

## Research Evolution in Liquid Diffusion from 2001 to 2016

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### Abstract

This article presents an investigation about the research evolution of liquid diffusion. This progression was done with a bibliometric analysis during 15 years of publications, obtaining the articles from Web of Science and using a software called HistCite to facilitate the study previously mentioned. The search identified a total of 761 publications related to liquid diffusion in the period from 2001 to 2016. Publication types, years of publication, languages countries, institutions, scientific journals, and authors were analyzed. It was noted that the three countries with the highest number of publications were the United States, Japan, and Germany. The three institutions with the largest number of papers published were the Russian Academy of Sciences, the Technological Institute of Tokyo and the University of Oxford. English was the predominant language in the articles with 743 records representing the 97.63% of the total number of publications. The research showed that most of the publications were made before 2010.

**Keywords:** liquid diffusion, bibliometric analysis, research, publications

## 1. Introduction

The study related to the liquid diffusion has had, in recent years, an important growth due to technological advances and the needs of the population, allowing a special interest in the development of the research on this topic. This phenomenon can be seen in many industrial processes [1], especially in separation operations, such as liquid-liquid extraction [2] or solvent extraction [3], gas absorption [4] and distillation [5]. Liquid diffusion is also frequent in nature [6], as in cases of oxygenation of rivers and lakes [7] and the diffusion of salts in the blood [8]. Considering that diffusion of solutes in liquids is the propagation of the molecules of one of the components, on the molecules of the liquid that participate in the process, the speed of the solute diffusion in the liquid is given thanks to the interactions and shocks that occur between the parties. The solute that participates in the diffusion process can be solid, liquid or gas depending on the desired result. Liquid diffusion is an important focus of study in engineering due to the great number of applications. Some of them happen in the food industry when it is wanted to supply preservative to the food in order to increase their shelf life. Another industry in which this process is highly important is the textile industry where liquid diffusion is used to impregnate fabrics with a pigment or dye [9]. The oil industry has lots of benefits as well because it requires the diffusivity of a solvent in another to separate the different components that are part of the so-called black gold.

To have general information about the research of liquid diffusion around the world, the present study focused in a bibliometric analysis performed on the research in this subject from 2001 to 2016. Basic publication items, including journals, countries and institutes, authors, and citation scores were identified to describe the status of liquid diffusion. The research trend helps researchers to determine the direction of science in this area.

## 2. Methodology

The data used in this study was based on the SCI-EXPANDED, SSCI online database published by Thomson Reuters Web of Science. "Liquid diffusion" was used as a string to search titles from 2001 to 2016. The research was carried out to analyze the trends and performance of the research that includes the types of files found, the years of publication, languages, countries, institutions, and journals from 2001 to 2016. HistCite software developed was used to determine the total score of local citations (TLC) with the number of publications (Recs), which were analyzed by Microsoft Excel.

## 3. Results and Discussion

A total of 761 files were found that responded to the search for "liquid diffusion." The distribution of the found documents are illustrated in Figure 1.

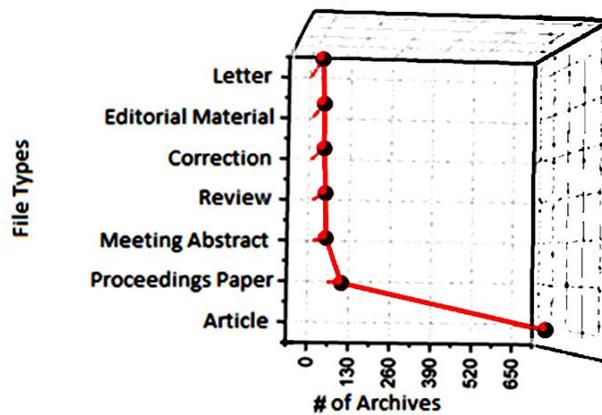


Figure 1. Distribution of water research by document types of publication output.

The years of publication of these archives go from 2001 to 2016 allowing a complete bibliometric study. It was also possible to know the years with the higher number of investigations about diffusion in liquids, as shown Figure 2.

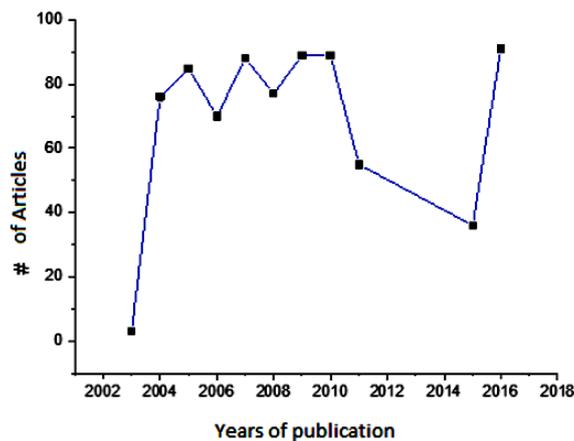


Figure 2. Number of articles of liquid diffusion published from 2003 to 2016.

