for the purpose of mineral separation. They should readily dissolve in water with a reasonable level of uniformity. The most frequently utilized frothers are generally compounds containing an amino group carbonyl group, carboxyl group and hydroxyl group. Frothers based on alcohol are considered the superior type of frother. Therefore, iron is naturally placed under this category of frother.

C. Activators

These activators are mineral surface towards the action of the Collectors, by improving their chemical properties. Therefore, they are often called friendly for collectors. Generally, they are easily ionizing able to soluble salts that react with the mineral surface.

D. Deactivators (Depressants)

These are deactivating the mineral surface towards the action of Collectors, by changing their chemical properties. Hence, they are also called the enemies of the Collectors. They increase the Selectivity of flotation, by controlling one mineral from flotation while allowing another mineral to float unrestricted. It can be classified into two categories; Inorganic depressants and Organic depressants

E. PH Modifiers

It is also a very important factor in the process of floatation. Even a slight change in the pH of the slurry can result in loss of productivity and efficiency of the operation. Thus to ensure the optimum use of the resources and production is maximum pH modifiers are used. Lime, Sodium carbonate, Sodium hydroxide and Ammonia are often used to maintain the basic nature of the slurry.

2.3 Trace Elements

The incorporation of even minor quantities of certain elements can have significant impacts on the behavioral traits of iron or the functioning of a smelter. These impacts can be either positive or negative, with some being extremely detrimental. Certain substances are intentionally added, such as flux, to enhance the efficiency of a blast furnace. Others are added to make the iron more malleable, tougher, or to provide it with other desirable characteristics. The selection of ore, fuel, and flux determines how the slag behaves and the operational traits of the iron produced. Ideally, iron ore should only consist of iron and oxygen. However, in reality, this is seldom the case. Typically, iron ore contains various elements that are often undesirable in modern steel.

2.3.1 Phosphorus

Phosphorus (P) has four main impacts on iron: increased toughness and strength, lower melting point, increased fluidity, and brittleness at low temperatures. Depending on the intended use of the iron, these effects can be either positive or negative. Bog ore often contains high levels of phosphorus (Gordon 1996, p.57). The strength and toughness of iron are enhanced with the presence of phosphorus. A concentration of 0.05% phosphorus in wrought iron makes it as tough as medium carbon steel. Cold hammering can also harden high-phosphorus iron. This hardening effect applies to any amount of phosphorus. The higher the phosphorus content, the harder the iron becomes and the more it can be hardened through hammering. Modern steel manufacturers can increase hardness by up to 30% while still maintaining shock resistance by keeping phosphorus levels between 0.07 and 0.12%.

2.3.2 Aluminum

Small quantities of aluminum (Al) can be found in various minerals such as iron ore, sand, and certain types of limestone. The former can be eliminated by rinsing the mineral before the process of melting. Prior to the use of brick-lined furnaces, the level of aluminum impurity was insignificant, and it did not impact the quality of either the iron or slag. However, when brick started being utilized for hearth construction and the internal lining of blast furnaces, the level of aluminum contamination significantly increased.

2.3.3 Sulfur

Sulphur (S) is a common impurity in coal. It is also found in small amounts in many ores, but can be eliminated by calcination. Sulphur readily dissolves in both molten and solid iron at the temperatures found in iron smelting. The consequences of even minor quantities of sulphur are immediate and severe. They were one of the initial discovered by iron manufacturers. Sulphur leads to iron becoming red or hot short. (Gordon 1996, p. 7)

CHAPTER THREE

3. Materials and methods

3.1Materials and Site

The specified region under examination is situated in the Sekota, Abergele, and Waghimra Administrative zone of the Amhara National Regional State. Sekota city is situated at a distance of 720 kilometers to the north of Addis Ababa and 430 kilometers to the north of Bahir Dar. The route from Addis Ababa to Sekota city passes through Dese-Weldieya and Gashena-Lalibela. From Sekota, the research site is located 50 kilometers to the north, and the road leading to it is an unpaved road. The AKY-B blocks of Akme Yohanis are positioned in the northeastern direction of Sekota city, approximately 8 kilometers away.

Figure 6: sample location map at Akim Yehanse

3.2 Sample preparation

Representative samples weight was (2kg). The sample was liberated (crushed and grinding) to passing particle size distribution was -0.0074mm (-200 mesh) of 250 g.

3.3 chemicals reverse iron flotation

In this study of beneficiation of iron was taken different reagents such that oleic acid as collector, ethanol of frother, pH of NaOH, calcium chloride, and calcium oxide.

