Bibliometric analysis on kaolinite flotation

http://dx.doi.org/10.1590/0370-44672016700119

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Abstract

The current work presents a bibliometric discussion on articles published worldwide concerning kaolinite flotation in international journals from 1992 to 2015. In total, 39 articles were selected from Elsevier's database, SciVerse ScienceDirect.

This work allowed to recognize and identify which are the thematic and methodological trends that are being used, in addition to the main collectors used in kaolinite flotation. The results show that a significant amount of articles is produced by Chinese authors, especially from 2013, as China is the second highest aluminum producer in the world, and kaolinite is the reject in the reverse flotation process of diaspore.

The results showed the difficulty of working with kaolinite flotation individually and confirmed that there is scientific collaboration among authors.

Bibliometric analysis showed that the reagents used in kaolinite flotation tests are mostly derived from cationic nitrogenated compounds. Additionally, best recovery results from kaolinite flotation occurred in acidic media.

Keywords: Flotation, bibliometric analysis, kaolinite.

1. Introduction

According to Guedes and Borschiver (undated) Bibliometrics can be defined as a set of laws and empirical principles that contribute to establishing the theoretical foundations of Information Science. According to the authors, the bibliography Statistics appeared in the year 1922 by Wyndham Hulme by means of document count.

The importance of studies of bibliometric nature is to have works that inform us about the methodologies of researches and results of the publications of a certain scientific area as well as number of authors, countries or magazines where these are published. Studies of this character allow to evaluate the quality and quantity of what is being produced and are an important tool in the real diagnosis of the potentialities of publications in a given subject area. (ARAÚJO, 2006; VIANNA, 2012; GUEDES e BORSCHIVER, undated).

Kaolinite, the target mineral of this bibliometric study, is a clay mineral composed of hydrated aluminum silicates, whose chemical composition is expressed by the formula $Al_4(Si_4O_{10})(OH)_8$ (LUZ and DAMASCO,1993). While its main application is in the paper industry, a large part of the studies involving kaolinite flotation is currently developed in China, where the mineral is treated as reject from bauxite deposits (RODRIGUES, 2009;YUEHUA *et al*., 2004).

Articles on the subject from the literature show flotation is performed under different operational conditions and in the presence of several surfactants, usually amine cationic collectors. Another important operational condition is flotation pH. In Brazil, kaolinite flotation is performed in alkaline medium and follows the electrostatic model, i.e., amines adsorption on the surface of silicates occurs above their Isoelectric point (IEP) when there is an excess of negative electric charges in the silicate/solution interface. While there is a consensus that the electrostatic model is the main mechanism of fatty amine adsorption in silicates (GAUDIN and FUERSTENAU, 1955), the ore presents its best flotation condition under acidic medium in kaolinite flotation in China.

2. Materials and methods

This work's focus is worldwide scientific production. The articles were selected from Elsevier's database, SciVerse ScienceDirect. Initially, 112 articles were analyzed. Following an individual analysis in the 112 articles in order to check whether each one meets this study's goal or not, 39 articles were chosen for bibliometric analysis.

Excel spreadsheets were used to determine the number of articles prepared by country, and affiliations among countries. With this information, it was possible to measure the Brazilian participation in publications on kaolinite flotation, and which are the leading countries in the ranking of studies.

The quantity of publications per year, authors per article, pages per publication, countries with more publications and keywords were also evaluated. All these items were statistically analyzed in Excel spreadsheets. Through the reading of articles, it was possible to categorize the articles by flotation pH, keywords, ores involved, methods used in the studies and recoveries in flotation.

Articles that describe kaolinite properties and reagents used as collectors in the flotation of this ore were taken into consideration.

3. Results and discussions

3.1 Geographic analysis

Only articles whose authors are from the same country were considered in the geographic analysis. Five countries have already published articles on kaolinite flotation in ScienceDirect/ Elsevier database. China leads the ranking, as kaolinite is abundant in Chinese bauxite ores, with 83% of publications, followed by Australia with 8%, and Germany, United States and Brazil with 3% each.

