

CHEMISTRY RESEARCH IN INDIA: MAKING PROGRESS, BUT NOT RAPIDLY

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ABSTRACT:

We performed a scientometric analysis of Indian contributions to prominent interdisciplinary chemistry journals from 1991 to 2015 in light of three recent studies that emphasized the high quality of Indian chemistry research: Thomson Reuters, Elsevier, and Nature Index. There was a comparison of India and China. From 2007 to 2014, there was a meteoric rise in chemical research in India. The number of articles produced each year increased by 8.9% during the course of the three-year moving average, with the top journals seeing an above-average growth. The citation counts of articles published in the Indian journals *Accounts of Chemical Research* and *Angewandte Chemie International Edition* (Angew. Chem. Int. Ed.) are significantly greater than those of publications from other countries. Indian experts are underrepresented in prominent scientific journals while making up 17% of the world's population. In percentage terms, this is equivalent to 0.7% of the journal's total volume. A total of 58.4% of these papers originated in the United States, 7.6% in Germany, and 5.1% in China, the same as India's share in Angew. The United States owns 28 percent, Germany 25 percent, and China 9 percent. The percentage in *Chemical International Edition* is 1.2%. Up until very recently, interdisciplinarity might have been illegal in Indian universities. The alarmingly low number of articles published by Indian academics and organizations is a major concern. Writings by Chinese authors rank highest in terms of citations for chemical articles. Items from India rarely make it into the top quartile. With 2,234 items in the top 1% in 2014, China had 38% and India had 2.3%.

Keywords: *Chemistry research; international collaboration; multidisciplinary journals; scientometric analysis.*

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1. INTRODUCTION

The foundation of this work is Arunan et al.'s brief but interesting study on Indian chemistry. Despite increases in research production and foreign participation, quantitative data show that Indian chemistry research remains uncompetitive.

Following that, we'll look at some statistics from sites like Natureindex.com, SCImago, and the Web of Science-Science Citation Index Expanded. Our talk will begin with some recent scientific news from India. Following that, we examine six general chemistry publications to see what Indian labs have contributed to them. *Science*, *Nature*, and the *Proceedings of the National Academy of Sciences of the United States* are among these magazines. This will make it easier to locate key businesses and people. India's performance is compared to those of other countries.

2. EARLIER STUDIES

Nature Index report on India

According to Nature Index², India excels in chemistry. Original research papers were examined by a global team of experts who chose 68 reputable journals. Despite "stagnant funding for R&D as a percentage of GDP, red tape, government indifference, and unfair appointments," scientists have managed to generate more work, according to the annual report. According to the survey, 14 chemistry publications and 4 interdisciplinary journals published articles praising India's chemistry capabilities. Scholars in India frequently

read the ten most prestigious journals in the physical and chemical sciences from the 68 publications that comprise the Nature Index. Chemistry appears to be popular in India, since it is cited in more than half of the Nature Index articles published there. According to Nature Index (<http://www.natureindex.com/>), India placed twelfth overall and sixth in the chemical sciences in 2015 and 2016, publishing 516.8 weighted fractional count (WFC) publications. According to Nature Index 3, India is experiencing a surge in chemical research. South Korea's WFC of 590.40 (www.worldmeters.info) and WFC related to chemistry fell short of China's WFC of 4,194.16% and India's nominal GDP of 60% (Statisticstimes.com; IMF World Economic Outlook, April 2016). China and South Korea have led the ranking since its inception. According to the research, India has surpassed South Korea. While China's WFC increased by 15.5% and South Korea's by 1.3% between 2012 and 2016, India's WFC increased by 175% with a CAGR (Compound Annual Growth Rate) of 12.65% (Nature Index, 24 July 2016).

Chemistry accounts for around one-third of the coauthored publications in the 68 journals that comprise Nature Index. The proportion of Indian articles published in Nature Index journals by chemists increased from 35.5% in 2012 (ref. 4) to 36.2% in 2015 (ref. 5). China's share increased to 53% in 2012 and again in 2015, while South Korea's share declined to 40% and 41%, respectively