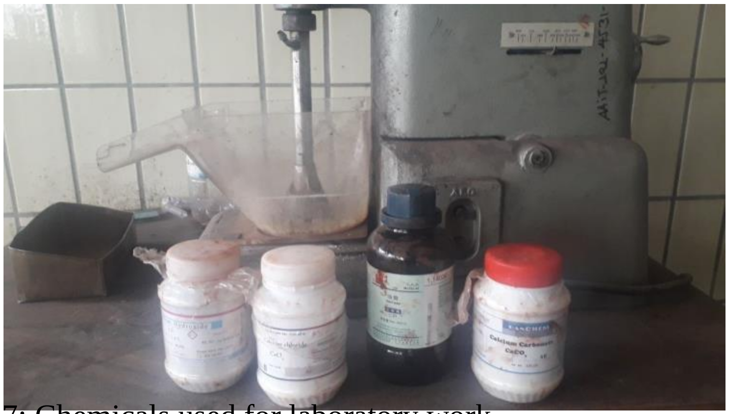


Figure 7: Chemicals used for laboratory work

3.4 Reverse Flotation

A quantity of samples (mass 250g) was added into the container (pulp density (%) by weight), in which 3L of volume water was filled later. The oleic acid collector was obtained from commercial sources and laboratory grade causticized depressant was obtained from commercial sources. Sodium hydroxide (NaOH) obtained from commercial were used to adjust the pH. Tap water 3L was obtained from in the laboratory. A depressant solution was prepared by adding depressant 5mg of NaOH in a 3L beaker. To that solution, 5mg solution was added and the solution was stirred The slurry was agitated for time at a stirring speed of in 1850 rpm before adding a solution to adjust pulp pH to a specific value. Reagent (oalic acid, calcium chloride, ethanol, caO) were added into the container with a 2 minute interval continually. The suspension was agitated for with that 5 minute after adding all the desired amount of reagents, and the flotation separation was conducted for different minute.

Figure 8: a, b and c show flotation of hematite ore and.

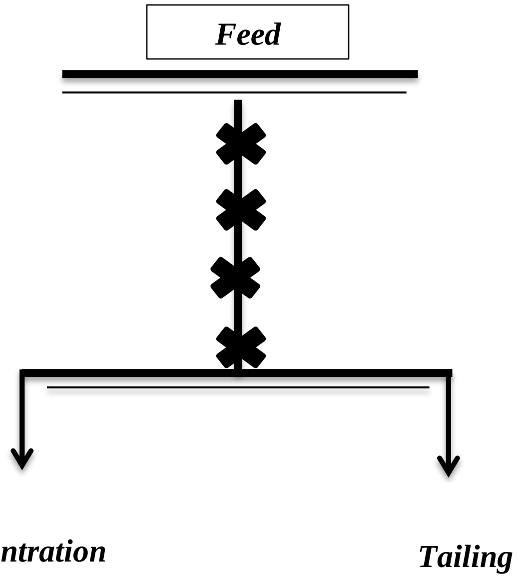


Figure 9: the flow sheet of flotation condition experiments was presented.

3.5 Characterization

Iron sample was chemically examined using full silicate. Mineralogical investigations conducted on the sample included quantitative silicate and these investigations would offer elemental distribution, mineral releases and connections as well as particle size distribution for Fe-containing stages (-0.0074mm at 250 gm). Moreover, elemental examinations included trace element supplying elemental compositions for the bearing phases and silicate phases. The samples were tested for Major minerals by quantitative AAS.

Figure 10 : an instrument for complete silicate (AAS)

3.6 Performance Calculations

There are various useful approaches for analyzing froth flotation processes; however there is no one method that can be used to indicate the effectiveness of a separation:

(a) **Concentration Ratio,** mass of the feed in relation to the mass of the concentrate, or ratio of concentration F/C, where C is the total mass of the concentrate and F is the total mass of the feed, is the ratio of concentration. Even while lab tests can provide this information, it's likely that in the facility the ore is not measured and only analyses will be available

Ratio of Concentration (k) = F/C ………………………………………………. Eq.1

(b) **Metal Recovery(R)**, of the metal recovered from the original feed that was it's the concentrate. Weights and assays can be used to calculate this, as

