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# Growth of Literature and Measures of Scientific Productivity of Indian Chemical Science Research during 2002-2016

M. Chaman Sab\*, P. Dharani Kumar, B.S. Biradar

Department of Library & Information Science, Kuvempu University, Shankaraghatta - 577 451, Karnataka, India.

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#### ABSTRACT

This study reports the data analysis of chemical science research World and India during 2002-2016. Different data sets have been used for application of different indicators, publications, growth rate, areas of research and discussing its media of communication, strength and weakness in the areas of research, quality of research output, nature of highly cited papers, collaboration (national and international). The analysis of chemical science has finds the publications share of India during 2002-2016 was 5.46%, which has increased from 3.94 in 2002 to 6.99 in 2016 and it is observed from the study that the percentage of India's papers compared to that of the world's papers. India's share of science and technology research output increased from 3.94% in 2002 to 6.99% in 2016. The study shows a significant increase and suggests a 5.30% average growth in the yearly share and data has been collected from Web of Science database.

# 1. Introduction

Scientometrics' is the branch science of science that describes the output traits in terms of organizational research structure, resource inputs and outputs, develops benchmarks to evaluate the quality of information output. Scientometric research publications are a quantitative measure for the basic research activity in a country. Scientometrics is one of the most important measures for the assessment of scientific productions. There are many definitions for the term 'Scientometrics' in the literature; Scientometrics is the quantitative study of the disciplines of science based on published literature and communication [1]. At present the scientometrics study is one of the truly interdisciplinary research fields extended to almost all scientific fields. Scientometrics applications are used to measure scientific activities, mainly by producing statistics on scientific publications indexed in databases [2].

The field of library and information science (LIS) has developed several quantitative methods to study the various aspects of subjects. The metrics of LIS are continuously increasing, starting from librametrics, bibliometrics, scientometrics, informatics, webometrics, netometrics to cybernetics [3]. The study intends to explore the blueprints of scholarly communication of Indian chemical science for the period 2002 to 2016 and determine to exposure the quality of contributions.

The generation of new scientific and technical knowledge/information has been accelerating over the past several years. In recent years an increasing attention has been paid to the social dimensions of scientific community that produces sciences. But this unprecedented growth in literature has become a major concern for the scientists, scholars, and library professional as they try to keep themselves abreast with new advances in their subject, and information professionals try to organize this knowledge. How the growth, origin and language of literature reflect in various national level activities in R & D is a matter of great concern to the managers of the scientific activities in government industry and in academic community.

The word 'growth' refers to an increase, expansion in actual size, implying a 'change of state'. Change in size of literature over a specific period of time is termed as 'growth of literature'. A systematic study of the increase in scientific literature, scientific community and institutions etc. facilitates quantitative and qualitative understanding of science and various scientific phenomena. In the recent past, studies dealing with the assessment of scientific research in chemical science by different nations

have been reported in this study. The present study seeks to assess the contribution of major countries as reflected by the coverage of publications in web of science database during 2002 to 2016.

The past decade has witnessed the modern advances of high-throughput technology and rapid growth of research capacity in producing large-scale biological data, both of which were concomitant with an exponential growth of chemical science literature. This wealth of scholarly knowledge is of significant importance for researchers in making scientific discoveries and healthcare professionals in managing health-related matters. However, the acquisition of such information is becoming increasingly difficult due to its large volume and rapid growth. In response, the web of science and other citation databases are continuously making changes to their web service for improvement to help users in quick and efficient search and retrieval of relevant publications [4].

Velmurugan [5] has studied the research output of 203 articles published in Annals of Library and Information Studies journal for a period 2007-2012, It was found that the most of the contributions are by two authored papers i.e., 88 (43.35 %.). The degree of collaboration ranges from 0.57 to 0.82 and the average degree of collaboration is 0.64. Thanuskodi [6] has examined the research output of social science subjects, study covers year-wise, institution-wise, country-wise, authorship pattern, range of references cited of the articles etc. Kumar et al. [7] analysed the growth and development of bibliometric and scientometric research in the field of physics and engineering and data has been retrieved from INSPEC Database during 1999-2008. It found that the authorship and collaboration trend was towards multi-authored papers. Guan & Ma [8] have observed the China's Semiconductor Literature and found mega authored papers records that show higher value for coauthorship index. Patra et al. [9] have explored the growth pattern, core journals and authors' distribution in the field of bibliometric using data from Library and Information Science Abstract (LISA) and found that the growth of literature does not show any definite pattern. Kannappanavar et al. [10] have analysed the publishing trends of Indian Chemical Scientists during 1996-2000, which shown average number of authors per paper has increased from 7.52 to 8.39.

