

Research Evolution on Liquid-Liquid Extraction: A Bibliometric Study

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Abstract

Liquid-liquid extraction is a necessary unit operation used in the recovery of essential solutes like the extraction of DNA in the area of health, the recovery of benzene in industrial processes, and the reduction of contaminants from the water like pesticides in the environment care. With the goal to make studies that give a high contribution in any of the mentioned areas, it is necessary to analyze the trend of research in liquid-liquid extraction. To help researchers to accomplish that aim, it was completed a research development of liquid-liquid extraction from 2007 to 2017 using specialized software. This study assessed a total of 5477 publications related to liquid-liquid extraction which were used to evaluate the trends of publications outputs, primary language, countries, author, institutions, main journal, and keywords. The Republic of China, Spain, and the USA, were the top 3 most productive countries with 1664, 582, and 466 publications respectively. The most productive institution was the Chinese Academy of Sciences followed by Jilin University and Bhabha Atomic Research Centre. The journals with the highest paper production were Chromatography A (11.0%) followed by Talanta (4.3%), and Journal of Separation Science (4.0%). The most keywords used were extraction, and liquid, followed by chromatography. The most productive authors were Hanqi Zhang from Jilin University with 59 publications, followed by Ji Chen from the Chinese Academy of Sciences with 43 papers.

Keywords: Bibliometrics, liquid-liquid extraction, research trend

1. Introduction

Liquid-liquid extraction is a vital separation process in many different fields like in some chemical industries where benzene is removed or recovered [1] from a liquid mixture, or in the area of health where the DNA is extracted [2] to treat different diseases or other health issues. This unit operation is used as well in the food industry, in infant foods [3], in the environment care like reducing copper pollution in water [4], or extraction of a variety of organic pollutants from water using Dispersive liquid-liquid microextraction with the solidification of floating organic drop [5]. Another use is the extraction of metal ions like Co(II), Cd(II), Cu(II), Fe(III), and Ni(II) [6] among others [7]. The high importance of the separation process of liquid-liquid extraction makes necessary to study its trend of research to find the best way that gives the highest research contribution possible. It is reached by analyzing a high amount of data with the tool called bibliometric. It helps to examine the scientific production and research tendencies of numerous fields. With this process, all the data is organized, measured, and evaluated with the help of additional computer programs. This paper presents the analysis of the trend of research in liquid-liquid extraction by screening this area of research worldwide from scientific publications issued from 2007 to 2017, by using a bibliometric analysis, and with the help of the software named HistCite™. It was done with the purpose of revealing and comparing the participation of recognized institutions and scientific journals, countries around the world and researchers, in relation to their interest in liquid-liquid extraction determining the direction of research in this subject.

2. Methodology

The documents used in this study were provided by Web of Science which is an online based scientific citation indexing database. To obtain the data, and perform the bibliometric analysis and visualization tasks, it was used a computer program that joins all the bibliographic information (titles, authors, dates, author addresses, references, etc.). It was found a total of 5477 documents about research in liquid-liquid extraction. The criteria of assessment for all the publications in the database were the following: year of publication, most productive countries, main journals, most productive authors, most productive institutions, and author keywords. It was employed a program of data analysis to adapt the results according to the settings of the user. To have a better comprehension of the results, they were grouped into tables and graphs of different types.

3. Results and Analysis

3.1 Publication outputs

From 2007 to 2017 a total of 5477 documents on liquid-liquid extraction were

identified. The type of document most commonly used was the article type with a total of 5477 publications (92.53%), followed by proceedings papers with 173 publications (3.16%), meetings abstract with 125 publications (2.28%), reviews with 60 publications (1.10%), corrections with 29 publications (0.53%), editorial material with 15 publications (0.27%), and letter with 7 publications (0.13%). The predominant language was English with 5292 publications out of 5477 publications, representing the 96.62%, followed by Chinese (154), Japanese (13), Portuguese (11), Polish (4), and Rumanian (2). Figure 1 shows an increment in the number of published documents from 2007 to 2017 presenting a linear behavior with a slope of 52.33 publications per year, which is a high number, evidencing the high importance of extraction liquid-liquid in the scientific community during that period. This subject has many application areas like DNA extraction, particular extraction of solutes in the food industry, the purification of amines, and metal extraction.

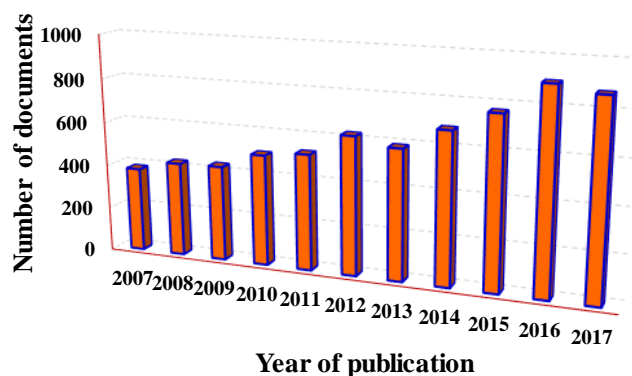


Figure.1 Number of published documents per year from 2007 to 2017.