SCImago

According to SCImago (<http://www.scimagojr.com>), the number of chemical articles published in Asia between 1996 and 2004 exceeded that of the United States and Western Europe combined. By 2014, the margin had grown. Asia produced 106,763 of the 228,428 chemical publications published globally, Western Europe produced 56,404, and North America produced 40,379. Asian chemistry benefits from Singapore and Taiwan, in addition to India, South Korea, China, Japan, and Taiwan. According to SCImago, the number of citable documents submitted to the chemical literature by Indian researchers climbed from 4,035 in 1996 to 6,664 in 2004 and 16,576 in 2014. The percentage of chemical literature written by Indians increased from 4.58% in 1996 to 7.37% in 2004. The share of Asian clients from India increased substantially, rising from 16.12% in 1996 to 14.35% in 2004 and 15.76% in 2014. Because of China's progress, India's position in Asia has largely been sustained. SCImago's index has 232,304 articles from 857 publications classified as "Chemistry" as of June 17th, 2016. After China (63,193 papers) and the United States (35,610 articles), India finished in third with 16,159 publications. Analytical chemistry (1,635), chemistry—miscellaneous (8,166), electrochemistry (491), inorganic (1,432), organic (3,402), physical and theoretical (3,096), and spectroscopy (1,376) were among the topics covered in Indian papers. Because journals can be categorized into so many different regions, the number of chemical subfields exceeds the overall number of subfields

Elsevier port to DST

Between 2009 and 2013, the New Delhi Department of Science and Technology commissioned Elsevier to do research. According to the findings, 64,492 (or 17.6 percent) of the 366,445 chemical researchers were affiliated with Indian institutes (p. 93). In December 2015, there were 8,367 (10.1%) women among the 82,501 active chemical researchers. According to Arunan et al. 1, ten thousand persons work as chemists. With 81,080 publications published in the area between 2009 and 2014, India supplied 6.9% of the world's chemical articles. Chemical sales increased 7.9% in India, 9.9% in China, and 4.4% globally between 2009 and 2013.

The Indian Institute of Science, Bengaluru (2,562), the University of Delhi (1,429), Jadavpur University (1,462), the Indian Association for the Cultivation of Science (1,598), and the Indian Institute of Technology Bombay (1,496) in Mumbai had the most chemistry publications.

During that time period, India produced 2,895 of every 10,000 referenced scientific articles. 394 (or 13.6 percent) of these were chemical items. Only 0.49% of the 81,080 chemical papers were referenced in the top 1%. Chemical papers accounted for 3,667 (or 21.6%) of the 16,999 most referenced publications in China. One-third of China's 276,000 chemical items were frequently cited. From 2009 to 2013, 55,402 Indian papers were among the top 10% of total citations. Chemistry came in third position with 7,211 points. The top ten most-cited chemical research papers were written by 8.9% Indians. Chemical sciences accounted for 37,937 (or 13.4%) of China's 282,498 highly cited papers. China's chemistry-related publications accounted for 13.71% of the most referenced articles. Chemistry has less Indian publications cited in the top 1% and top 10% when

compared to other fields. In India that year, there were 2,895 scientific articles published, with 949 (32.8%) credited to engineering. 542 (18.7%) were in computer science, 538 (18.6%) in medicine, and 538 (18.6%) in physics and astronomy. The most often referenced subjects in India's scientific literature are computer science (17,535; 31.7%), physics and astronomy (8343; 15.1%), engineering (19,532; 35.3%), and materials science (8172; 14.8%).

Thomson Reuters report to DST

Thomson Reuters reported in a study for DST that chemical research in India is increasing. Between 2005 and 2014, India published more than twice as many chemistry-related articles. From 2005 to 2014, Indian scientists published a total of 89,598 chemistry-related articles. China controlled 15.64 percent of the chemical literature in 2005, and by 2014, it had climbed to 28.67 percent. India, on the other hand, has 5.34 percent and 8.07 percent, respectively. Despite an increase in the volume of research undertaken, an Elsevier survey indicated that only 0.49% of chemical papers in India were among the most widely referred in 2013 and 2014, compared to 1.19% in China. China accounts for 97 percent of the top ten most-cited papers, while India accounts for 69 percent.

According to InCites, Indian scholars were responsible for 3.4% of the scientific and technology publications indexed by WoS in 2014. Given that India is home to 17% of the world's population, this is quite low. The International Monetary Fund forecasted 3% nominal GDP growth in April 2016. Among India's scientific publications in 2014, 6.8% were related to chemical sciences. Among the 22 categories covered by the Essential Science Indicators database from Thomson Reuters, India had the biggest percentage of chemistry publications (19.7% in 2014).

From 2007 to 2014, there was an 8.9% rise in the number of chemical items produced in India, according to data from the World Organization for Science and Chemical Information (WoS-SCIE) as of August 1, 2016. The fields of atomic, molecular, and chemical physics witnessed a 12.7% growth, while biochemistry and molecular biology saw a 13.4% gain.