The main objective of the study is to present the growth of literature and make the quantitative assessment of status of chemical science research in India by way of analyzing the following features of research output, to find out year-wise growth of publications, the domain-wise contributions, language-wise distribution of publications, the channels of communications used by the scientists, collaboration pattern in the publications, the extent of international collaboration, and source-wise distribution of journals.

<sup>\*</sup>Corresponding Author: chamansabm@gmail.com(M. Chaman Sab)

# 2. Experimental Methods

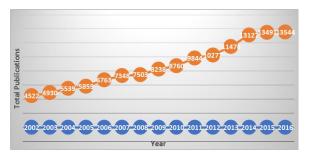
The data for the present study were retrieved from ISI Web of Science database (including Science Citation Index (SCI), Social Science Citation Index (SSCI) and Arts & Humanities Citation Index (AHCI)). The data are extracted from Web of Science on 21st April, 2017. By using suitable search syntax, the data has been downloaded for the period 2002-2016. The collected data were analysed using MS-Excel Spreadsheet and MS-Word.

#### 3. Results and Discussion

#### 3.1 Status and Growth of World Chemical Science Literature

It could be clearly observed from the Table 1, the research output of India and Average Citations per Papers of India. India has produced 1,31,212 papers, and received 12,70,317 citations during the period 2002-2016, Average Citations per Paper is 9.68. As per the Web of Science data, the cumulative publications growth of chemical science research output of India had increased from 27,613 publications during 2002-2006 to 41,693 publications during 2007-2011, and 61,915 publications during 2012-2016

India has produced the highest publication i.e. 13,544 papers in 2016. The lowest publication is 4,522 in 2002. Chemical science publications are gradually increased year by year, the publications share of chemical science which has increased from 3.94% in 2002 to 6.99% in 2016. According to the research the trend line shows that there is a steady and significant increase in the publications in chemical science (Fig. 1). India's publications are gradually increased year by year. The global publications share of India during 2002-2016 was 5.46%, which has increased from 3.94 in 2002 to 6.99 in 2016.



 $\textbf{Fig. 1} \ \ \textbf{Indian} \ \ \textbf{Research output in chemical science}$ 

 $\textbf{Table 1} \ \textbf{Status of World and Indian Chemical science Literature}$ 

WORLD			INDIA				
Year	TP	%	TP	TC	ACPP	H-index	TP Share
2002	114912	4.78	4522	94726	20.95	105	3.94
2003	122020	5.08	4930	102072	20.7	113	4.04
2004	129479	5.39	5539	120603	21.77	114	4.28
2005	135085	5.62	5859	126800	21.64	122	4.34
2006	145318	6.04	6763	138815	20.53	127	4.65
2007	147836	6.15	7348	142009	19.33	119	4.97
2008	153488	6.38	7503	131716	17.56	112	4.89
2009	158723	6.60	8238	138103	16.76	110	5.19
2010	158913	6.61	8760	135258	15.44	109	5.51
2011	174805	7.27	9844	140215	14.24	100	5.63
2012	182690	7.60	10277	NA	NA	NA	5.63
2013	191773	7.98	11476	NA	NA	NA	5.98
2014	203848	8.48	13127	NA	NA	NA	6.44
2015	191732	7.97	13491	NA	NA	NA	7.04
2016	193822	8.06	13544	NA	NA	NA	6.99
2002-06	646814	26.90	27613	583016	21.11	NA	4.27
2007-11	793765	33.01	41693	687301	16.48	NA	5.25
2012-16	963865	40.09	61915	NA	NA	NA	6.42
2002-16	2404444		131221	1270317	9.68	NA	5.46

TP= Total Papers; ACPP=Average Citations per Paper, NA= Not available

The global research output in chemical science has increased from 1,14,912 in 2002 to 1,93,822 in 2016. World's publications had increased from 6,46,814 publications during 2002-2006 to 7,93,765 publications during 2007-2011, and 9,63,865 publications during 2012-2016. In the same manner, the Indian research output in chemical science too has increased from 4,522 in 2002 to 13,544 by 2016 (Table 2).

It is observed from the study that the above point gets clarified when we analyse the percentage of India's papers compared to that of the world's papers. India's share of science and technology research output

increased from 3.94% in 2002 to 6.99% in 2016. The plot shows a significant increase and the trend suggests a 5.30% average growth in the share per annum in the study period.

