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A Summary of the Literature on Leaching: Contributions and Tendencies

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Abstract

Leaching is an important industrial process that is highly used in the handling of solids to recover important solutes, and its study has increased during the last years due to a large number of applications and new methods of the optimization process. It is essential to follow the direction of science in the area of leaching to communicate researchers about the type of future trend of investigations in this area and give a high research contribution. It was completed a research development of leaching from 2007 to 2017, using s specialized software. This study assessed a total of 1767 publications associated with leaching which were used to evaluate the trends of publications outputs, author, institutions, main journal, and keywords. The Republic of China, Spain, and the USA, were the top 3 most productive countries. The journals with the highest scientific article production were Chromatography A followed by Talanta, and Chromatography B. The most productive institution was the Chinese Academy of Sciences followed by Hebei University and University of Santiago de Compostela. China is the leader in this field of research since seven of the top ten most productive universities are from China The most keywords used were solid, followed by extraction and liquid. The most productive authors were Zhang HQ from the Chinese Academy of Sciences, with 20 publications, followed by Row HK from Inha University with 19 publications.

Keywords: Bibliometrics, leaching, research trends, publications

1. Introduction

Leaching, which is the unit operation of solid-liquid extraction, has great importance in industries as miner, where essential metals are obtained like gold, copper, and platinum. Different materials are used to get the wanted solute, e.g., to recover gold, it is used ammonium, calcium and sodium thiosulphates [1], to recover platinum and palladium, concentrated chloride solutions and ozone are used [2]. This operation is used in food processing as well. Studies about sugar extraction have been done [3], relations between nitrogen leaching and food productivity, as an expression of the environmental efficiency of food production in organic and conventional cropping systems in a long-term field study [4].

A significant application of leaching processes is orientated to the environment, e.g., copper, iron and lead leaching from waste [5, 6], the recovery of zinc from alkaline batteries leaching [7].

Leaching is such an important operation in different fields like agriculture, metallurgy, and chemistry that it is necessary to follow its tendency of research so that future projects follow the optimum way to obtain the highest investigative contribution possible. The high number of publications on this subject around the world made difficult to see the participation of authors, organizations, and journals in this field. However, there is a way to organize and analyze all that large amount of information by the use of a tool called bibliometric. This method needs the use of computational tools that can quantitatively measure and evaluate the research impact and evolution of a topic of interest by analyzing publication characteristics. The method emphasizes identifying research strengths and weaknesses, measuring author, institution, and country contributions, and identifying the impact of journals. This kind of organized analysis allows summarizing the global information on leaching and help to visualize the trends on the mentioned topic that can be seen as a guide of interest on future investigations.

This paper was designed to screen leaching research worldwide developed on scientific publications from 2007 to 2017, by using a bibliometric analysis. It was done with the purpose of revealing the contribution of well-known institutions, scientific journals, countries all over the world, and researchers, about their interest in leaching determining the direction of science in this area.

2. Methodology

All the data were gotten with the use of a friendly computer program that helps to join all the bibliographic information (titles, authors, dates, author addresses, references, etc.) to perform bibliometric analysis and visualization tasks. The text file used was provided by the online based scientific citation indexing database Web of Science. It was found a total of 1767 documents about leaching research. All the documents identified in the database were assessed by the following criteria: year of publication, major journals, most productive institutions, most productive countries, most productive authors, and keywords using a software of interactive graphing and data analysis which has a simple interface and allows to customize

the results according to the user criteria. To better visualize the results obtained, they were grouped into tables and graphs.

3. Results and Analysis

3.1. Publication outputs

From 2007 to 2017 a total of 1767 documents on leaching were recognized. The type of document with the highest use was the article type with a total of 1660 publications (93.94%), followed by proceedings papers with 54 publications (3.06%), meetings abstract with 24 publications (1.36%), reviews with 13 publications (0.74%), corrections with 7 publications (0.40%), letter with 5 publications (0.28%), and editorial material with 4 publications (0.23%). 1651 of the 1767 publications were written in English, followed by Chinese (102), Japanese (7), Portuguese (5), Polish (1), and Rumanian (1). Figure 1 shows a rise in the number of publications from 2007 to 2017 presenting a linear behavior as shown. The number of publications keeps on the increase from 2007 to 2017 with a slope of 7.46 publications per year. This trend indicates the importance of leaching in the scientific community. This area is mainly focused on the environment care because of the extraction of contaminants.