Concerning the affiliation of more than one country involved in the same publication, authors from three countries with articles in Science Direct were found among mineral technology institutes. In articles written through scientific collaboration among countries, partnerships occurred between China - Canada (two articles) and China - United States (one article).

Based on the data, China was found to have an international collaborative activity and is the country that most develops research for kaolinite flotation. Out of 33 articles published by Chinese authors, 30 have no collaboration from other countries and three present partnerships. Brazil has one article published with no international collaboration.

3.2 Temporal analysis

The temporal evolutionary analysis (Figure 1) of searched articles enabled to determine that the number of publications on kaolinite flotation was insignificant before 2003: only one article from 1992 to 2002.

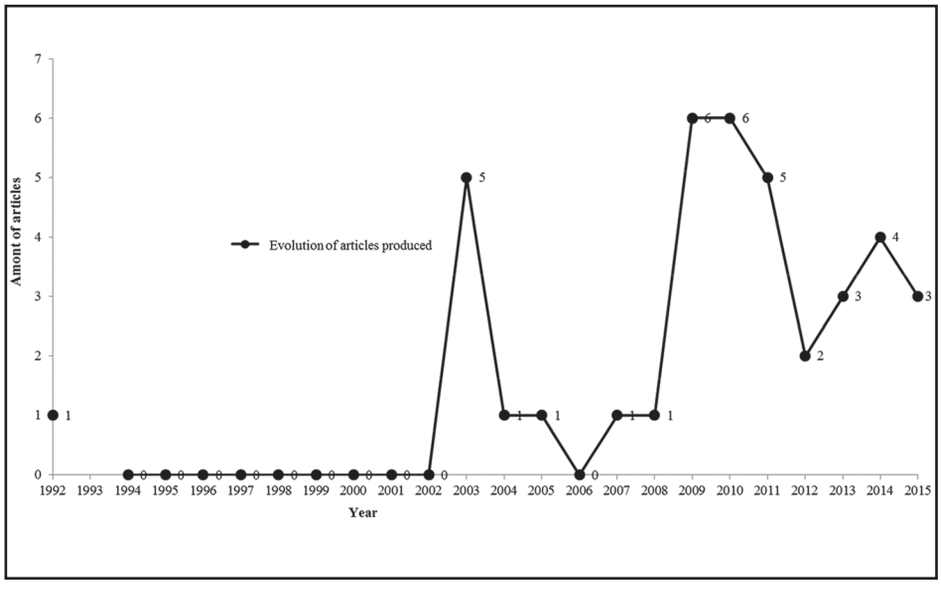

Figure 1
Evolution of articles produced from 1992 to 2015.

In 2003, there was a jump in the amount of publications on kaolinite flotation. In total, there were five articles, all from Chinese technology institutes. According to the report "The aluminum industry: structure and trends" BNDES Bank price of aluminum presented high, between the years of 2003 and 2008, mainly due to the expansion of consumption in China. In addition, from 2002 onwards, according to " O Relatório de Estudos Setoriais: Alumínio" (XAVIER, 2012), the average electric energy tariff for primary aluminum production in the world rose from US $ 20 / MWh to US $ 50 / MWh estimated for 2012. In this case, it may justify the increase of the publications of the scientific community due to the interest of the industries in reducing the silica content in the bauxitic ores, because kaolinite increases the costs in the Bayer process. According to the BNDES (undated) in 2009, when China became the world's largest aluminum producer, there was the largest amount of publications (15%) that involved kaolinite flotation (BNDES, undated).

3.3 Analysis of number of authors per article

Table 1 presents the number of articles produced according to the number of authors. The predominance of articles produced by more than one researcher is noted, proving that there is scientific collaboration among authors. The fact that only one article was developed by a single researcher indicates the difficulty of working individually with kaolinite flotation.

