
Mapping of Green Chemistry Research in India: A Scientometric Analysis

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Abstract

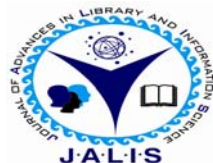
The study deals with the Scientometric study on the publication of "Green Chemistry" research in India. The records are collected from Scopus Database for the period of 1999-2013. A total of 1448 papers were identified in scopus database. The study reveals that, most researchers preferred to publish their research results in journals; as such 88.47% of articles were published in journals. More numbers (328, 25.60%) of articles were published in 2012. The degree of collaboration in Green Chemistry was 0.95. The authorship trend shows that, out of total 1448 literature published, 96% of them or published under the joint author of publications in Green Chemistry research output. It is observed that author productivity is not in agreement with Lotka's law, but productivity distribution data partially fits the law when the value of Chi-square to 218.72

Keywords

Mapping, Bibliometrics, Scientometrics, Green Chemistry

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1. INTRODUCTION

In recent years, the Scientometric techniques have become very popular. The literature on Scientometrics has been growing over the past two decades. It reveals that it is measurement of the pattern of all forms of written communication and their authors. Scientometric analysis has been increasingly used to calculate the research performance of the scientists and the growth of the various disciplines of science. The major focus of the study is to apply the Scientometric analysis with a view of analyze the mapping of research output on Green Chemistry. This study has resulted in a special attention on the performance of research output in Green Chemistry. It aims to examine the emergence of research areas, research groups and countries with a view to map the cognitive or intellectual structure of research. Further, this study spells out the relationship between authors, institutions, journals and articles and other means of assisting the peer review procedure. The study attempts to evaluate the performance of Green Chemistry Research output in terms of content and coverage, growth rates and areas of research concentration in Green Chemistry Research, research performance of various institutions, author productivity. This type of analysis reflects a wider notion of the present study.

1.1 Green Chemistry

Green chemistry is the utilization of a set of principles that will help reduce the use and generation of hazardous substances during the manufacture and application of chemical products. Green chemistry aims to protect the environment not by cleaning up, but by inventing new chemical processes that do not pollute. It is a rapidly developing and an important area in the chemical sciences. The term *Green Chemistry* was coined in 1991 by Anastas. The purpose is to design chemicals and chemical processes that will be less harmful to human health and environment.

1.2 Definition of Green Chemistry

According to Anastas and Warner (1998) defined as “**Green Chemistry** is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and applications of chemical products.”

2. OBJECTIVES

The researcher has framed the following objectives for the purpose of present research.

1. To identify the pattern of distribution of Green Chemistry research output in India.
2. To examine the effectiveness of various sources of research publications in Green Chemistry research.
3. To identify the authorship pattern of Green Chemistry research output in India.
4. To identify the proportion of single and multi-authored papers of Green Chemistry research output.
5. To identify the geographical representation of journals.
6. To prepare a ranking list of core journals.
7. To test the applicability of Lotka's law to the scientific productivity of authors.
8. The distribution of Green Chemistry research output journals conforms the implication of Bradford's law.

1. STUDY DATABASES (Scopus)

Scopus is the largest abstract and citation databases of research literature and quality web sources. It is designed to find the information that scientist need. Quick, easy and comprehensive, Scopus provides superior support of the literature research process, The data are updated regularly, This databases also helps the research and finds innovative tools that give an at-a-glance overview of search results.

4. Methodology

The analysis related to the Statistical analysis with respect to growth of literature, absolute growth rate and relative growth rate., source wise research output, country wise research output authorship pattern, Institution wise research output, word frequency, doubling time, priority index, Activity index and degree of collaboration in research output of Green Chemistry in scientometric and so on. Further, this study is exploratory in nature by identifying the research performance of Green chemistry in Scientometric, and is analyzed in nature in strengthening the empirical validity through application of suitable statistical tools. All the Publications retrieved from the Scopus database on Green chemistry and cover the period from 1999 to 2013, Further, the research has downloaded the bibliographical data in the form of notepad files. Then the bibliographical details are converted to the form of MS –EXCEL format using the PHP (hyper

text pre processor), Scripting language text extracting based an delimiters Programme. Finally, the unique data are rearranged in MS –EXCEL format to eliminate duplication from the downloaded data. Overall data retrieved by the researcher are **1448** records and the researcher chosen only 1448 records for analyzing the present study.