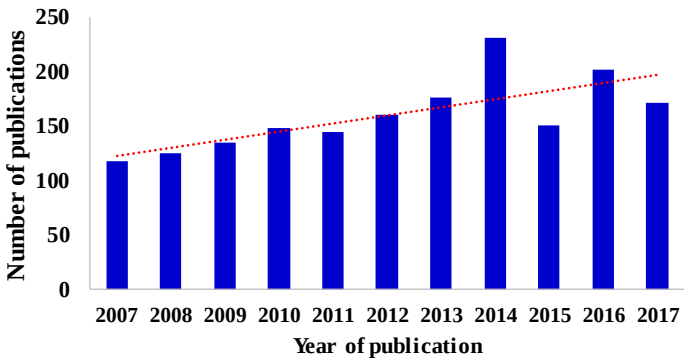

Figure.1 Trend of publications from 2007 to 2017.

Table 1 shows the top 10 main scientific journals with the highest number of papers. NP refers to the number of publications, TLCS is the total local citation score, TGCS is the total global citation score. Journal of Chromatography A was the first in the top with 305 publications corresponding to the 17.3% of the total number of publications. Talanta follows that journal with 109 publications (6.2%) and Journal of Chromatography B with 108 publications (6.1%). As mentioned before, the area of leaching is mainly focused on environmental care. The cause is the world growing population that is causing an increase in solid waste which is a serious problem that is gaining more importance.

As can be seen, the top two journals mentioned before have the top TLCS indicating their high-quality articles. Besides, when evaluating with another quality parameter such as the ratio TLCS/NP, they still have the maximum values.

Table 1. Top ten journals with the highest number of publications

#	Journal	NP	NP %	TLCS	TGCS	TLCS/NP
1	Journal of chromatography A	305	17.3%	779	9506	2.55
2	Talanta	109	6.2%	182	2785	1.67
3	Journal of chromatography B. Analytical technologies in the biomedical and life sciences	108	6.1%	113	1795	1.05
4	Journal of separation science	103	5.8%	115	840	1.12
5	Chinese journal of analytical chemistry	94	5.3%	45	334	0.48
6	Analytical and bioanalytical chemistry	83	4.7%	89	1537	1.07
7	Analytical methods	63	3.6%	31	353	0.49
8	Analytica chimica acta	55	3.1%	173	1873	3.15
9	Food analytical methods	40	2.3%	26	247	0.65
10	Food chemistry	37	2.1%	51	709	1.38

Table 2 shows the countries with the highest number of publications, where the Republic of China registered 683 representing the 38.7% of the total NP. Spain follows it with 205 publications (11.6%), The USA with 140 (7.9%), and Iran with 100 (5.7%).

Table 2. Top 10 most productive countries during 2007-2017

#	Country	NP	NP %	TLCS	TLCS/NP
1	China	683	38.7%	889	1.302
2	Spain	205	11.6%	327	1.595
3	USA	140	7.9%	124	0.886
4	Iran	100	5.7%	106	1.060
5	Italy	59	3.3%	78	1.322
6	Brazil	55	3.1%	37	0.673
7	France	49	2.8%	43	0.878
8	UK	47	2.7%	68	1.447
9	Japan	45	2.5%	21	0.467
10	India	40	2.3%	32	0.8

Most of the countries shown in table 2 are developed countries, which is a coherent result with their industrial level. They have big industries that use leaching in agriculture, metallurgy, and chemistry. They are researching in bioleaching as well. Most of the countries mentioned in table 2 have the largest values of TLCS. It indicates that they have not only the highest number of publications but also the highest quality articles. Nevertheless, the country with the highest quality papers is

Spain with the highest ratio TLCS/NP (1.595). Figure 2 shows the distribution of the percentage of countries with the highest TLCS. It validates China, Spain, and the USA as the countries with the highest quality papers. China is the largest gold and copper producing country. It is related to its paper production.

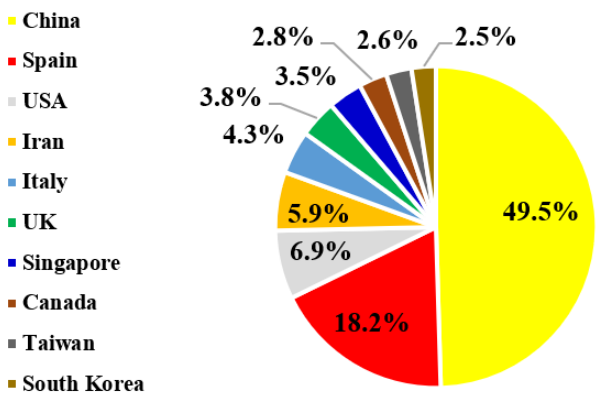

Figure 2. Countries with the most significant percentage of TLCS

Table 3 shows the organizations with the highest number of publications. The top two institutions with the highest paper production were from China, the Chinese Academy of Science with 72 publication, and Hebei University with 33 publications followed by the University of Santiago de Compostela from Spain with 28 papers.