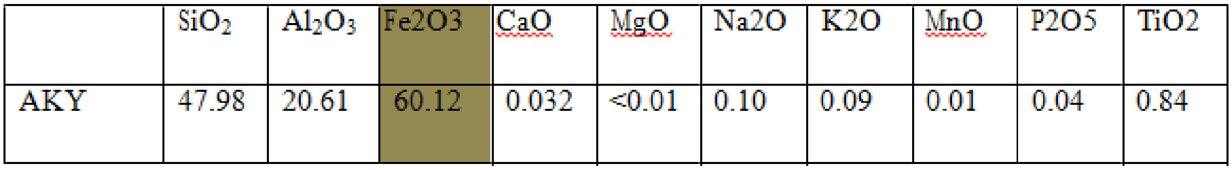
R = 100 c/Kf ………………………………………………………………Eq.2

(c) **Metal Loss** is the opposite of the metal recovery, and represents the material lost to the tailings

CHAPTER FOUR

4. Result and Discussion

The data was obtained in chemical analysis of hematite ores with complete silicate (AAS) technique in geological survey laboratory and Sekota geological document.



	SiO_2	Al_2O_3	Fe2O3	CaO	MgO	Na2O	K2O	MnO	P2O5	TiO2
AKY	47.98	20.61	60.12	0.032	<0.01	0.10	0.09	0.01	0.04	0.84

Time(min)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na2O	K2O	MnO	P2O5	TiO2
5min	29.38	19.68	45.84	<0.01	0.01	0.16	<0.01	0.04	0.05	<0.01
12min	29.38	17.88	48.00	<0.01	0.01	0.48	<0.01	0.08	0.09	<0.01
19min	34.06	9.36	48.99	<0.01	0.06	0.48	<0.01	<0.01	0.18	<0.01

Table 1: complete silicate result of feed and time respectively.

Figure 11, demonstrates the concentrates' reverse flotation outcome. It means that all reverse flotation is true. to achieve a decrease in grade of up to 38.66%. This calculation was made using the iron composition obtained from the AAS analysis, as shown in table 5. The composition of the hematite ore sample consists mainly of which are the main gangue. Additionally, small impurities such as hematite are also present, as show in this study, as depicted in figure 16. The optimal time to obtain a good grade is 12 minutes.

Time (min)	Weight (%)	Grade (%)	Recovery (%)
5min	60	40	42.31
12min	60	40	44.30
19min	58	38.66	45.22

Table 2: relationship grade and recovery

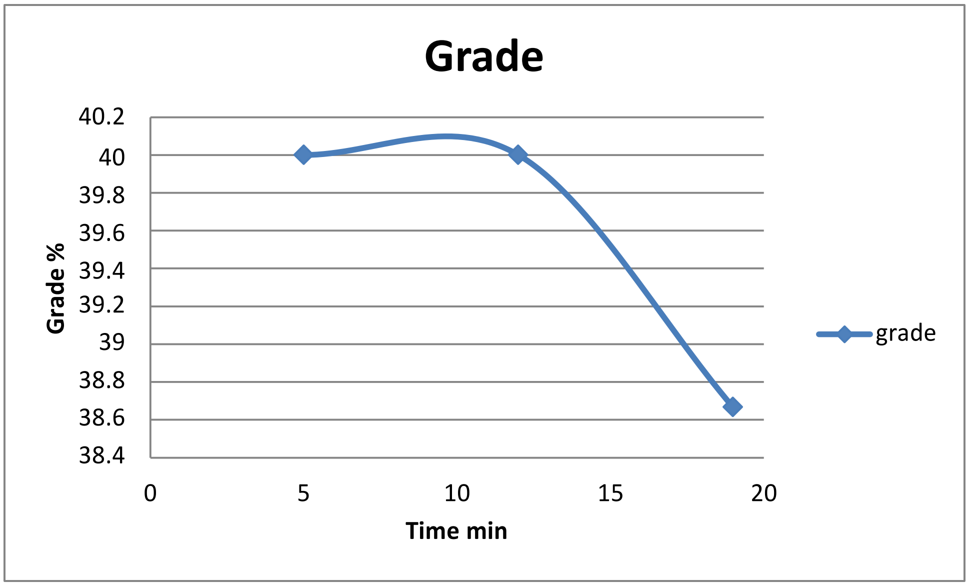


Figure 11: Grade and time relation

Figure 12, demonstrates the concentrates' reverse flotation, It suggests all opposite method tests outcome boosted the extraction till 45% at duration of 19 minutes, as determined using the iron content obtained from the AAS examination displayed in table 5. The concentration of hematite in the concentrate improved with longer durations. Conversely, the concentration of silica in the concentrate declined with longer durations. The prolonged duration in the flotation cell restricts the movement of particles, resulting in increased interaction between solid particles and the reagents.