AUTHORSHIP	AMOUNT	PARTICIPATION (%)
1 author	1	2.56
2 author	2	5.13
3 author	8	20.51
4 author	9	23.08
5 author	13	33.33
6 author	3	7.69
7 author	3	7.69
Total	39	100

Table 1
Amount of articles per number of authors.

3.4 Analysis of articles according to the number of pages

Figure 2 quantifies the number of pages of each study in the article. Most studies are in the range of six or seven pages per article. Only four articles have 10 pages, which corresponds to only 10% of the sample, and one article has 12 pages.

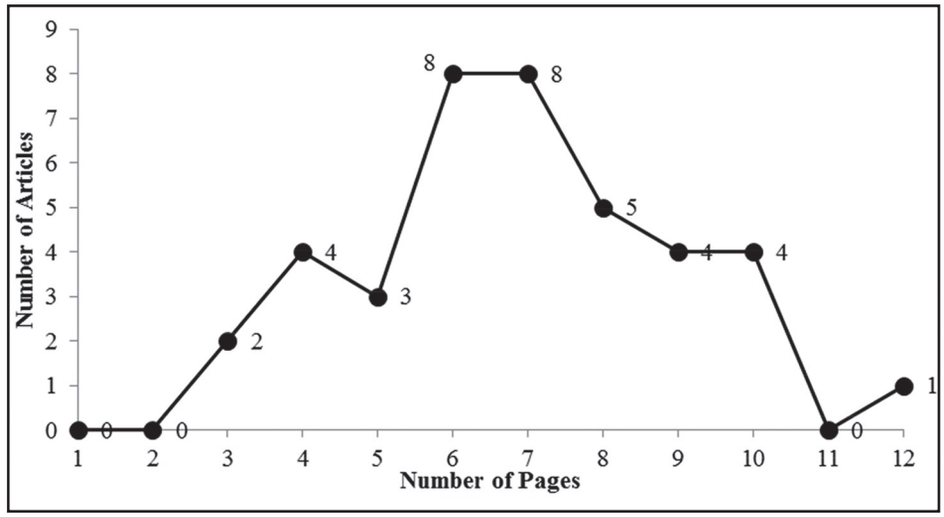

Figure 2
Number of articles per number of pages.

3.5 Analysis of articles by keywords

Altogether, the 39 articles present 180 keywords in total. Keywords are fundamental in the articles, as they describe the theme or subject of the text. They are also an important search tool, as they represent the context of the article. In the analysis of keywords per article, an average amount of 4.5 per article was found, ranging from a minimum of 2 to a maximum of 8 words.

One of the large difficulties of this study was to select the articles that would comprise the bibliometric analysis. This difficulty is justified by the fact that kaolinite is not always present in the keywords. According to Table 2, it is possible to note that kaolinite is in the keywords of only 15 articles. The terms "aluminosilicate", "oxidized ores" and "diaspore" are frequently found in articles, as China is the largest aluminum producer in the world, and kaolinite is the reject in the reverse flotation process of diaspore. Kaolinite is cited as a keyword in only 39% of the articles.

Ores involved	(%)
No ore	5.13
Pyrophyllite and Gibbsite	2.56
Diaspore	5.13
Aluminosilicates	7.69
Oxidized ores	23.08
Kaolinite and Aluminosilicates	5.13
Diaspore and Aluminosilicates	17.95
Kaolinite	15.38
Kaolinite and Feldspar	2.56
Kaolinite and Hematite	2.56
Kaolinite Diaspore	12.82
Articles	100
With Kaolinite ore (total)	38.46

Table 2
Ores found in the keywords of the 39 articles.

The most frequent keywords in the 39 articles were also evaluated. Of all the 180 keywords, 12 stood out due to the number of times they appear in the articles, 100 occurrences, or due to their importance in flotation. In Figure 3, the terms that stand out are “flotation”, “froth flotation”, “kaolinite”, “diaspore”, “oxidized ores”, “aluminosilicates” and “adsorption”.