Table 3. Top 10 most productive institutions from 2007 to 2017

#	Institution	NP	NP %	TLCS	TGCS	TLCS/NP
1	Chinese Acad. Sci.	72	4.07%	151	1797	2.10
2	Hebei Univ.	33	1.87%	60	737	1.82
3	Univ. Santiago de Compostela	28	1.58%	80	948	2.86
4	Jilin Univ.	27	1.53%	68	465	2.52
5	Islamic Azad Univ.	23	1.30%	11	194	0.48
6	China Agr. Univ.	21	1.19%	16	182	0.76
7	China Pharmaceut. Univ.	21	1.19%	37	314	1.76
8	Chinese Acad. Agr. Sci.	20	1.13%	9	183	0.45
9	Inha Univ.	19	1.08%	36	276	1.89
10	Zhejiang Univ.	19	1.08%	21	265	1.11

The Chinese Academy of Science has the Research Center for Eco-Environmental Sciences, the Dalian Institute of Chemical Physics, the Lanzhou Institute of Chemical Physics, and the State Key Laboratory of Environmental Chemistry and

Ecotoxicology were investigations about leaching are done. Hebei University has the College of Chemistry and Environmental Science, where research in this topic is done. Even though both universities have the highest number of publications, the University of Santiago de Compostela, and Jilin University has the highest quality papers as can be seen with the ratio TLCS/NP.

The analysis of keywords gives perception about the tendency, exposing areas of particular research interest. Table 4 shows the top author keywords that appear in articles from 2007 to 2017 with a total of 3331 keywords where the most important are solid, extraction and liquid, validating the research trend specifically in leaching.

Table 4 Top ten authors keyword from 2007 to 2017

#	Keyword	NP	TLCS	#	Keyword	NP	TLCS
1	Solid	1765	2077	11	Tandem	584	743
2	Extraction	1764	2071	12	Using	379	420
3	Liquid	1743	2027	13	Coupled	332	395
4	Phase	1569	1970	14	Analysis	287	394
5	Chromatography	1326	1537	15	Samples	268	527
6	Determination	941	1177	16	Water	261	508
7	Mass	800	914	17	Dispersive	210	382
8	Spectrometry	779	906	18	Method	199	176
9	Performance	643	678	19	Detection	197	204
10	High	631	730	20	Line	189	292

3.2. Most productive authors

The authors with the maximum number of documents were Heqing Zhang from the Research Center for Eco-Environmental Sciences, at The Chinese Academy of Science with 20 publications, followed by Kyung Ho Row from the Center for Advanced Bio-Technology at Inha University in the Republic of Korea with 19 publications.

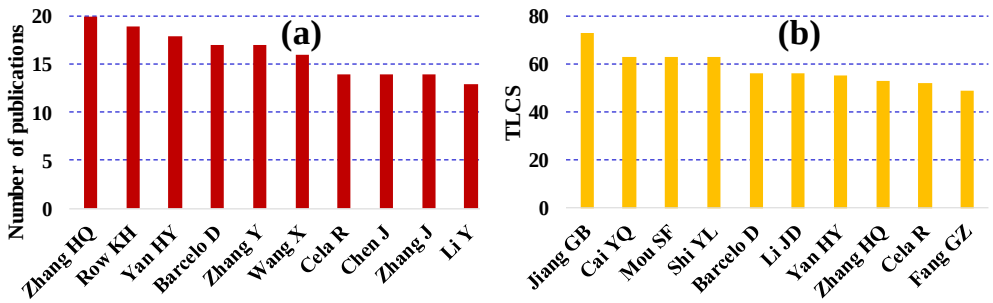

Figure 3. Most productive authors from 2007 to 2017

HQ Zhang appears number 8 in the list of the top ten authors with the highest TLCS. Row HK does not appear in that list. Yan HY, Barcelo D., and Cela R. appear in figure 3 a and b indicating their high-level paper quality. Most of the work of the researchers shown in figure 3 a and b, is done in specialized research centers of high level.

4. Conclusions

A worldwide trend in the research productivity associated to leaching from 2007 to 2017 was done considering a bibliometric analysis of the publications outputs, international productivity, major journals, most productive authors and keyword using the software HistCiteTM. Most of the research focused on environmental care which is a problem that is facing the world nowadays because of the population growth. The number of publications remained on the increase from 2007 to 2017 with a slope of 7.46 publications per year. The Republic of China was not only the country leader in publications with 683 documents but also the country with the highest quality of papers presenting a value of TLCS of 889. Spain was also characterized for having high-quality papers as well, presenting the highest ratio of TLCS/NP=1.595. The top 2 institutions with the highest paper production are located in China, the Chinese Academy of Science with 72 publication, and Hebei University with 33 documents. These two institutions have important research centers like the Research Center for Eco-Environmental Sciences, and the College of Chemistry and Environmental Science. The journals that have the highest ratio TLCS/NP were Analytica Chimica Acta (3.15), Journal of Chromatography A (2.55), and Talanta (1.67).

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