Table 2 Growth of Indian Research output in chemical science

Year	TP	% of TP Share
2002	4522	3.94
2003	4930	4.04
2004	5539	4.28
2005	5859	4.34
2006	6763	4.65
2007	7348	4.97
2008	7503	4.89
2009	8238	5.19
2010	8760	5.51
2011	9844	5.63
2012	10277	5.63
2013	11476	5.98
2014	13127	6.44
2015	13491	7.04
2016	13544	6.99
2002-2006	27613	4.27
2007-2011	41693	5.25
2012-2016	61915	6.42
2002-2016	131221	5.46

#### 3.2 Relative Growth Rate and Doubling Time

The table also represents the chronological distribution, Relative Growth Rate (RGR is the growth rate relative to the size of population or continuous growth rate with reference to scientific literature publication time, Relative Growth Rate (GR) is the increase in the number of publications per unit time) and Doubling Time (The doubling time (Dt) is the given period required for quantity to double in size or value) of world publications in the field of chemical science during the period 2002-2016.

One of the obvious features of scientific literature in recent years has been its rate of growth. A number of growth models have been proposed regarding the rate of growth. Price (1963) proposed an exponential rate of growth of scientific literature. He predicted a regular exponential growth with doubling period of ten to fifteen years.

# 3.2.1 World and India

The total output of world and India has been shown in Table 3 (fifteen year) (Figs. 2-5) along with the growth rate and doubling time. The table shows that the relative growth rate of world output decreases gradually from 0.72 to 0.02 in fifteen year's period (2002-2016). The reason for this growth due to the information communication technology and World Wide Web. The doubling time (Dt) correspondingly increases from 0.96 to 8.25 in this period. The mean growth rate and doubling time for the world is 1.13 and 1.17 respectively.

Indian output, as shown in Table 3, the growth rate decreases gradually from 0.74 to 0.11 during fifteen years period (2002-2016). This growth may be due to the establishment of major scientific institutions like DST, CSIR, NPL, NCL, etc., which resulted into more scientific research in chemical science. Correspondingly, the doubling time increases from 0.94 to 6.36 in the same period. The mean growth rate and doubling time for Indian output is 0.12 and 0.93.

But the year-wise analysis of growth rate and doubling time for world and India indicates a different finding. The growth rate of World is comparatively more than that of India. The average growth rate of world and India is 0.22 and 0.24 respectively. Correspondingly, the doubling time of world is 4.58 and India is 3.83 respectively.

Table 3 Relative Growth Rate and doubling time of World and India

Year	World Output	RGR	Dt	India Output	RGR	Dt
2002	114912			4522		
2003	122020	0.72	0.96	4930	0.74	0.94
2004	129479	0.44	1.59	5539	0.46	1.50
2005	135085	0.31	2.21	5859	0.33	2.10
2006	145318	0.25	2.72	6763	0.28	2.47
2007	147836	0.21	3.37	7348	0.24	2.94
2008	153488	0.18	3.92	7503	0.19	3.56
2009	158723	0.15	4.48	8238	0.18	3.91
2010	158913	0.13	5.17	8760	0.16	4.35
2011	174805	0.13	5.36	9844	0.15	4.52
2012	182690	0.12	5.80	10277	0.14	5.01

2013	191773	0.11	6.21	11476	0.13	5.14	
2014	203848	0.11	6.51	13127	0.13	5.15	
2015	191732	0.09	7.64	13491	0.12	5.69	
2016	193822	0.08	8.25	13544	0.11	6.36	
Mean		1.13	1.17		0.12	0.93	

RGR = Relative Growth Rate; Dt = Doubling Time

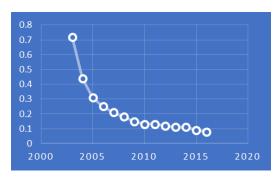


Fig. 2 Realtive Growth Rate (RGR) of world

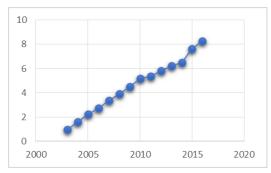


Fig. 3 Doubling Time (Dt) of world

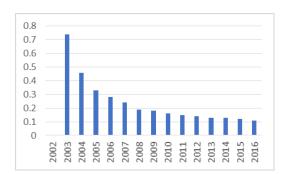


Fig. 4 Realtive Growth Rate (RGR) of India

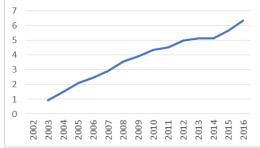


Fig. 5 Doubling Time (Dt) of India

# 3.3 Most Productive Authors in Indian Chemical Science Research

The table shows the highly productive authors from Indian chemical science research output during the study period. The top 25 authors having been identified as most productive authors in Indian chemical science research, the publications profile of these 25 authors along with their research output, citations received and h-index values are presented in Table 4. These 25 authors together contributed 21,257 papers with an average of 817.58 papers per author and account for 16.20% share in the cumulative Indian publications output during 2002-2016.