5. ANALYSIS

5.1 GROWTH OF PUBLICATIONS

Table–1 indicates that the year wise research output from 1999 to 2013. Totally 1448 scholarly paper published with in India level fifteen years. Highest percentage of papers was published in the year 2012, 2011 and 2010 respectively. In the year 2013, the publication percentage was 11.6 percent, 8.49 percent of publication published in 2009. The years 2006 and 2008 contributed 5.39% and 4.7 percent. The year 2005 had contributed 3.17 percent of research papers. The year 1999 had a very least percentage of only 0.35 in terms of publication of research papers.

Table 1: Year wise Distribution of Publications

Year	No. of Paper	% of paper	Cum. No. of paper	% of Cum.
1999	5	0.35	5	0.08
2000	10	0.69	15	0.25
2001	17	1.17	32	0.52
2002	16	1.1	48	0.78
2003	25	1.73	73	1.20
2004	31	2.14	104	1.71
2005	46	3.17	150	2.46
2006	78	5.39	228	3.75
2007	63	4.35	291	4.78
2008	68	4.7	359	5.90
2009	123	8.49	482	7.92
2010	170	11.74	652	10.72
2011	260	17.96	912	15.00
2012	368	25.41	1280	21.05
2013	168	11.6	1448	23.81
Total	1448	100		100

It could be deduced from the above discussion that among the study period of the research paper published trend in increasing and decreasing. Highest percent of publication published in 2012. In the year 1999 the publication research paper minimum.

5.1.1 Relative Growth Rate and Doubling Time of Green Chemistry Publication

Table2: Relative Growth Rate of Green Chemistry Publications

Year	Publication output	Cum. No. of output	W_1	W_2	$R(a) = \frac{W_2 - W_1}{W_2 \cdot W_1}$	Mean $R(a) = \frac{R(a)}{W_2 - W_1}$	Doubling time $Dt = \frac{0.693}{R(a)}$	Mean Dt (a)
1999	5	5		1.60	1.60		0.43	-0.11 Yrs.
2000	10	15	1.60	2.30	0.69		1.00	
2001	17	32	2.30	2.83	0.53		1.30	
2002	16	48	2.83	2.77	-0.06		-11.55	
2003	25	73	2.77	3.21	0.44		1.57	
2004	31	104	3.21	3.43	0.21		3.3	
2005	46	150	3.43	3.82	0.39		1.77	
2006	78	228	3.82	4.35	0.52	0.54	1.33	1.81 Yrs.
2007	63	291	4.35	4.14	-0.21		-3.3	
2008	68	359	4.14	4.21	0.07		9.9	
2009	123	482	4.21	4.81	0.59		1.17	
2010	170	652	4.81	5.13	0.32		2.16	
2011	260	912	5.13	5.56	0.42		1.65	
2012	368	1280	5.56	5.90	0.34		2.03	
2013	168	1448	5.90	5.12	-0.78	0.11	-0.88	
Total	Mean					0.33		0.85Yrs.

Table-2 indicates that the relative growth rates for all sources of Green Chemistry research output have decreased from 0.69 in 2000 to -0.78 in 2013. The mean relative growth rates for the periods 2000-06 and 2007-13 are -0.54 and 0.11 respectively. The overall study period has witnessed a mean relative growth rate of 0.33.

Contrastingly, the doubling time for publication of all sources of Green Chemistry research output has increased from 1.00 in 2000 to 2.03 in 2012. The mean doubling time for publications for the periods of 2000-06 and 2007-13 are -0.11 and 1.81 years respectively. The whole study period has witnessed a doubling time for publications at 0.85years. In general, Green Chemistry research output has shown a declining trend as far as the Indian publications are concerned inversely doubling time for publications have increased progressively.