Table 1 presents the results of the ten major scientific journals with the highest number of publication in the mentioned topic, where NP denotes the number of documents, TLCS is the total local citation score, and TGCS refers to the total global citation score. Journal of Chromatography A was the first in the top with 602 publications corresponding to the 11.0% of the total number of publications. Talanta follows that journal with 238 publications (4.3%) and Journal of separation science with 220 publications (4.0%). The area of liquid-liquid extraction has many working areas of study as mentioned before, but it is mainly focused on DNA extraction and solute extraction from food in the industry. The cause is the advance in technology which let to do experiments on extraction in an easy and faster way. The top 2 journals mentioned before have the top TLCS indicating their high-quality articles. Though, when assessing with another quality parameter such as the ratio TLCS/NP, the top journals are Separation and purification technology, and Analytica Chimica Acta.

Figure 2b shows the countries with the highest paper production in this topic from 2007 to 2017, where the Republic of China registered 1664 representing the 30.38% of the total NP. Spain follows it with 582 publications (10.63%), the USA with 446 (8.51%), and Iran with 378 (6.90%). The Republic of China produced three times

more papers than the second country with more paper production demonstrating its advance in knowledge and technology.

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

#	Journal	NP	NP %	TLCS	TGCS	TLCS/NP
1	Journal of chromatography A	602	11.0%	2421	20545	4.02
2	Talanta	238	4.3%	928	6733	3.90
3	Journal of separation science	220	4.0%	428	2924	1.95
4	Journal of chromatography B-analytical technologies in the biomedical sciences	203	3.7%	324	3711	1.60
5	Analytica Chimica Acta	175	3.2%	783	5958	4.47
6	Analytical and bioanalytical chemistry	165	3.0%	327	3490	1.98
7	Analytical methods	164	3.0%	112	945	0.68
8	Separation and purification technology	143	2.6%	713	3376	4.99
9	Chinese journal of analytical chemistry	138	2.5%	92	577	0.67
10	Food chemistry	95	1.7%	197	2009	2.07

The countries illustrated in figure 2 refers to developed and developing countries. They have many kinds of industries in all the fields mainly in foods, and they have a significant advance in medicine, especially in the extraction of DNA. As can be seen, the five top countries have the highest values of TLCS as well, demonstrating that they have not only a high number of publications but also a high number of papers with high quality.

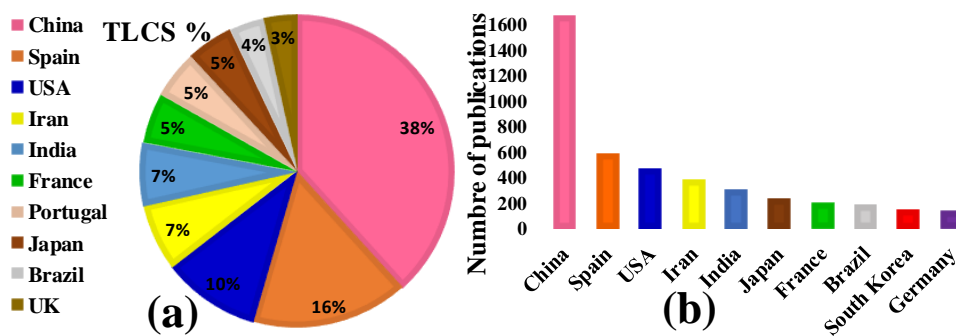


Figure 2 Top ten countries with the a) highest proportion of TLCS b) highest number of published documents

On the other hand, we can see that the country with the highest ratio TLCS/NP (11.71) was Ukraine, followed by Portugal (4.43), and Netherlands (3.59).

However, five of the top ten countries shown in figure 2 appear in the list of the top 20 countries with the highest TLCS/NP demonstrating their high-quality papers.

Table 2. Countries with the highest quality papers

#	Country	TLCS/NP	#	Country	TLCS/NP
1	Ukraine	11.71	11	UK	2.84
2	Portugal	4.43	12	Spain	2.79
3	Netherlands	3.59	13	Austria	2.76
4	Ethiopia	3.56	14	France	2.64
5	Singapore	3.42	15	Denmark	2.35
6	Ireland	3.32	16	Greece	2.34
7	Finland	3.26	17	China	2.31
8	Belgium	3.07	18	Thailand	2.19
9	Sweden	3.03	19	USA	2.18
10	Slovakia	2.92	20	India	2.17

Table 3 illustrates the institutions that have made the best researches about liquid-liquid extraction with the major number of publications. The top 2 institutions with the highest paper production were from China, the Chinese Academy of Science with 201 publication, and Jilin University with 82 publications followed by Bhabha Atomic Research Centre in India with 67 papers.