**Table 4** Most productive authors in Indian Chemical Science Research

Sl. No.	Authors	Affiliation	TP	% of 131221	TC	ACP	H-index
1	Kumar, A.	National University of Singapore, Department of Chemical & Bio	2227	1.70	29647	13.31	65
2	Kumar, S.	molecular Engineering Indian of Technology, Chemical Engineering,	1674	1.28	19748	11.8	52
3	Ghosh, S.	Gandhinagar Indian Institute Science, Bengaluru	1253	0.96	16984	13.55	51
4	Singh, S.	National Institute of Pharmaceutical Education and Research, Mohali	1121	0.85	12222	10.9	45
5	Kumar, R.	Guru Jambheshwar University, Haryana	1101	0.84	15068	13.69	51
6	Yadav, J. S.	Indian Institute of Chemical Technology, Hyderabad	914	0.70	17521	19.17	54
7	Das, S.	Indian Institute of Technology, Uttar Pradesh	897	0.68	11881	13.25	45
8	Singh, A. K.	Indian Institute of Technology, Uttar Pradesh	845	0.64	11457	13.56	46
9	Kumar, P.	Centre for Development of Advanced Computing,	804	0.61	9524	11.85	41
10	Kumar, V.	Pune Polymer Research Laboratory, Govt. Autonomous Science	760	0.58	9642	12.69	41
11	Sharma, S.	College, Jabalpur Indian Institute Science, Bengaluru	719	0.55	6784	9.44	33
12	Roy, S.	Indian Institute of Petroleum, Dehra Dun	698	0.53	8908	12.76	43
13	Kumar, M.	Gauhati University, Assam	677	0.52	9944	14.69	46
14	Sharma, A.	National Chemical Laboratory, Pune	663	0.51	8730	13.17	42
15	Singh, A.	Guru Nanak Dev University, Punjab	625	0.48	6058	9.69	28
16	Singh, P.	Indian Institute Technology, Kanpur	615	0.47	6995	11.37	35
١7	Das, D.		594	0.45	8671	14.6	44
18	Ghosh, A.	Indian Institute Science, Bengaluru	585	0.45	9290	15.88	46
19	Reddy, B. V. S.		578	0.44	11101	19.21	49
20	Pal, S.	Indian Institute of Chemical Technology,	574	0.44	7444	12.97	36
21	Kumar, D.	Hyderabad Birla Institute Technology & Science, Pilani	573	0.44	6764	11.8	36
22	Singh, N.	Guru Nanak Dev University, Punjab	569	0.43	8975	15.77	45
22	Banerjee, S.	National Chemical Laboratory, Pune	569	0.43	8036	14.12	38
23	Singh, B.	Indian Institute of Technology, Kanpur	551	0.42	6146	11.15	38
24	Sarkar, S.	Centre for DNA Fingerprinting and	537	0.41	6960	12.96	37
25	Bhattacharya, S.	Diagnostics, Hyderabad Jadavpur University, Kolkata	534	0.41	8881	16.63	42

TP= Total Papers; TC= Total citations; ACPP=Average Citations per Paper

The top 25 scientists from Indian chemical science research listed for their highest productivity are shown in Table 4. These 25 scientists have together contributed 21,257 papers in India's cumulative publications output with an average of 817.58 papers per scientist. According to highest publications Kumar, A, occupies first rank with 2,227 articles (29,647 citations) with 13.31 of aveage citations per paper and his h-index is 65, followed by Kumar, S. published 1,674 papers and received 19,748 citations with an average of 11.8 and his h-index is 52, Ghosh, S. published 1,253 papers (16,984 citations), Singh, S. produced 1,121 papers and received 12,222 citations (h-index 45), Kumar, R. published 1,101 articles and received 15,068 citations. Yadav, J. S. has published 914 articles and received 17,521 citations with an average of 19.17 and his h-index is 54 and Das, S. published 897 articles.