Study by Arunan et al

Scientific research in India started to expand in the mid-1990s after a lengthy period of stagnation; by 2013, it made up 3.5% of all research generated globally. There was a global ranking of the top five chemical publications from India. Numerous recommendations for changes followed an evaluation of India's pitiful performance. Half of India's chemical research, they claim, is done by just twenty prestigious universities. 1. Phys. Chem. Chem. Phys. (2.2%), Org. Lett. (2.5%), Langmuir (2.9%), Angew. Chem. Int. Ed. (1.1%), Inorg. Chem. (5.0%), J. Org. Chem. (5.2%), Phys. Chem. Chem. Phys. (6.0%), and other esteemed chemistry journals published papers by Indian writers between 2007 and 2011. They have previously said that potential results from chemical research in India were underappreciated until the late 1970s. People are ignoring the JACS system. It is unusual for Angew. Chem. Int. Ed. to publish articles written by Indian scientists.

We looked at WoS-SCIE from 2012–2015 to see what proportion of articles were published in Indian journals. This includes both solo publications and those in which Indian writers collaborated with scientists from other countries. When we compared India's share across all journals to Arunan et al., we found that it increased dramatically. Angew. Chem. Int. Ed. has 10,027 papers, with 176 coming from India. This represents 1.76 percent of the total. A number of reputable publications have estimated India's chemistry share to be higher than 6.8 percent, which, along with funding from Phys. Chem. Chem. Phys. and the creation of new Indian Institutes of Science Education and Research and Technology, all contribute to this disparity. The Research Board, established after the Science and Engineering Research Council was reorganised, was established for a legitimate reason, according to academics. Not a single evaluation has been conducted.

3. INDIA'S CONTRIBUTIONS IN THE LEADING CHEMISTRY JOURNALS

Citations include: Journal of the Indian Chemical Society (283 papers), Dalton Trans. (274 articles), New Journal of Chemistry (240 articles), Journal of Molecules and Structural Biology (219 pieces), Eur. J. Med. Chem. (192), Chem. Commun. (197), RSC Advances (2,174 articles), Journal of Alloys Compounds (306), and Medical Chemical Research (168 articles). Indian chemists used a couple of these periodicals.

Finding credible interdisciplinary chemistry research was essential for understanding India's contributions to the chemical literature. In addition, we reviewed articles from India that appeared in high-profile journals covering a broad variety of chemical subjects (Box 1).

Despite being founded in 1879 and 1887, respectively, JACS and *Angewandte Chemie* did not publish any Indian articles for a considerable amount of time. Lastly, JACS approved a 24-year-old Indian work that had been published by Dhar¹⁰. Indeed, modern chemistry in India can be traced back to Ray⁹'s inaugural publication. After splitting 70 pieces, Ray and his friends went their separate ways. There were 696 Indian publications published by JACS up until 2015. Since searching by country is not an option on the JACS website, most of the Indian paper data had to be collected manually.

Box 1. Quality journals across all branches of chemistry considered to assess the rise in contributions from India

Accounts of Chemical Research
Angewandte Chemie International Edition
Biochemistry
Chemical Communications
Chemical Science
Crystal Growth & Design
Dalton Transactions
Electrochemical Communications
Electrochimica Acta
Inorganic Chemistry
Journal of Biological Chemistry
Journal of Catalysis
Journal of Chemical Physics
Journal of Organic Chemistry
Journal of Physical Chemistry A
Journal of Physical Chemistry B
Journal of Physical Chemistry Letters
Journal of the American Chemical Society
Journal of the American Society of Mass Spectrometry
Journal of the Electrochemical Society
Langmuir
Macromolecules
Nature
Nature Chemistry
Organic Letters
Polymer
Proceedings of the National Academy of Sciences of the United States of America
Science

In 1937, Srikantan and Rengachari¹¹ from Andhra University published the sole Indian paper in *Angew. Chem.* before it began publishing in English. Like other countries, India's next contribution to this journal didn't come out until after the International Edition began publishing in 1962; the piece in question was written by Palit¹². *Angew. Chem. Int. Ed.* has published 425 articles between 1972 (the year of the second Indian paper¹³) and 2015 (the year of the last).

Journal of the American Chemical Society

From 1991 to 2015, scientists from a handful of Asian nations published a total of a hundred articles, as shown in Table 1. You can better understand the bigger picture of India's activities by keeping this in mind when you peruse the articles published in prominent multidisciplinary chemistry publications. The top two countries in terms of JACS paper production are China and Singapore. Table 1 shows that 495 JACS papers were written by academics from 82 different universities in India. University of Hyderabad contributed 39 papers, IIT Kanpur contributed 32, the Jawaharlal Nehru Centre for Advanced Scientific Research contributed 107, the National Institute of Interdisciplinary Science and Technology contributed 46, the National Chemical Laboratory contributed 44, and the Indian Institute of Science contributed 107. As the number of researchers working together increases, more and more studies include writers from other universities.