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

#	Institution	NP	NP %	TLCS	TGCS	TLCS/NP
1	Chinese Acad Sci	201	3.67%	747	4844	3.72
2	Jilin Univ	82	1.50%	204	1315	2.49
3	Bhabha Atom Res Ctr	67	1.22%	233	907	3.48
4	U. Santiago de Compostela	64	1.17%	296	2145	4.63
5	Islamic Azad Univ	61	1.11%	58	600	0.95
6	Zhejiang Univ	58	1.06%	220	1203	3.79
7	Univ Tehran	56	1.02%	128	837	2.29
8	Tarbiat Modares Univ	47	0.86%	168	1211	3.57
9	Univ Porto	45	0.82%	144	911	3.20
10	Univ Rovira & Virgili	45	0.82%	187	1005	4.16

The Chinese Academy of Science has different important research centers like 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 where studies about liquid-liquid extraction are done. Jilin University has the College of Chemistry and, the College of environment and resources where research in this topic is made. Even though

both universities have the highest number of publications, the University of Santiago de Compostela, and the University of Rovira and Virgili have the highest quality papers as can be seen with the ratio TLCS/NP.

Table 4. Top 20 authors keyword from 2007 to 2017

#	Keyword	NP	TLCS	#	Keyword	NP	TLCS
1	Extraction	5461	11787	11	Ionic	1168	5237
2	Liquid	5074	9732	12	Performance	1168	1676
3	Chromatography	2368	3758	13	Tandem	905	1542
4	Determination	1849	3191	14	Analysis	697	1287
5	Phase	1741	3265	15	Based	633	1861
6	Solid	1636	2583	16	Samples	603	1372
7	Mass	1460	2405	17	Coupled	571	884
8	Spectrometry	1411	2344	18	Water	533	1327
9	Using	1368	2867	19	Method	489	705
10	High	1175	1748	20	Assisted	485	1388

The study of author keywords gives facts about article topics and the trend areas of specific research interest. Table 4 presents the top twenty keywords most frequently used in articles from 2007 to 2017 with a total of 7471 keywords where the most important were extraction, liquid, and chromatography.

3.2 Most productive authors

The authors with the maximum number of papers were Zhang HQ from the College of Chemistry in Jilin University with 59 publications, followed by Ji Chen from Changchun Institute of Applied Chemistry in the Chinese Academic of Science, with 43 publications, see figure 3. As can be seen, the results are coherent with the most productive institutions.

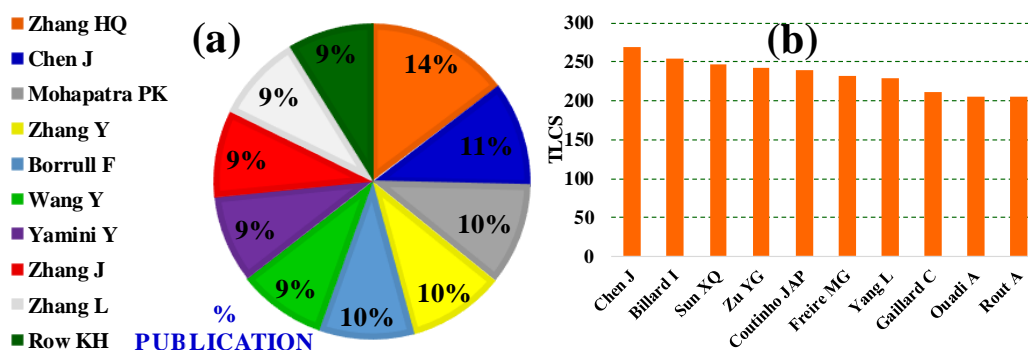


Figure 3. Top ten authors with the a) highest quantity of publications b) highest proportion of TLCS

Even though Hanqi Zhang has the highest number of publications, he is not the author with the highest number of TLCS. However, his number of TLCS is high (159) assuring the high quality of his papers. On the other hand, Ji Chen is not only the second with the highest number of publications but also the number one with the highest value of TLCS indicating the high quality of his papers.

4. Conclusions

Based in a bibliometric analysis of the number publications, most productive authors, international productivity, major journals, and author keywords using specialized software, a universal tendency in the research productivity associated to liquid-liquid extraction from 2007 to 2017 was done. The number of publications keeps on the increase with a slope of 52.33 publications per year. The Republic of China, Spain, The USA, Iran, and India were not only the countries leaders in publications with 1664, 582, 466, 378, and 300 documents respectively, but also the countries with the highest quality papers presenting TLCS values of 3849, 1625, 1015, 695, and 650 respectively. The top 2 institutions with the highest paper production are located in China, the Chinese Academy of Science with 201 publications, and Jilin University with 82 publications. These two institutions have important research centers like the Research Center for Eco-Environmental Sciences and the College of environment and resources. The journals that obtained the highest ratio TLCS/NP were the Journal of Chromatography A (4.02), Talanta (3.90) and the Journal of Separation Science (1.95).

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