# 3.4 Channels Used for Communicating Cheimical Science Research

Table 5 lists the channels used for communicating of Chemical science research include articles published in the journals, reviews, conference and seminars proceedings, editorial materials, corrections and book

chapters. This study has observed a total of 1,31,221 publications in chemical science from India It has been observed from the table there are many communicating channels are used by scientists to publish their research articles in Indian chemical science literature. The majority of publications are published in Journals i.e. 1,22,712 (95.62), followed by Reviews 3,150 (2.40%) publications, 2,692 (2.05%) of papers published in Proceedings, 1,317 are as published as meeting abstracts and less than 1% of articles are published in other communication channels.

 $\textbf{Table 5} \ \textbf{Channels used for communicating cheimical science research}$ 

Sl. No.	Document Types	TP	% of 131221
1	Article	122712	95.62
2	Review	3150	2.40
3	Proceedings Paper	2692	2.05
4	Meeting Abstract	1317	1.00
5	Editorial Material	525	0.40
6	Correction	506	0.39
7	Letter	185	0.14
8	Book Chapter	47	0.04
9	Biographical Item	36	0.03
10	Retracted Publication	27	0.02
11	Software Review	11	0.01
12	News Item	7	0.01
13	Retraction	3	0.00
14	Reprint	2	0.00
15	Book Review	1	0.00

#### 3.5 Language-Wise Distribution of Publications

Table 6 provides the language-wise distribution of publications, the scientists researchers from Indian chemical science are published in different languages; English, Chinese, Japanese, German, Welsh, French, Estonian and Danish. It is observed that the majority (99.98%) of articles published in english language, 0.008 % articles published in chinese language and very less number of articles are published in remaining languages.

Table 6 Language-wise distribution of publications

Sl. No.	Languages	Records	% of 131221
1	English	131202	99.987
2	Chinese	10	0.008
3	Japanese	3	0.002
4	German	2	0.002
5	Welsh	1	0.001
6	French	1	0.001
7	Estonian	1	0.001
8	Danish	1	0.001

# 3.6 Organizational/Institutional Collaboration

Table 7 reveals the ranking list of top 25 highly productive Research Institutions in India based on their highest publications, citations, average citations per publication and h-index. According to the web of science database Indian Institute of Technology (IIT), Delhi contributed the highest publications to the field of engineering, i.e. 13,297 publications, followed by Bhabha Atomic Research Centre published 4.02 % i.e. 5,273 articles and received 1,00,899 citations with an average (average citations per paper) 19.14 and h-index is 102, Indian Institute of Chemical Technology produced 5,078 papers and received 61,095 citations next to this Indian Institute of Science published 3.73% of papers (4,888 papers and received 1,04,872 citations), National Chemical Laboratory published 3,992 papers University of Delhi produced 3,373 articles and received 63,109 citations and average citations per paper is 18.71, Banaras Hindu University produced 3,306 articles and received 61,905 citations and University of Hyderabad published 3,008 papers with 16.08 average citations per paper.

Table 7 Organizational/Institutional collaboration

Sl.	Organizations	TP	TC	ACP	H-	%
No.					index	
1	Indian Institute of Technology	13297	•	•		10.13
2	Bhabha Atomic Research Centre	5273	100899	19.14	102	4.02
3	Indian Institute of Chemical	5078	61095	12.03	79	3.87
	Technology					
4	Indian Institute of Science	4888	104872	21.45	113	3.73
5	National Chemical Laboratory	3992	85250	21.36	103	3.04
6	University of Delhi	3373	63109	18.71	88	2.57
7	Banaras Hindu University	3306	61905	18.73	88	2.52

University of Hyderabad 3008 48361 16.08 72 2.29 University of Calcutta 2845 50596 17.78 2.17 84 National Institute of Technology 10 2806 40332 14.37 71 2.14 Aligarh Muslim University 2697 48244 17.89 81 2.06 Anna University 2480 35230 70 12 14.21 1.89 13 Jawaharlal Nehru Centre for 2423 38147 15.74 1.85 Advance Science Research 14 Guru Nanak Dev University 2132 26736 12.54 55 1.62 15 Panjab University 2127 44319 20.84 82 1.62 University of Rajasthan 1844 21229 11.51 1.41 17 University of Madras 1836 27524 14 99 64 1.40 18 Annamalai University 1603 50581 31.55 96 1.22 19 Shivaji University 1577 37419 23.73 90 1.20 20 University of Allahabad 59 1556 21176 13.61 1.19 21 Central Drug Research Institute 1461 15184 10.39 44 1.11 Institute of Chemical Technology 1440 13.55 58 22 19515 1.10 Indian Institute of Technology 1342 23742 17.69 60 1.02 Guwahati 23 Osmania University 1280 18435 58 0.98 14.4 24 Sri Venkateswara University 1265 12981 10.26 39 0.96 University of Kalyani 1247 19268 15.45