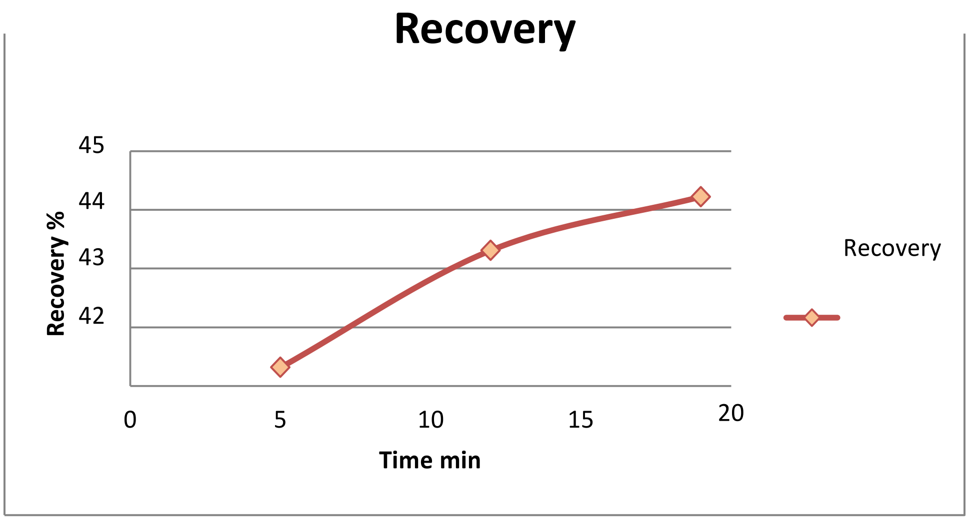


Figure 12: Recovery respect with time

Figure 13, demonstrates the concentrates' reverse flotation shows the result of reverse flotation in the concentrates time is one effect on grade and recovery percentage. It suggests that all reverse flotation experiments demonstrated an increase in recovery. The duration of 19 minutes was determined based on the iron composition obtained from the AAS analysis presented in table 5, which showed a decrease in grade. By increasing the time, there was an improvement in the recovery of hematite in the concentrate. However, the recovery of silica in the concentrate decreased with increasing time. A longer duration in the flotation cell reduces the particles, leading to increased relation of solid particles and chemicals. Therefore, this project indicates that the optimum recovery is achieved at 19 minutes with a grade of 45%. However, the best time for achieving good grade and recovery is 12 minutes, with a grade of 40% and a recovery of 45% respectively.

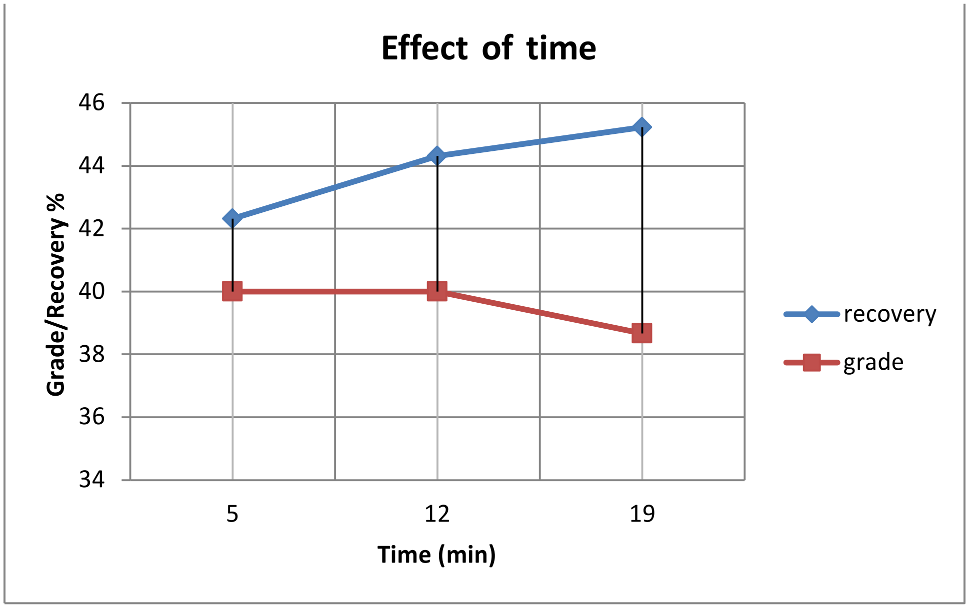


Figure 13: Recovery and grade effect on time

Collector (g/ton)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na2O	K2O	MnO	P2O5	TiO2
1	43.64	4.54	34.29	2.24	<0.01	<0.01	1.32	<0.01	0.14	0.37
2	44.74	5.36	43.64	1.64	<0.01	<0.01	1.24	<0.01	0.15	0.27
3	34.29	10.7	44.74	0.94	0.05	0.06	0.70	<0.01	0.59	0.387