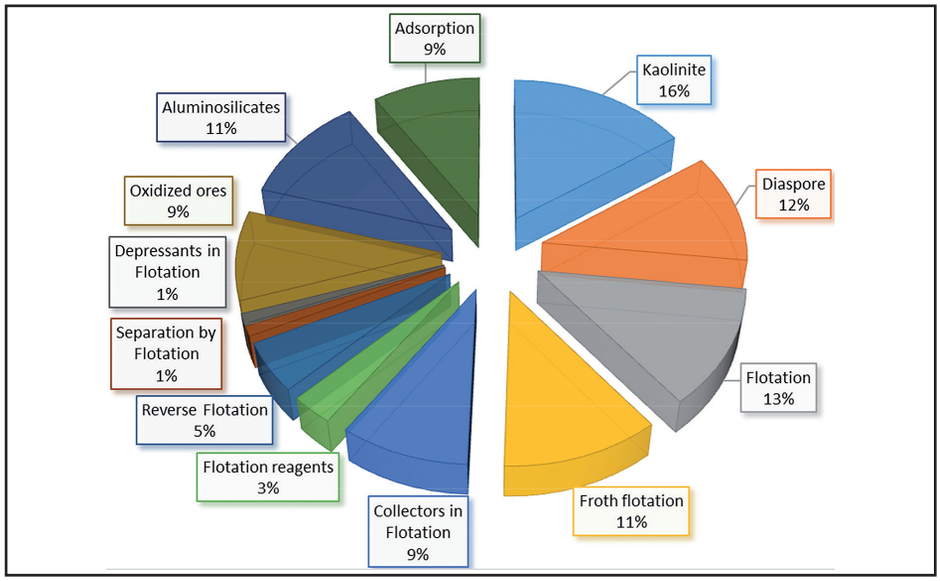

Figure 3
Most frequent keywords in the 39 articles.

3.6 Analysis of the most significant characterization methods used in the articles

This analysis was performed through the methods used in the 39 articles. Twelve most representative characterization methods were found, which are important to understand the physicochemical phenomena in flotation.

As can be seen in Figure 4, most representative sample characterization methods are: zeta potential (28%), methods of mineralogical characterization (31%) and adsorption studies (14%).

It can also be seen in Figure 4 that contact angle tests to determine mineral hydrophobicity were scarcely used, representing only 3% of the tests used in the research.

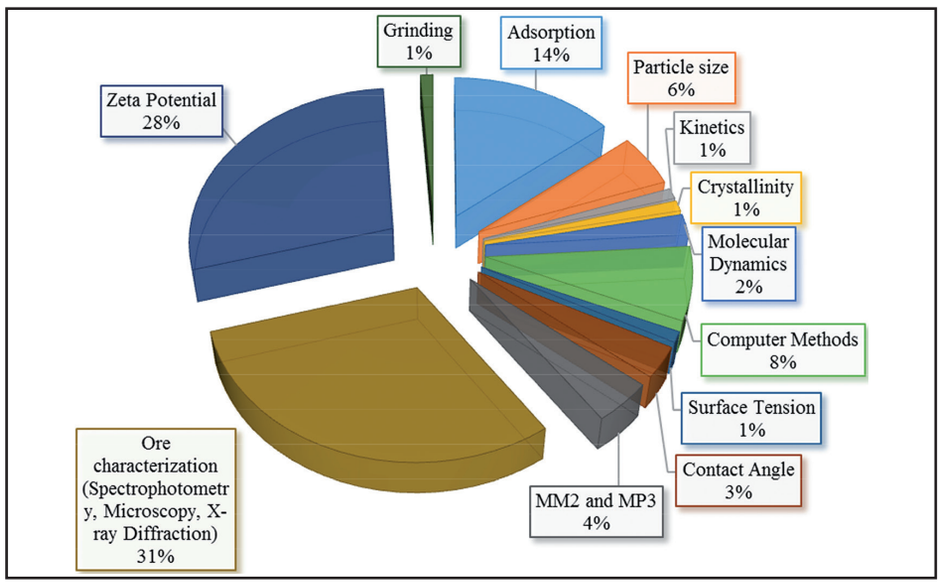

Figure 4
Most used characterization methods in the articles.