Figure 2 shows that between 2004 and 2010 the number of publications remained relatively constant, while in the years 2012 to 2014, the number of publications decreased. These results show that the years 2004 to 2010 saw the need to go deep in the research of liquid diffusion, which is directly proportional to the growth of the industry in this period. The year that obtained the highest number of articles was 2016.

It was observed that the predominant language in the articles was in English with 743 files, which is 97.63% of the total number of publications. They are followed by Chinese (0.91%), Japanese (0.39%), Russian (0.39%), Polish (0.26%), Korean (0.14%), Portuguese (0.14%) and Ukrainian (0.14%). Table 1 shows the countries that had the highest number of publications, where the United States registered 141

out of 761 representing the 18.32% of the total. In the list follows Japan with 99 publications, Germany with 92, The People's Republic of China with 78 and France with 59. All the countries mentioned above are considered world power countries, so the results are coherent with the industrial level in all these territories.

Table 1. Top 10 countries with the highest number of articles

Country	Articles	Article's Quality, TLCS/Pubs
<i>United States</i>	141	82,97%
<i>Japan</i>	99	67,67 %
<i>Germany</i>	92	64,13 %
<i>People's Republic of China</i>	78	41,02 %
<i>France</i>	59	47,45 %
<i>Canada</i>	55	123,63 %
<i>Russia</i>	39	2,56 %
<i>United Kingdom</i>	39	97,43 %
<i>India</i>	29	13,79 %
<i>Italy</i>	28	32,14 %

Table 1 also shows the quality of the publications in which Canada obtained the highest percentage with 123.63, which shows that articles published by this country were cited 68 times, thus proving that their publications have a high impact. However, the publications made by the countries of the United Kingdom, the United States, Japan, and Germany are also highlighted. Figure 3 shows the geographic distribution. It can be seen that the highest amount are located in Europe.



Figure 3. Global geographic distribution of articles

In table 2 it can be appreciated the institutions with the highest number of publications in the period studied. When analyzing the data shown in Table 2, the institution that published the highest number of publications was the Russian Academy of Sciences. However, it is possible to appreciate that is the institutions with the lowest quality of the papers.

Table 2. Top 10 institutions with the highest number of publications.

<b>Institutions</b>	<b>Articles</b>	<b>Article's Quality, TLCS/Pubs</b>
<i>Russian Academy of Sciences</i>	16	12,50 %
<i>Technological Institute of Tokyo</i>	15	120,00 %
<i>Oxford University</i>	14	142,85 %
<i>University of Victoria</i>	14	300,00 %
<i>Chinese Academy of Sciences</i>	13	38,46 %
<i>University of Queens</i>	13	53,84 %
<i>Oak Ridge National Laboratory</i>	11	45,45 %
<i>University of California at Berkeley</i>	11	109,09 %
<i>University of Tennessee</i>	11	54,54 %
<i>University of Wisconsin</i>	11	36,36 %

The University of Victoria located in Canada was the university with the highest quality in its publications. It verifies the data obtained in table 1 where Canada is the country with the best quality in the articles. This table shows similarly, the University of Oxford, Tokyo Institute of Technology and the University of California at Berkeley with high quality in their papers. Table 3 shows the journals with the highest number of publications on liquid diffusion.

Table 3. Top 10 journals with the highest number of publications.

<b>Journal</b>	<b>Articles</b>	<b>Article's Quality, TLCS/Pubs</b>
<i>Journal of Physical Chemistry B</i>	49	126,53 %
<i>Journal of Chemical Physics</i>	44	15,90 %
<i>Physical Review E</i>	22	0 %
<i>Electrochimica Acta</i>	16	181,25 %
<i>Journal of Power Sources</i>	16	125 %
<i>Journal of the Electrochemical Society</i>	12	191,66 %
<i>Physical Chemistry Chemical Physics</i>	12	25 %
<i>Physical Review B</i>	12	0 %
<i>Abstracts of Papers of the ACS</i>	11	0 %
<i>Fluid Phase Equilibria</i>	11	100 %

The Journal of Physical Chemistry B had the higher number of publications with 49 in total. Also, it can be seen that although the Journal of Physical Chemistry B has the highest number of publications, it is not the one with the best quality of the

papers. The first place in quality of papers was achieved by the journal of the Electrochemical Society.