In the last quarter of a century, JACS has published works by prominent Indian authors such as G. R. Desiraju (16 articles), A. Ajaya-ghosh (15 articles), P. Balaram (IISc, 21 articles), E. D. Jemmis (IISc, 25 articles), and D. Ranganathan (14 articles). The years 2011–2015 saw the publication of a number of books written by promising young Indian authors. The study claims that 691 writers (including many non-US citizens) penned 144 pieces. Among the many distinguished Indian academics are SharathKandambeth, ParthaSarathy Mukherjee, AbhishekDey, Rahul Banerjee, and AbhishekDey (IACS, 5, 4, and 6 respectively). Applicants are not

required to submit their work to each and every school to which they apply. They held a position at UH before joining the team at IISc. Eighteen of their twenty-five publications appeared there, with twelve of those appearing in JACS. Finding the right association and author for a project might be difficult. Sudipta Roy (IISER, Kolkata; three JACS papers; average cites per publication: 66.6 worldwide, 56.93 in India, and 75.49 in China) and S. Roy (IISc; two JACS articles, 2011–2015) are examples of this type of author. The average number of citations for Chinese articles in Angew is 58.52, whereas Asian papers average 65.63. Chemical. There are 28.9 citations per article worldwide, 24.9 in India, and 28.82 in China.

Table 1. Number of papers published by selected Asian countries in three general chemistry journals during 1991–2015 (as seen from Science Citation Index Expanded)

Country	1991–2000		2001–2010		2011–2015		Total	
	No. of papers	Sum of citations	No. of papers	Sum of citations	No. of papers	Sum of citations	No. of papers	Sum of citations
<i>JACS</i>								
Japan	2,111	181,678	3,820	293,250	1,509	44,657	7,440	519,585
China	95	8,549	1,513	169,758	1,857	83,257	3,465	261,564
South Korea	135	13,660	649	65,910	485	19,198	1,269	98,768
Australia	269	18,726	363	26,545	225	7,550	857	52,821
India	138	9,029	213	14,948	144	4,206	495	28,183
Taiwan	97	7,158	263	18,622	128	3,928	488	29,708
Singapore	7	779	184	20,593	228	9,496	419	32,505
Total	2,852	239,579	7,005	609,626	4,576	172,292	14,433	1,023,134
World	22,229	1,697,637	30,981	2,364,429	14,428	442,825	67,638	4,504,891
<i>Angew. Chem.</i>								
Japan	479	37,814	1,771	129,574	1,292	28,646	3,542	195,356
China	48	5,246	1,049	113,757	2,210	75,134	3,307	193,536
South Korea	33	3,221	404	36,841	405	11,246	842	51,124
Australia	53	7,765	177	16,009	240	6,731	470	30,391
India	39	4,784	155	16,501	202	4,791	396	25,991
Singapore	9	735	109	10,298	269	9,019	387	20,008
Taiwan	19	867	109	7,251	135	3,529	263	11,612
Total	680	60,432	3,774	330,231	4,753	139,096	9,207	528,018
World	6,515	488,126	14,848	1,190,169	12,204	316,050	33,567	1,934,945
<i>Chem. Commun.</i>								
China	331	12,657	2,219	118,910	6,084	117,338	8,634	248,905
Japan	2,161	62,312	2,313	82,188	1,850	25,037	6,324	168,918
South Korea	137	5,895	662	33,236	946	15,517	1,745	54,648
India	377	11,653	462	17,678	794	11,347	1,633	40,678
Australia	352	10,931	361	16,416	470	7,809	1,183	35,156
Taiwan	164	4,210	232	9,653	312	5,131	708	18,994
Singapore	38	1,987	183	8,316	410	8,940	631	19,243
Total	3,560	109,645	6,432	286,397	10,866	191,119	20,858	586,542
World	11,887	378,785	15,831	652,149	17,520	276,443	45,238	13,07,377

Four in ten Indian JACS papers had an international author as a co-author. America, Europe, Asia, and Oceania were the most common countries of origin for our foreign collaborators. The majority of the research conducted at the institutional level have involved writers from the following agencies: the US Department of Defense (17), the Navy (16), the Naval Research Laboratory (15), the CNRS (12), France, and the DOE (9). Compared to Gottingen and the University of California System, eight each, Oxford, Osaka, and Stuttgart have contributed fewer. Globally, 60% of papers are now co-authored, up from just 20% in 1992 (ref. 15). Our 25-year prediction for Indian papers was 44%.