3.7 Ores involved in kaolinite flotation

Through reading and analysis of articles, it was possible to classify the ores cited in the body of the text together with flotation of kaolinite ore. This part of the study was developed because not all ores appear in the keywords and are studied in sample articles.

It was noted that 23% of kaolinite ore are studied individually, with no secondary mineral ores. Conversely, 31% of articles perform reverse flotation of diaspore, in which kaolinite is characterized as reject ore. The studies with kaolinite, illite and pyrophyllite (together) represent 15% of the total. Kaolinite, diaspore and illite represent 13% of the study sample. Kaolinite, diaspore, illite and pyrophyllite correspond to 8% of the working ores. Only 3% of articles use kaolinite together with hematite and 3% kaolinite with feldspar.

Participation of diaspore (aluminum hydroxide), pyrophyllite (hydrated magnesium silicate) and illite (clay mineral) in articles of kaolinite flotation is due to the fact these ores are present in the bauxite deposits in China. As illite belongs to the group of clay minerals, illite and kaolinite have similar surface characteristics, which makes the process of kaolinite flotation difficult.

3.8 Reagents used in flotation assays of the 39 articles

Figure 5 presents the list of reagents used in flotation assays of sample articles. The largest amount of studies used quaternary ammonium salt collectors (22%), followed by carboxylic acid collectors with 19%. While carboxylic acids are significant in this table, they were used in large amount in only three articles and presented low flotability for kaolinite ore.

Tertiary amines represent 9% of the sample, primary amine and primary amine salt together represent 12%, ether amine, monoamine and ether diamine 5% and amide 5%.

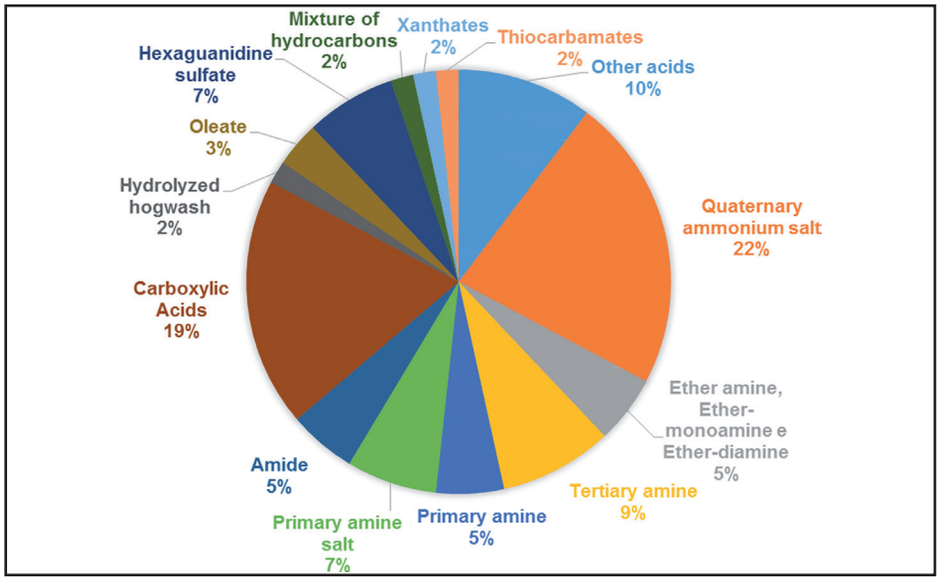

Figure 5
Reagents used in flotation assays of the 39 articles.