# 3.7 Subject-Wise Productivity of Indian Chemical Science Research

Table 8 indicate the subject-wise productivity of India in chemical science research. Materials Science, Biochemistry Molecular Biology, Science Technology Other Topics, Pharmacology Pharmacy, Engineering, Electrochemistry, Crystallography, Metallurgy Metallurgical Engineering, Polymer Science, Food Science Technology, Thermodynamics, Energy Fuels, Nuclear Science Technology, Biophysics, Instruments Instrumentation, Environmental Sciences Ecology were considered on the basis of the total number of publications.

Table 8 Subject-wise productivity of Indian chemical science research

Sl.	Research Areas	TP	% of	TC	ACP	H-
No.			131221			index
1	Materials Science	16316	12.434			
2	Biochemistry Molecular	6922	5.275	89357	12.91	92
	Biology					
3	Science Technology Other	6891	5.251	121545	17.64	119
	Topics					
4	Pharmacology Pharmacy	5619	4.282	90529	16.11	97
5	Engineering	5593	4.262	69934	12.5	90
6	Electrochemistry	3888	2.963	74479	19.16	90
7	Crystallography	3623	2.761	54103	14.93	72
8	Metallurgy Metallurgical	2950	2.248	36214	12.28	57
	Engineering					
9	Polymer Science	2791	2.127	48148	17.25	79
10	Food Science Technology	2750	2.096	42802	15.56	78
11	Thermodynamics	2429	1.851	25652	10.56	49
12	Energy Fuels	2160	1.646	41837	19.37	75
13	Nuclear Science Technology	1958	1.492	11682	5.97	32
14	Biophysics	1741	1.327	37336	21.45	73
15	Instruments	1396	1.064	27375	19.61	69
	Instrumentation					
16	Environmental Sciences	1226	0.934	18645	15.21	62
	Ecology					
17	Agriculture	1164	0.887	13693	11.76	48
18	Spectroscopy	922	0.703	7629	8.27	33
19	Nutrition Dietetics	761	0.58	20090	26.4	64
20	Computer Science	722	0.55	8002	11.08	36
21	Plant Sciences	680	0.518	4186	6.16	27
22	Biotechnology Applied	655	0.499	15135	23.11	55
	Microbiology					
22	Mathematics	463	0.353	3750	8.1	25
23	Radiology Nuclear Medicine	324	0.247	2321	7.16	21
	Medical Imaging					
24	Toxicology	310	0.236	2778	8.96	25
25	Acoustics	287	0.219	6561	22.86	43

#### 3.8 High Productive Subject Areas in Chemical Science (World and India)

Table 9 provides the observation from the table Pharmacology Pharmacy, Electrochemistry and Crystallography have been identified as the three high priority research areas of Indian chemical science with each contributing publication share 4.28%, 2.96% and 2.77% in the national publication output during 2002-2016. High productive subject areas in chemical science Pharmacology Pharmacy had increased from 1,380 publications during 2002-2006 to 2,036 publications during 2007-2011,

and 2,203 publications during 2012-2016, Electrochemistry had increased from 544 publications during 2002-2006 to 1,210 publications during 2007-2011, and 2,134 publications during 2012-2016 and Crystallography had increased from 733 publications during 2002-2006

to 1,107 publications during 2007-2011, and 1,792 publications during 2012-2016. With regard to world Pharmacology Pharmacy, Electrochemistry and Energy Fuels are identified as the three high priority areas of world's chemical science research.