5.2 SOURCEWISE DISTRIBUTION OF RESEARCH OUTPUT

A study of data in table-3 indicates the source wise distribution of research output in Green Chemistry.

This study has observed a total of 1448 publications in Green Chemistry during the period of fifteen years from 1999 to 2013. The publications of research output are not uniform throughout the study period. This is due to sharp increase in the number of publications in 2006 to 2013 than those of the remaining years of the study period. Out of various sources of publications in Green Chemistry, journal articles that appeared in the journals have shown a predominant contribution (88.47%) and this source occupies the first position. The source of Review papers comes second in order (5.59%) of sharing total research output in Green Chemistry during the period of analysis. The conference Paper form of publications occupies the third position (5.18%) with respect to total output in Green Chemistry research during the study period. The Article in press as the source of output comes fourth (0.41%) of the total Green Chemistry output. The Letter and short survey constitute 0.14 percent in overall Green Chemistry output. It records the fifth place in the overall publications of Green Chemistry literature. Finally Editorial as the source of Green Chemistry literature contributes 0.07 % of output in the overall publications and it was reported only in the year 2001.

Table-3: Source wise distribution of Green Chemistry Research output

Year	Article	Review	Conference Paper	Article in Press	Letter	Short Survey	Editorial	Total
1999	5	-	-	-	-	-	-	5
2000	10	-	-	-	-	-	-	10
2001	11	1	4	-	-	-	1	17
2002	11	1	4	-	-	-	-	16
2003	24	-	1	-	-	-	-	25
2004	27	4	-	-	-	-	-	31
2005	41	5	-	-	-	-	-	46
2006	59	2	16	-	-	1	-	78
2007	57	2	4	-	-	-	-	63
2008	64	-	4	-	-	-	-	68
2009	113	5	5	-	-	-	-	123
2010	153	11	5	-	1	-	-	170
2011	243	13	4	-	-	-	-	260
2012	328	25	13	1	-	1	-	368
2013	135	12	15	5	1	-	-	168
Total	1281 (88.47)	81 (5.59)	75 (5.18)	6 (0.41)	2 (0.14)	2 (0.14)	1 (0.07)	1448 (100)

5.3 Ranking of Authors Productivity based on Publications

Table- 4 indicates ranking of authors by number of publications. Authors “Yadav GD” published highest number of articles for the study period with 26 records, consecutive authors “Kidwai M” are published next highest number of articles for the study period with 20 records. “Kumar R”, Ranu, B C and Philip are published same number of articles published for the study period 12 records. Thus the most-cited authors are distinguished from the most-published ones. It is found from the analysis that Lotka’s law may not be applicable with regard to author productivity in proliferation of research in Green Chemistry as the research papers equally distributed by a large number of authors.

5.4 DEGREE OF COLLABORATION

It could be learnt from the above discussion that the percentage of single authored paper is less than that of multi authored papers. In order to determine the collaboration in quantitative terms, the formula suggested by K. Subramanyam was tested. It is inferred from the table -5 that at the aggregate level, the degree of collaboration is of 0.95 during the study period 1999 to 2013 i.e., that is out of total 1448 literature published, 96% of them or published under the joint author of publications in Green Chemistry

research output. The period wise analysis indicates that its level is somewhat less in the first period [1999-2006: 0.94] and it has shown. An increasing trend during the period [2007-13: 0.96]. This brings out clearly the high level of prevalence of collaborative research in Green Chemistry. Based on this study, the result of the degree of collaboration $C=0.95$ i.e., 95 percent of collaboration authors articles published during the study periods