3.9 Flotation pH

Figure 6 presents results of best flotation pH concerning all the above-mentioned reagents used. In this figure, only the pH in which the largest recovery of collectors occurred from all values presented in the articles was taken into consideration. It is important to point out that many collectors also presented excellent results in other pH ranges.

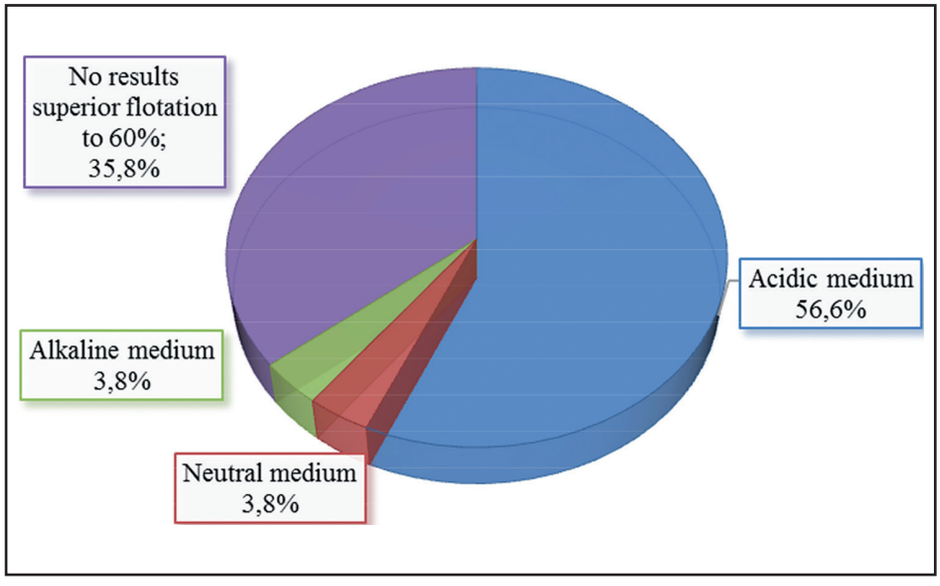

Figure 6
pH presenting the largest value of kaolinite recovery of collectors.

Largest kaolinite recovery is predominant in acidic medium among collectors (56.6% of the collectors). The best recovery in alkaline medium was noted for 3.8% only. Collectors that presented the largest recovery in neutral medium were 3.8%. Conversely, those that presented low recovery in kaolinite flotation, lower than 60%, were 35.8% of all collectors.

While there is a consensus that the electrostatic model is the main mechanism of fatty amine adsorption in silicates in kaolinite flotation, the ore presents its best flotation condition under acidic medium (mainly in China).

4. Conclusion

Concludes that a Chinese participation in high-impact journals has been significant in the academic area, in terms of quantity. The articles favor diaspore ore over kaolinite ore. This is due to the fact that China is the largest aluminum producer in the world, and kaolinite is the reject in the reverse flotation process of diaspore.

According to the temporal evolutionary analysis, it was concluded that kaolinite flotation studies increased significantly from 2003 onwards. Publication peak occurred in 2009 and 2010, with a total of 12 articles. The results presented indicate there is a strong trend for more studies on kaolinite flotation, as studies optimizing flotation technique for bauxite ores are required. Since kaolinite is the process reject, these studies will allow to reduce costs in subsequent ore treatment processes.

In the study of ores involved in the kaolinite flotation, it was noted that kaolinite is only studied with diaspore in 31% of articles. In addition to diaspore, kaolinite was also studied with illite, pyrophyllite, hematite and feldspar.

The publications focus primarily on variable quantification and opt for experimental studies. Concerning flotation pH of reagents used in this study, predominance of better flotation performance in acidic medium was noted, although the literature reports better performance in alkaline medium. It is important to point out that in a large part of the studies, the authors do not report if the reality of ore treatment plant matches the results obtained in their studies.

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Received: 19 August 2016 - Accepted: 24 April 2017.