Table 9 High Productive Subject Areas in chemical science (World and India)

Highest Productiv	e Sub-fields in In	dian Chemical Sci	ence Literature	!						
	Pharmacol	ogy Pharmacy		Electroche	emistry	Crystallography				
Year	TP	TC	ACPP	TP	TC	ACPP	TP	TC	ACPP	
2002-2006	1380	38294	27.75	544	20103	36.95	733	18712	25.53	
2007-2011	2036	38183	18.75	1210	33934	28.04	1107	21424	19.35	
2012-2016	2203	15175	6.89	2134	21578	10.11	1792	14635	8.17	
2002-2016	5619	91652	16.31	3888	75615	19.45	3632	54771	15.08	
Highest Productiv	e Sub-fields in W	orld Chemical Sci	ence Literature		•	·				
	Pharmacol	ogy Pharmacy		Electroche	ochemistry Energy Fr			iuels		
Year	TP	TC	ACPP	TP	TC	ACPP	TP	TC	ACPP	
2002-2006	30920	722700	23.37	13243	530962	40.09	6169	277645	45.01	
2007-2011	36683	679832	18.53	27050	767619	28.38	16240	561222	34.56	
2012-2016	37175	249732	6.72	43278	464175	10.73	37349	605854	16.22	
2002-2016	104778	1652264	15.77	83571	1762756	21.09	59758	1444721	24.18	

Table 10 Medium Productive Subject Areas in chemical science (World and India)

	Polymer	Science		Thermod	Thermodynamics			Energy Fuels			Nuclear Science Technology		
Year	TP	TC	ACPP	TP	TC	ACPP	TP	TC	ACPP	TP	TC	ACPP	
2002-2006	328	11664	35.56	450	8761	19.47	232	8136	35.07	420	4549	10.83	
2007-2011	605	18684	30.88	803	10350	12.89	588	17284	29.39	547	4394	8.03	
2012-2016	1858	18422	9.91	1176	6851	5.83	1340	17153	12.80	991	2860	2.89	
2002-2016	2791	48770	17.47	2429	25962	10.69	2160	42573	19.71	1958	11803	6.03	
Medium Produ	ictive Sub-fie	elds in World	Chemical Sci	ence Literat	ure				·	•	*	•	
	Crystallo	graphy		Polymer	Science		Thermod	Thermodynamics			Instruments Instrumentation		
Year	TP	TC	ACPP	TP	TC	ACPP	TP	TC	ACPP	TP	TC	ACPP	
2002-2006	10441	223813	21.44	6473	228545	35.31	9061	165260	18.24	5726	141702	24.75	
2007-2011	15175	339954	22.40	11920	352206	29.55	11775	159345	13.53	10282	193711	18.84	
2012-2016	19732	155256	7.87	20415	207420	10.16	13997	73639	5.26	17261	133382	7.73	
2002-2016	45348	719023	15.86	38808	788171	20.31	34833	398244	11.43	33269	468795	14.09	

Table 11 Low Productive Subject Areas in chemical science (World and India)

Low Productive Su	ıb-fields in Indian	Chemical Science I	iterature							
	Instrument	s Instrumentation		Spectrosco	ру		Toxicology	Toxicology		
Year	TP	TC	ACPP	TP	TC	ACPP	TP	TC	ACPP	
2002-2006	184	7041	38.27	135	1812	13.42	67	945	14.10	
2007-2011	416	11115	26.72	264	2952	11.18	94	1209	12.86	
2012-2016	796	10663	13.40	523	2979	5.70	149	682	4.58	
2002-2016	1396	28819	20.64	922	7743	8.40	310	2836	9.15	
Low Productive Su	ıb-fields in World	Chemical Science I	iterature							
	Spectrosco	ру		Nuclear Sc	ience Technology		Toxicology			
Year	TP	TC	ACPP	TP	TC	ACPP	TP	TC	ACPP	
2002-2006	8681	216067	24.89	5684	57659	10.14	3579	74573	20.84	
2007-2011	10041	179785	17.91	6071	49272	8.12	3864	62036	16.05	
2012-2016	14451	83019	5.74	8149	23947	2.94	3997	23618	5.91	
2002-2016	33173	478871	14.44	19904	130878	6.58	11440	160227	14.01	

# 3.9 Medium Productive Subject Areas in Chemical Science (World and India)

Table 10 deals that Polymer Science, Thermodynamics, Energy Fuels and Nuclear Science Technology have been identified as the medium productive subject areas of Indian chemical science with each contributing publication share 2.13%, 1.85%, 1.65% and 1.49% in the national publication output during 2002-2016. Medium productive subject areas in chemical science Polymer Science had increased from 328 publications during 2002-2006 to 605 publications during 2007-2011, and 1,858 publications during 2012-2016, Thermodynamics had increased from 450 publications during 2002-2006 to 803 publications during 2007-2011 and 1,176 publications during 2012-2016, Energy Fuels had increased from 232 publications during 2002-2006 to 588 publications during 2007-2011 and 1,340 publications during 2012-2016 and Nuclear Science Technology had increased from 420 publications during 2002-2006 to 547 publications during 2007-2011, and 991 publications during 2012-2016. In the same manner in world's chemical science literature Crystallography (1.89% of total output), Polymer Science (1.61%), Thermodynamics (1.45%) and Instruments Instrumentation (1.38%) subjects are identified as the medium productive sub-fields.