Table 4: Author Productivity

Name of the Authors	No. of Article Published	Rank
Yadav, G.D.	26	1
Kidwai, M.	20	2
Kumar, S.	12	3
Ranu, B.C.	12	3
Philip, D.	12	3
Maiti, S.K.	11	4
Rai, S.B.	11	4
Singh, R.K.P.	10	5
Sharma, L.K.	10	5
Gopalakrishnan, M.	9	6
Singh, S.	8	7
Kanagarajan, V.	8	7
Dandia, A.	8	7
Thanusu, J.	8	7
Sureshkumar, P.	7	8
Shingate, B.B.	7	8
Shingare, M.S.	7	8

Table-5: Showing Degree of Collaboration

Year	Single Author		Multiple Authors		Total	Degree of Collaboration	Mean in Degree of Collaboration
	No of Output	%	No of Output	%			
1999	-	-	5	100	5	1	0.94
2000	1	10	9	90	10	0.9	
2001	2	11.76	15	88.24	17	0.88	
2002	1	6.25	15	93.75	16	0.94	
2003	1	4	24	96	25	0.96	
2004	3	9.68	28	90.32	31	0.90	
2005	-	-	46	100	46	1	
2006	8	10.26	70	89.74	78	0.90	0.96
2007	2	3.17	61	96.83	63	0.97	
2008	4	5.88	64	94.12	68	0.94	
2009	8	6.56	114	93.44	122	0.93	
2010	9	5.29	161	94.71	170	0.95	
2011	12	4.60	249	95.40	261	0.95	
2012	7	1.90	361	98.09	368	0.98	
2013	4	2.38	164	97.62	168	0.97	
Total	62		1389		1448		0.95

5.5 Lotka’s law in Relations to Author Productivity

It is relevant to analyse the implications of Lotka's law in relation to author productivity. It explains that a number of authors making ‘n’ contribution is about 1/n² of those making a single contribution and the proportion of the contribution that make a single contribution is about 60 per cent. In the present study Green Chemistry scientists author productivity is

examined. At the first observation that analysed data invalidate Lotka's findings that the proportion of all contribution that make a single contribution is less than 60 per cent. Further, Lotka's dx² model confirms the same fact. It explains the fact that the calculated dx² value of 269.60 is much less than the table value in 14 degrees of freedom at 5 per cent level of significance. Thus the present analysis clearly invalidates Lotka's findings.

Table 6: Showing productivity of author based on Lotka’s law

No. of contribution	Observed number of authors with ‘n’ or (an) or (f)	Observed percentage of authors 100Xan/al	Expected number of authors (an=an/n ²)or(p)	Expected percentage of authors predicted by Lotka (1926)100/n ²	(F-P) ² /P
1	325	100	325	100	0
2	147	45.23	81.25	25	53.21
3	72	22.15	36.11	11.11	35.67
4	51	15.69	20.31	6.25	46.37
5	24	7.38	13	4.00	9.31
6	18	5.54	9.03	2.77	8.91
7	10	3.08	6.63	2.04	1.71
8	13	4.00	5.08	1.56	12.35
9	12	3.69	4.01	1.23	15.92
10	7	2.15	3.25	1.00	4.37
11	9	2.77	2.69	0.86	14.80
12	6	1.85	2.26	0.69	6.18
13	5	1.54	1.92	0.59	4.94

14	4	1.23	1.66	0.51	3.29
15	3	0.92	1.44	0.44	1.69
124	706			X ²	218.72

Testing of a prediction depends upon several factors. In the present analysis, the productivity is observed which is affected by several factors. If complete publication details of authors are taken, Lotka's law testing may present a different picture. Moreover, if sampling size increases the results may get changed. But as a whole, the data analyzed here, discounted Lotka's law to a larger extent.

5.6 Analysis the Ranking list of Journals and their Published Articles

Journals, one of the primary sources of information are the vehicles of current output of knowledge. A higher birth rate of periodicals can be a measure of the growth of in the field of knowledge. It is an .

accepted fact that in the field of science there is apparently on increasing rate of birth of journals to meet the rapid explosion of information. Table -7 shows that ranking of journals according to their productivity. The total number of 350 journals published 1281 articles. These 350 journals are arranged in the decreasing order of productivity.