Table 3: complete silicate of collector result

Figure 14, demonstrates the concentrates' reverse flotation shows. It suggests that reverse flotation tests reduce the quality by up to 39.16%. The amount of collector used, which was determined by analyzing the iron content using AAS (as shown in table 4), was 3g/ton. The AAS patterns of the standard feed indicate that the iron sample contains the gangues. Increasing the amount of collector causes the gangue to separate more easily, but it also results in some minerals being sent to the tailings. Additionally, minor impurities such as hematite can be observed in the peaks.

Collector (g/ton)	Weight (%)	Grade (%)	Recovery (%)
1g/ton	62	42.17	31.65
2g/ton	64	40.97	40.28
3g/ton	60	39.16	41.29

Table 4: relationship scheme of grade and recovery

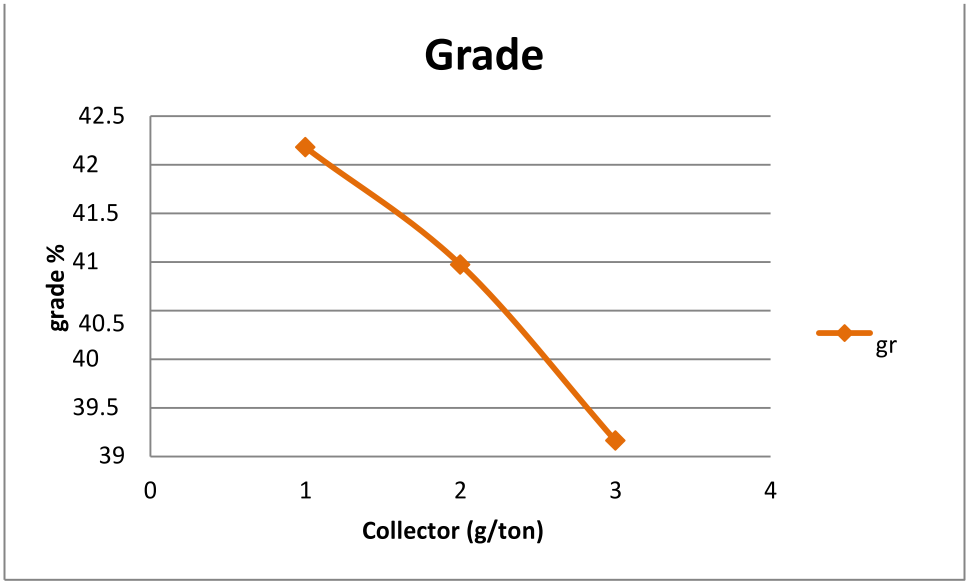


Figure 14: grade and collector

Figure 15, demonstrates the concentrates' reverse flotation shows. It indicates that reverse Flotation increased the recovery till 41.29%. The collector of 3g/ton was findout based on the iron content of resulted from the AAS analysis show on table 6. Based on Fig. 15, there was an improvement of hematite retrieval in the concentrate by extending the duration. Conversely, the silica retrieval in concentrate declined as the duration increased, a greater quantity of solids in the flotation cell will reduce the mobility of particles, thereby enhancing the interaction between solid particles and the chemicals.