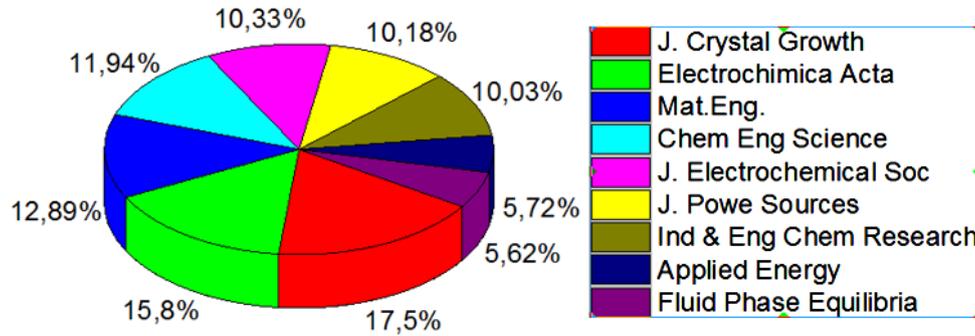


Figure 4. Top 10 journals with the highest number of citations per year

Figure 4 shows the journals with the highest number of citations per year. It is possible to appreciate that the Journal of Crystal Growth was the one that had the highest number of citations per year with a percentage of 17.5%. To have a deeper and complete bibliometric study on liquid diffusion, it is necessary to know the authors who have played an important role in the development and research in this area.

Table 4. Top 10 authors with the best quality articles and highest number of publications.

<i>Author</i>	<i>Article's Quality, TLCS/Pubs</i>	<i>Author</i>	<i>Publications</i>
Wang C Y	557,14 %	Smith R W	12
Sinha P K	700,00 %	Dost S	10
Hayamizu K	233,33 %	Frohberg G	8
Compton R G	183,33 %	Guiochon G	8
Djilali N	366,66 %	Karger J	7
Sinton D	550,00 %	Suzuki S	7
Hardacre C	250,00 %	Wang C Y	7
Litster S	1000,00 %	Compton R G	6
Price W S	333,33 %	Guo W	6
Brooks C A	900,00 %	Hayamizu K	6

Table 4 shows the ten authors with the highest number of publications and with the high-quality in their papers. It is possible to appreciate that Smith R. W. is the researcher with the highest number of publications. However, he does not appear in the same table with the authors with the highest quality papers. The only author that appears twice in the table is Wang C. indicating that is a researcher highly productive and with high effectivity. The author who has the highest quality in his publications was Litster S. with a percentage of 1000%. Finally, a study was carried

out on publications that obtained the highest number of total local citations (TLC) published from 2001 to 2016. To determine if an article has the best category taking into account the level of research, it was excluded the citations where the authors were cited by themselves (TLCx). The list was filtered choosing the first 5 articles, as shown in Table 5.

Table 5. Top 5 publications with the highest number of TLCx.

Title	Authors	Year of Publication	TLCx
<i>Pore-network modeling of liquid water transport in gas diffusion layer of a polymer electrolyte fuel cell</i>	Sinha PK, Wang CY	2007	11
<i>Ex situ visualization of liquid water transport in PEM fuel cell gas diffusion layers</i>	Litster S, Sinton D, Djilali N	2006	10
<i>Liquid water transport in gas diffusion layer of polymer electrolyte fuel cells</i>	Pasaogullari U, Wang CY	2004	9
<i>Concentration-dependent diffusion in room temperature ionic liquids: a microelectrode study</i>	Brooks CA, Doherty AP	2004	9
<i>Liquid water transport in a mixed-wet gas diffusion layer of a polymer electrolyte fuel cell</i>	Sinha PK, Wang CY	2008	9

It can be seen that Sinha P. K. and Wang C. Y. appear twice in this top 5. From this information, it can be inferred that the authors mentioned above, have high knowledge and mastery of the liquid diffusion.

#### 4. Conclusion

A global trend in the research output related to liquid diffusion from 2001 to 2016 was developed considering a statistical analysis allowing to determine the number of publications related to this topic. There was an increase since 2016, which suggests that this topic has boomed in recent years and could be maintained in increase due to the advances in technology.

Developed countries are the leaders in publications about liquid diffusion were the United States had the first place with 141 articles, followed by Japan with 99 and Germany with 92. The universities that commanded the highest number of publications were the Russian Academy of Sciences with 16 publications, the University of Tokyo with 15 publications and the University of Oxford with 14 publications. The authors that obtained the best quality in the publications was Litser S. and Wang C. The journal with the highest number of citations per year with a percentage of 17.5% was Journal of Crystal Growth.

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