The Spectrochimica Acta Part A Molecular and Biomolecular Spectroscopy ranked first in order published 69(5.38%) articles. Green Chemistry occupied second in order published 54(4.22%) articles during the period of study. The Journal of Tetrahedron letters ranked third in order published 52(4.06%) articles. The journal of Rsc Advances ranked fourth in order published 41(3.2%) articles during the period of study the remaining journals ranked to their published articles.

Table-7 Showing Ranking of Journals according to Bradford's Distribution

S.NO	Name of the Journal	No. of Article Published	%	RANK
1	Spectrochimica Acta Part A Molecular and Biomolecular Spectroscopy	69	5.38	1
2	Green Chemistry	54	4.22	2
3	Tetrahedron Letters	52	4.06	3
4	Rsc Advances	41	3.2	4
5	Asian Journal of Chemistry	24	1.87	5
6	Colloids and Surfaces B Biointerfaces	24	1.87	5
7	Synthetic Communications	24	1.87	5
8	Journal of the Indian Chemical Society	22	1.72	6
9	Dalton Transactions	21	1.64	7
10	International Journal of Chemtech Research	19	1.48	8
11	Indian Journal of Chemistry Section B Organic and Medicinal Chemistry	18	1.41	9
12	Journal of Agricultural and Food Chemistry	17	1.33	10
13	Journal of Materials Chemistry	16	1.25	11
14	Chemical Communications	15	1.17	12
15	Catalysis Science and Technology	15	1.17	12
16	Journal of Hazardous Materials	14	1.09	13
17	International Journal of Chemtech Research	19	1.48	8
18	Langmuir	12	0.94	14
19	Chemistry A European Journal	11	0.86	15
20	Der Pharma Chemica	11	0.86	15

5.7. BRADFORD DISTRIBUTION

The Bradford law was formulated in the year 1948. It examines essentially that a group of journals are arranged in an order of decreasing productivity. It means the journals that yield that most relevant article coming first and the most unproductive in the last. Table No.30 shows clearly that the ranking list of journals contributed by Indian Green chemistry scientists in an order of decreasing productivity.

Table No. 8 indicates that the first fourteen journals covered more than one third of the total articles published. The next sixty journals covered another one third of the articles. The remaining 276 journals covered the last one third of the published articles. According to Bradford's distribution the relationship between the zone is 1: a: a², while the relationship in each zone of the present study is 14:60:276 which does not fit into Bradford's distribution.

Table -8: Ranking Journals According to Bradford Distribution

S. NO.	No. of Journals	No. of Articles	Total No. of Articles	Cum. No. of Articles
	1	69	69	69
2	1	54	54	123
3	1	52	52	175
4	1	41	41	216
5	3	24	72	288
6	1	22	22	310
7	2	21	42	352
8	1	19	19	371
9	1	18	18	389
10	1	17	17	406
11	1	16	16	422
12	2	15	30	452
13	1	14	14	466
14	1	12	12	478
15	3	11	33	511
16	4	9	36	547
17	5	8	40	587
18	12	7	84	671
19	10	6	60	731
20	22	5	110	841
21	25	4	100	941
22	28	3	84	1025
23	33	2	66	1091
24	190	1	190	1281

The easy and interesting observation from the table is the number of journals in each zone. As per Bradford's formulation, it should be 3:9:27, whereas the observed number of journals in the three zones stands as 14:60:276. This shows that core contributions are given by a very few journals, i.e., less than Bradford formulated and the final zone contains a very large number of journals, i.e., much more than the Bradfordian formula.

It is a clear indication that core zone is much concentrated and the other zone is much extended and that shows the scattering of information in Green chemistry is more. When this analysis is done for a wider range of periods, the extent of scattering can get increased. Hence the analysis of data clearly discounts Bradford's law of scattering.

5.8 Country wise Distribution of published Article

It is evident from the table-9 Indian Green chemistry Scientist published their articles in the journals of 43 countries including India. It is noted that Indian rank the first place (83.55%) in terms of the number of articles published in total. Next to India, USA ranks second in order (3.52%) in published research article in total. Next, South Korea ranks third in order (1.79%) in publishing Green Chemistry research articles respectively.