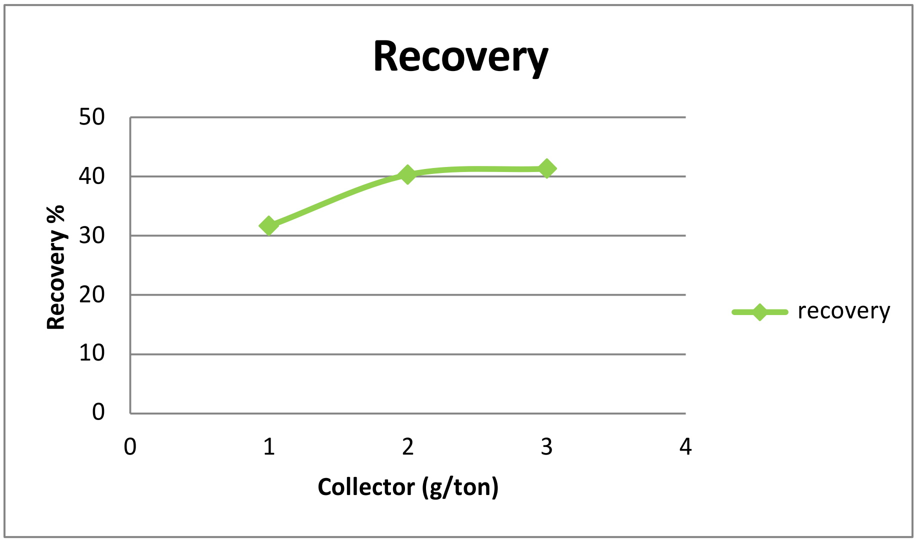


Figure 15: recovery and collector

Based on Fig. 16, utilizing substantial percentages of allows for the efficient separation of concentrate from tailing 1g/ton to 3 g/ton in the flotation cell. The use of 3g/ton solids resulted in iron in the concentrates of 40.29%.

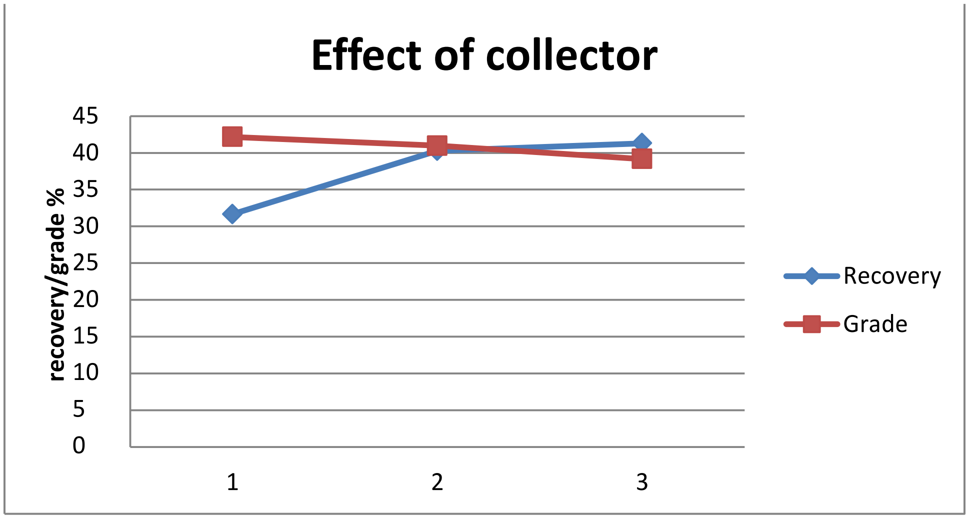


Figure 16: interactions scheme grade and recovery with collectors.

Figures 14 - 26 the results from 1, 2 and 3 grams per ton using oleic acid as a collector are shown. The greatest level of selectivity was attained at a consistent pH of 10.5, where the amount of 3 grams per ton in the concentrate was 41.2%. Because the reverse flotation process operated with the activation of the collector in the form of cationic ions and the reactive silica surfaced in the form of anionic ions, the connection between oleic acid and reactive silica can occur through electrostatic effects or hydrogen bonding to become hydrophobic. The influence of the collector on the flotation process was evaluated during the reverse flotation of silica, where the variations in surface charge between reactive silica and aluminum are crucial in the mechanism of collector adsorption. The findings demonstrate that successful separation was achieved with varying time and collector concentration of 3 grams per ton of hematite ores, with gangue in the concentrate being less than 50% and the remaining percentage present in the tailings.

CHAPTER FIVE

Conclusion and recommendation

5.1 Conclusion

The analysis carried out by the AAS demonstrated that performing reverse flotation experiments in this investigation yielded higher recovery rates. Specifically, the hematite recovery ranged from 31% to 42% and 42.3% to 45.2% when altering the duration and collector, respectively. Elevating the duration and collector in the input slurry resulted in improved recovery rates for both iron and gangues in the concentrate. Utilizing 3ml/ton collector yielded recovery rates exceeding 30%. The optimum condition was achieved at duration of 19 minutes. Examination of the input ores using AAS indicated the presence of gibbsite, kaolinite, quartz, and hematite. It was observed that the concentrate contained similar minerals, albeit in smaller quantities or as trace amounts. To tackle these concerns, it is imperative to beneficiate the low grade iron ore in order to decrease the gangue minerals and enhance the grade. The addition of oleic acid as a collector had a significant impact on the flotation response of hematite in the rougher flotation. The reconstructed recovery-time curve for the combined products was higher than that of the rougher tailings used as scavenger feed. Increasing the quantity of collectors (oleic acid) in the feed resulted in a 41.29% increase in hematite recovery. Similarly, increasing the flotation duration in the feed led to a 45.22% increase in hematite recovery.