# 3.10 Low Productive Subject Areas in chemical science (World and India)

Table 11 reveals that Instruments Instrumentation, Spectroscopy, Toxicology have been identified as the low productive subject areas of https://doi.org/10.30799/jacs.178.18040101

Indian chemical science with each contributing publication share 1.06%, 0.70% and 0.24% in the national publication output during 2002-2016. Low productive subject areas in chemical science Instruments Instrumentation had increased from 184 publications during 2002-2006 to 416 publications during 2007-2011, and 796 publications during 2012-2016, Spectroscopy had increased from 135 publications during 2002-2006 to 264 publications during 2007-2011 and 523 publications during 2012-2016 and Toxicology had increased from 67 publications during 2002-2006 to 94 publications during 2007-2011, and 149 publications during 2012-2016. Spectroscopy, Nuclear Science Technology and Toxicology are the three low productive subject fields in world's chemical science literature.

# 3.11 International Collaboration

Due to the interdisciplinary growth of subject, the universe of knowledge is ever dynamic and is ever-growing. More and more specialization in the subjects is achieved by the scientists, which is a result of increased participation of group of researchers of different expertise. It has been found from earlier studies that collaboration in research varies from discipline to discipline and for the same discipline from time to time and from one country to another [11].

Collaborative research has become a well established feature in the field of chemical science. It is observed that there is a consistently increasing

trend towards collaboration among various branches of chemical science which leads to collaborative authorship in literature.

Table 12 International Collaboration

Sl. No.	Countries	TP	% of 131221
1	USA	5255	4.005
2	Germany	2597	1.979
3	South Korea	2461	1.875
4	Japan	2062	1.571
5	England	1549	1.18
6	France	1484	1.131
7	Spain	1224	0.933
8	Saudi Arabia	1188	0.905
9	Italy	1040	0.793
10	Taiwan	1028	0.783
11	Canada	777	0.592
12	Peoples R China	699	0.533
13	Australia	691	0.527
14	Malaysia	663	0.505
15	South Africa	545	0.415
16	Switzerland	433	0.33
17	Singapore	400	0.305
18	Portugal	396	0.302
19	Poland	342	0.261
20	Belgium	322	0.245
21	Czech Republic	302	0.23
22	Sweden	301	0.229
23	Iran	276	0.21
24	Israel	275	0.21
25	Scotland	274	0.209

Table depicts the international collaborative papers of India with top with 25 countries during 2002-2016. The share of International collaborative publications in the Indian chemical science research output was 20.26% during 2002-2016. The largest number of collaborative publications (5,255) of India in chemical science research was with United States with 4.005% share, followed by Germany contributed 2,597 papers with 1.979% of total share, South Korea published 2,461 papers, Japan produced 2,062 papers, England published 1,549 articles, France contributes 1,484 papers, Spain published 1,224 papers and Saudi Arabia has contributed with India in chemical science research i.e. 1,188 papers. Many countries are contributed with below 1% share with India in chemical science research during 2002 to 2016 (Table 12).

## 4. Conclusion

The analysis of chemical science has finds the publications share of India during 2002-2016 was 5.46%, which has increased from 3.94 in 2002 to 6.99 in 2016 and it is observed from the study that the percentage of India's papers compared to that of the world's papers. India's share of science and technology research output increased from 3.94% in 2002 to 6.99% in 2016. Scientometric studies enable the science policy makers and

administrators to understand and grasp the growth, development and impact of research and to know the countries, institutions and the individual scientists who are active in a particular field of research activity. These studies will also provide some insights into the dynamics of research activity and enable one to gauge the direction of research activity and take appropriate measures.

Considering the above facts; it may be concluded that there is variation from one discipline to different periods, form one region to another. The collaboration in research is affected by various socio – economic and the other environmental factors prevailing in a specific society. Hence it is proposed further research be conducted to study the nature of collaborative output of different subject areas in science, social science and humanities. The investigations of such nature may be found useful in understanding the research and communication patterns for Indian Chemical Science. The observing study will be helpful in planning more effective research and communication systems.

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