Table 9: Country wise Distribution of published Article

Country	No. of articles	Percentage	Cumulative
India	1448	83.55	1448
United states	61	3.52	1509
South korea	31	1.79	1540
United kingdom	20	1.15	1560
Germany	18	1.04	1578
France	15	0.87	1593
Taiwan	12	0.69	1605
Spain	11	0.63	1616
Japan	11	0.63	1627
Saudi arabia	9	0.52	1636
Canada	8	0.46	1644
Portugal	8	0.46	1652
Australia	7	0.40	1659
Italy	7	0.40	1666
Switzerland	6	0.35	1672

Malaysia	5	0.29	1677
Belgium	5	0.29	1682
Netherlands	5	0.29	1687
China	5	0.29	1692
South africa	4	0.23	1696
Sweden	4	0.23	1700
Singapore	4	0.23	1704
Nigeria	3	0.17	1707
Poland	2	0.11	1709
Israel	2	0.11	1711
Ireland	2	0.11	1713
Mauritius	2	0.11	1715
Egypt	2	0.11	1717
Denmark	2	0.11	1719
Belarus	1	0.06	1720
Bulgaria	1	0.06	1721
Norway	1	0.06	1722
Oman	1	0.06	1723
Philippines	1	0.06	1724
Libyan arab jamahiriya	1	0.06	1725
Russian federation	1	0.06	1726
Slovakia	1	0.06	1727
Hungary	1	0.06	1728
Hong kong	1	0.06	1729
Mexico	1	0.06	1730
Argentina	1	0.06	1731
Ukraine	1	0.06	1732
New zealand	1	.06	1733
Total	1733	99.9	

6. Findings and Conclusion

The present study comes out the following remarkable observations:

The findings of source wise distribution of Green Chemistry research output bring out the facts that of the various sources of Green Chemistry literature publications, the articles that appeared in journals record the first order followed by Review, Conference paper, Article in press, letters, Short survey, and editorial in their respective order. In general, publications of articles in journals take the predominant representation. It is due to the prevalence of greater level of procolative and dissemination effects of journals throughout the world.

The finding of growth of publication of Green Chemistry research output brings out the research

paper published trend in increasing and decreasing trend. The overall study period the highest percentage publication published in 2012.

The analysis of the growth of Green Chemistry literature at the Indian level reveals that the relative growth rates of Green Chemistry research output have shown a declined trend, contrastingly doubling the time for publications that have increased remarkably.

The find output author contribution, Yada G.D has published the highest number of articles (26articles) in the field of Green chemistry in Scientometric with the first rank. And followed Kidwai M has published next highest (20 article) with second rank. The following of Author's highest contribution, Indian Country author contribution is high.

The findings of degree of collaboration analysis reveal the following facts that the case of single author contributed papers is less. It brings out clearly the high level prevalence of collaborative research in Green Chemistry. It indicates that research activity; now-a-days relies mainly on group of researchers.

The findings of classification of journals according to Bradford distribution reveal the facts that the first fourteen journals covered more than one third of the total articles published. The next sixty journals covered another one third of articles. The remaining 276 journals covered the last one third of published articles, suggesting the validity of Bradford law.

The findings of the analysis of geographical representation and subject of journals and then published papers reveal the following facts. Out of various aspects of Green Chemistry related journals the Spectrochimica Acta part A molecular and biomolecular spectroscopy, Green Chemistry, Biointerfaces takes the first order followed by biological aspect, fisheries aspect and other aspect. The greater level of research output in Chemical aspect indicates the progress of research in the field.

The findings of distribution of Indian Green Chemistryscientists published articles in the journals of various countries .reveal the fact that Indian Green Chemistryscientists have contributed their research focus mainly in Indian journals. The countries such as USA, Southkorea and United Kingdom have considerably recognized the research articles of Indian Green Chemistryscientists and published the

same in their journals. It is not up to the mark in the case of other countries.

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