5.2 Recommendation

The current project work shows promising outcomes in utilizing the country's potential resources to boost its economy. However, it is recommended to conduct further research on how to convert these resources into usable products. There is a significant gap in studying the Sekota iron ore deposit area and the country as a whole. Therefore, a more comprehensive and scientific approach is necessary to fully understand the processing techniques and effective management of waste mineral disposals. The aforementioned results are insufficient to confidently determine the gangue present, so it is recommended to employ additional methods such as X-ray diffraction (XRD), scanning electron microscope (SEM), and X-ray fluorescence (XRF) methods to gain a complete understanding of the qualitative and quantitative mineral compositions.

Reference

1. Anthony, John W. Bideaux, Richard A ,Bladh, Kenneth W, Nichols, Monte C. (2005). "Goethite" (PDF). Hand book of Mineralogy and Mineral Data Publishing. Archived (PDF) from the original on 2022-10-09,Retrieved 14 March 2022.
2. Du Trémolet de Lacheisseri e, Étienne; Damien Gignoux; Michel Schlenker (2005). Magnetism: Fundamentals, Springer. pp. 3–6.ISBN 0-387-22967-1.
3. Das S.K, Kumar, Sanjay, Ramachandrarao. P (December 2000). "Exploitation of iron ore tailing for the development of ceramic tiles" Waste Management 20 (8): 725–729. doi:10.1016/S0956-053X(00)00034-9.
4. "Discovery of a hexagonal ultra- dense hydrous phase in (Fe,Al)OOH" Proceedings of the National Academy of Sciences of the United States of America. 547 (12): 205–208. doi:10.1073/pnas.1720510115. PMC 5866593. PMID 29507221.
5. Frederichs, T., von Dobeneck, T.; Bleil, U., Dekkers, M.J. (January 2003)."Towards the identification of siderite, rhodochrosite, and vivianite in sediments by their low-temperature magnetic properties" Physics and Chemistry of the Earth, Parts A/B/C. 28 (16–19): 669–679. Bibcode: 2003PCE....28.669F. doi :10.1016/S1474-7065(03)00121-9.
6. Guijón, R.; Henríquez, F.; Naranjo, J.A. (2011). "Geological, Geographical and Legal Considerations for the Conservation of Unique Iron Oxide and Sulphur Flows at El Laco and Lastarria Volcanic Complexes, Central Andes, Northern Chile". Geoheritage. 3 (4): 99–315. doi:10.1007/s12371-011-0045-x,S2CID 129179725.
7. Graphic from The "Limits to Growth" and 'Finite' Mineral Resources, p. 5, Gavin M. Mudd Suzuki, Akio (2010) "High-pressure X-ray diffraction study of ε-FeOOH" Physics and Chemistry of Minerals. 37 (3):153–157. Bibcode:2010PCM....37..153S. doi:10.1007/s00269-009-0319-x. S2CID 92941002.
8. “Global Fe–O isotope correlation reveals magmatic origin of Kiruna-type apatite-iron-oxide ores" doi:10.1038/s41467-019-09244-4, ISSN 2041-1723.
9. Hurlbut, Cornelius Searle,W. Edwin Sharp, Edward Salisbury Dana (1998). Dana's minerals and how to study them, John Wiley and Sons. pp. 96. ISBN 978-0-471-15677-2.
10. Hu, Qingyang; Kim, Duckyoung; Yang, Wenge; Liuxiang, Yang; Yue, Meng; Zhang, Li; Mao, Ho-kwang (2016)."FeO_2 and FeOOH under deep lower-mantle conditions and Earth's oxygen–hydrogencycles". Nature. 534 (7606):241,244. Bibcode:2016Natur.534..241H. doi:10.1038/nature18018. PMID 27279220.

