



Literature review on the use of natural products in the flotation of iron oxide ores



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ABSTRACT

The use of natural products is essential in the processing of iron oxide ores by flotation. It is the purpose of this review to trace the historic development of the use of some natural products in the processing of iron oxide ores. The reagents used for floating either iron oxides or activated silica are usually derived from vegetable origin, frequently from wood products containing primarily unsaturated carboxylic acids. In the reverse flotation of iron ores, the iron oxides are often depressed using polysaccharides, with various starches being extensively used. Hematite depression is usually conducted at high values of pH, and cationic surfactants are generally used to float off the silica. It is through the previous research and development of natural products that global commercial processing of iron oxide ores by flotation is economically viable, and the only method for treating fine grained iron ores. There are also some reports of the use of bacteria to modify the surfaces of the hematite leading either to its flotation or depression, but this has not been adopted at industrial scale as yet.

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1. Introduction

The successful processing of iron oxide ores by flotation requires a number of reagents, and many of these are derived from natural products. These generally fall into two main categories: use of products from vegetable or marine oils as flotation frothers or collectors, and the use of polysaccharides, tannin, quebracho, starches or guar gums as depressants. It is very difficult to decide which reagents to include and which ones to omit. This is because most of the reagents used in the processing of iron oxide ores can be derived from natural products.

The main characterisation used for the fatty acids was their Iodine Value (I.V.), which is related to their degree of unsaturation. Fully saturated fatty acids have a low I.V., usually < 1. I.Vs. for the mono-unsaturated oleic acid are normally around 90, with the value for linoleic acid, with its two double bonds per molecule, being around 180. The I.V. is the mass of iodine consumed by 100 g of a substance.

An example to illustrate this is the use of a product marketed by the Ajax Chemical Company as “sodium stearate”, but containing 25.6% palmitic acid, 19.8% stearic acid and 36.8% oleic acid, with an I.V. of 42. This “sodium stearate” was used by the author in a recent publication on the use of conditioning time to investigate the mechanisms of interactions of selected fatty acids on hematite (Quast, 2015). Although this is marketed as a laboratory chemical, to all intents and purposes it is a product formed by the saponification of tallow, which is a product derived from a natural feedstock. Quast (2015) showed how the flotation recovery of hematite using this sodium “tallowate” was much more susceptible to extended conditioning time compared to oleic acid containing 66.9% oleic acid. Flotation test work was conducted on mineral samples using a laboratory flotation machine. Hematite flotation data, previously published by the author (Quast, 1999a) using a sodium tallowate from BDH containing 22.3% palmitic acid, 16.8% stearic acid and 35% oleic acid and an I.V. of 49.4, showed similar flotation characteristics to a purer oleic acid sample for both single mineral and selective hematite flotation on a hematite-quartz ore except that higher additions of the mixed sodium salt were required to achieve similar metallurgical performance compared to the purer oleic acid. Adsorption isotherm measurements of the BDH sodium tallowate on hematite at pH 7 have also been published by the author (Quast, 2010) using differential thermal analysis on conditioned, concentrate and tailing samples produced in the laboratory.

This review is only concerned with the processing of iron oxide ores by flotation, and selective flocculation information has been deliberately omitted. The inclusion or omission of reagents in this review is purely at the discretion of the author. Publications in each section are mainly in chronological order to show the developments of each type of process with time.

In their timeline on the history of the flotation of industrial minerals, Lynch et al. (2010) cite the Gaudin patent for the flotation of hematite in 1934 and the de Vaney patent for the flota-

tion of magnetite in 1945 as milestones in the development of the flotation of iron ores. (De Vaney (1945) used aliphatic amines as collectors for floating gangue away from the magnetite). The first all flotation plant for processing iron ores was commissioned in 1954 by the Humboldt Mining Company in Michigan, USA using “red oil and other oleate containing reagents” (Roe, 1957). These authors (Lynch et al., 2010) also traced the development of iron ore flotation, primarily in the United States and South America, up till about 2006. Obviously the selection of a flow sheet to process a particular iron ore will be governed by its mineralogy. Araujo et al. (2003) discussed how the mineralogy of South American iron ores determined how they are processed. It is through the previous research and development of natural products that global commercial processing of iron oxide ores by flotation is economically viable, and the only method for treating fine grained iron ores.

Many of the natural products described in this paper have been derived from fats and oils. Falconer (1960) has reported an extensive table showing typical compositions of common fats and oils, and though it has been published a long time ago, it remains a classic reference for this information. Crozier (1992) gave a partial list of the fatty acid contents of some fats and oils, including soy bean oil, fish oil, coconut oil and tallow (see Table 1). The Cn nomenclature is given by the number of carbon atoms in the hydrocarbon chain followed by the number of double bonds e.g. C18.1 is oleic acid.

Crozier (1992) reported that the majority of the fatty acids used industrially are of vegetable origin, rather than animal fats. Tall oil fatty acids are the most consumed organic reagents used in non-metallic ore flotation. Their main components are oleic, linoleic and linolenic (unsaturated) acids, and palmitic and stearic (saturated) acids. All commercial products also contain a varying amount of rosin acids which act as frothers rather than selective collectors.

Over the years there have been a number of reviews concerning the beneficiation of ores containing iron oxides by flotation (e.g. Trahar, 1963; Houot, 1983; Iwasaki, 1983, 1989, 2000; Nummela and Iwasaki, 1986; Yang, 1988; Uwadiale, 1992; Ma, 2012). It is the purpose of this review to address and compare the types and chemistries of some of the natural products used in the flotation of iron oxide minerals and ores. This is a different approach to that described in previous reviews which tended to focus on the mineralogy and surface chemistry of the minerals and the use of synthetic reagents, rather than a detailed description the chemistries and performances of the natural products used.

2. Use of natural products as hematite collectors in iron ore flotation

2.1. Collectors primarily based on oleic acid

As early as 1931, Adams et al. (1931) tested oleic acid, sodium oleate and fish oil as collectors for hematite from a Mesabi washing plant tailing containing 17% Fe. Sodium carbonate added at 1 kg/t

Table 1
Fatty acid contents of some fats and oils (in weight%) (after Crozier, 1992).

Cn	Soy bean	Fish oil	Coconut oil	Tallow	Lard
C14.0		7.0	17.5	1.0	1.0
C16.0	8.3	16.0	8.8	21.0	28.0
C16.1		17.0			3.0
C18.0	5.4	1.0	2.0	30.0	13.0
C18.1	24.9	27.0	6.0	43.0	46.0
C18.2	52.7		2.5	5.0	6.0
C18.3	7.9				0.7
C20.0	0.9				2.0
C20.4		20.0			
C22.5		12.0			

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