11. Harrison, R. J.; Dunin-Borkowski, RE; Putnis, A (2002). "Direct imaging of Nano-scale magnetic interactions in minerals" Proceedings of the National Academy of Sciences. 99 (26): 16556–16561. Bibcode:2002PNAS...9916556H. doi:10.1073/pnas.262514499. PMC 139182. PMID 124 82930.
12. Hurlbut, Cornelius S.; Klein, Cornelis (1985). Manual of Mineralogy (20th ed.). Wiley. ISBN 0-471-80580-7.Barthelmy, David (2012). "Goethite Mineral Data". Mineralogy Database. Retrieved 8 April 2022.
13. Hu, Qingyang; Kim, Duckyoung; Yang, Wenge; Liuxiang, Yang; Yue, Meng; Zhang, Li; Mao, Ho-kwang (2016). "FeO2 and FeOOH under deep lower-mantle conditions and Earth's oxygen hydrogen
cycles".Nature. 534 (7606):241,244. Bibcode:2016Natur.534..241H. doi:10.1038/nature18018. P MID 27279220
14. Iron ore pricing emerges from Stone Age, Financial Times, October 26, 2009 Archived 2011-03-22 at the Way back Machine.
15. J. Pease, "Increasing the energy efficiency of grinding". Presented at *Crushing and Grinding, Brisbane, September 2007*. Accessed 24 May 2013.
16. Li,Chao; Sun, Henghu; Bai, Jing; Li, Longtu (2010-02-15)."Innovative methodology for comprehensive utilization of iron ore tailings: Part 1.The recovery of iron from iron ore tailings using magnetic separation after magnetizing roasting".Journal of Hazardous Materials. 174 (1–3): 77. doi:10.1016/j.jhazmat.2009.09.018. PMID 19782467.
17. Ludvigson, G.A., Gonzalez, L.A., Metzger, R.A., Witzke, B.J., Brenner, R.L., Murillo, A.P., and White, T.S., 1998, Meteoric sphaero-siderite lines and their use for paleohydrology and paleoclimatology: Geology, v. 26, p. 1039-1042.
18. Morgenthau, Mengo L. (1923). Minerals and Cut Stones: Reference Book Containing Condensed and Simplified Descriptions from Standard Works on Mineralogy"Iron Ore – Hematite, Magnetite & Taconite". Mineral Information Institute. Archived from the original on 17 April 2006. Retrieved 7 April, 2006.
19. Mozley, P.S., 1989, Relation between depositional environment and the elemental composition of early diagenetic siderite: Geology, v. 17, p. 704- 706.
20. Northrop, Stuart A. (1959) "Limonite" Minerals of New Mexico (revised edition) University of New Mexico Press, Albuquerque, New Mexico, pp. 329–333, OCLC 2753195.
21. Nesse, William D. (2000). Introduction to mineralogy New York: Oxford University Press. pp. 371–372. ISBN 9780195106916

22. Nishi, Masayuki; Kuwayama, Yasuhiro; Tsuchiya, Jun; Tsuchiya, Taku (2017)"The pyrite-type high-pressure form of ε-FeOOH"Nature.
23. Nishi, Masayuki, Kuwayama, Yasuhiro, Tsuchiya, Jun, Tsuchiya, Taku (2017)."The pyrite-type highpressureformofεFeOOH".Nature, 547 (7662):205,208, Bibcode:2017Natur.547.205N. doi:10. 1038/nature22823. PMID 28678774,S2CID 205257075.Ramanaidou and Wells, 2014.
24. Sirkeci, A. A.; Gül, A.; Bulut, G.; Arslan, F.; Onal, G.; Yuce, A. E. (April 2006)"Recovery of Co, Ni, and Cu from the tailings of Divrigi Iron Ore Concentrator" Mineral Processing and ExtractiveMetallurgyReview. 27 (2):131,141. Bibcode:2006MPEMR.27.131S. doi:10.1080/0882 7500600563343,ISSN 0882-7508. S2CID 93632258.
25. Suzuki, Akio (2010),"High-pressure X-ray diffraction study of ε-FeOOH". Physics and Chemistry of Minerals. 37 (3): 153–157. Bibcode:2010PCM....37..153S. doi:10.1007/s00269-009-0319-x. S2CID 92941002.
26. Troll, Valentin R.; Weis, Franz A.; Jonsson, Erik; Andersson, Ulf B.; Majidi, Seyed Afshin; Högdahl, Karin; Harris, Chris; Millet, Marc-Alban; Chinnasamy, Sakthi Saravanan; Kooijman, Ellen; Nilsson, Katarina P. (2019-04-12).
27. Wasilewski, Peter; Günther Kletetschka (1999). "Lodestone: Nature's only permanent magnet - What it is and how it gets charged". Geophysical Research Letters. 26 (15): 2275–78. Bibcode:1999GeoRL..26.2275W. doi:10.1029/1999GL900496. S2CID 128699936.
28. Zhang,Li, Yuan, Hongsheng, Meng, Yue; Mao, Ho-kwang (2017). "Discovery of a hexagonal ultradense hydrous phase in (Fe,Al)OOH" Proceedings of the National Academy of Sciences of the United States of America. 547 (12): 205–208. doi:10.1073/pnas.1720510115. PMC 5866593, PMID 29507221.