There is a great deal of international cooperation in JACS research from Asian countries, such as China (>65%), Australia (57%), Singapore (54.9%), South Korea (48.6%), Taiwan (31.8%), and Japan (20.7%). The average number of citations for Indian JACS publications is 57, while the global average is 66.6 and China's average is 75.5. During the 25-year history of JACS, 67,638 papers were published, with 39,477 (58.4%) coming from the

United States, 5156 (7.6%) from Germany, 3465 (5.1%) from China, and 495 (0.7%) from India. As of 12 May 2016, there have been over 4.5 million citations for these works, with four over 5,000, seven exceeding 4,500, and seventy-one above 1,000.

Angew andte Chemises International Edition

The countries of Asia and their Angew. Chem. Int. Ed. papers are listed in Table 1. More and more publications are coming in from Asia, particularly Singapore and China. With assistance from Asian chemistry organizations like the Chemistry Research Society of India, Wiley-VCH—publisher of Angew. Chem. International Edition—published Chemistry: An Asian Journal and Asian Journal of Organic Chemistry¹⁶. Greater emphasis on chemical research in the region allowed for the completion of this investigation.

The 84 Indian schools represented in Angew. Chem. Int. Ed. published 396 publications between 1991 and 2015 (Table 1). Respected experts in their domains, Ajayaghosh, Desiraju, Rao, and George are all researchers. There were a total of 729 authors mentioned in 202 publications published between 2011 and 2015. Not many of these writers were native-born citizens. Outstanding academic credentials are possessed by DebabrataMaiti (IITB 6), GovindasamyMugesh (IISc 4), Upadrasta Ramamurthy (IISc 4), TapanKanti Paine (IACS 5), SuhritGhosh, Narayan Pradhan, TalappilPradeep, and VenkataramanaRao G. Anand (IISER 4).

Worldwide authors accounted for around 38%. Members of the United States, Britain, Japan, and France made up the bulk of the international team. Most of the joint research came from the following places: the University of Gottingen (11 publications), the Max Planck Society (6 articles), the CNRS (10 papers), Stuttgart (7), Wurzburg (5), Duisburg Essen (4), and Cambridge (5).

China (34.3%), Singapore (33.1%), South Korea (40.3%), Australia (58.7%), and Japan (18.7%) are the countries that contribute the most to the research published in Angew. Chem. Int. Ed. Angew. Chem. Int. Ed. mentions 65.6 Indian papers, 57.6 worldwide, and 58.5 Chinese papers. Of the 33,567 papers published in Angew. Chem. Int. Ed., 9,395 (28%) were from Germany, 8,489 (25.3%) were from the US, and 3,307 (9.9%) were from China. As of May 12, 2016, these works had 1.16 million citations, with 4,657 exceeding 100, 9,300, 89, and 1000, respectively.

Chemical communications

Table 1 shows that although there are more publications published in Chem. Commun. by India, there are significantly more articles published by China, South Korea, and Singapore. Out of 178 institutes that published in 1985, 15 were Indian chemists; out of 1633 in 2015, 197 were. India has been publishing more papers at a faster rate than JACS and Angew. Chem. since 2008, as seen in Figure 1. What is causing this to occur? These communications are appreciated by many consumers since they are urgent, brief, and of excellent quality. If you're trying to sell a concept rather than evidence, like in cases involving strong interpretation, a long-time journal user will tell you that "it lets me say exactly what I want to say" in a journal. Some respectable publications may be too selective in their choice of referees, which could limit the creativity of their writers. Due to the exponential increase of articles in the domain, some more seasoned chemists are concerned that certain recently published experiments may not meet the standards set a few years ago.

In comparison to 29 papers from China and other countries, India had 25 papers out of 1,633 that were cited. There is an overseas author for about 35% of the articles published in India. The United States (76), Germany (48), France (30), Japan (34) and the United Kingdom (46). More than half of the Indian contributions come from institutions in the following lists: 204 from NCL, 202 from IISc, 139 from IACS, 127 from UoH, 109 from IICT, and 76 from IITB. Notable chemical research institutes and 19 publications from Guru Nanak Dev University are published in this magazine. Twenty researchers from the French National Center for Scientific Research (CNRS) and ten from the Japanese National Institute of Materials Science have teamed up with eight researchers from the University of California System, eight from the Japan Science and Technology Agency, and eight from Howard University. As shown in Table 2, India's activity is published in JACS, Angew. Chem., and Chem. Commun. Among these three journals, just 35 Indian universities have published. In the last 25 years, just nine schools have published 100 publications across all three journals: IISc

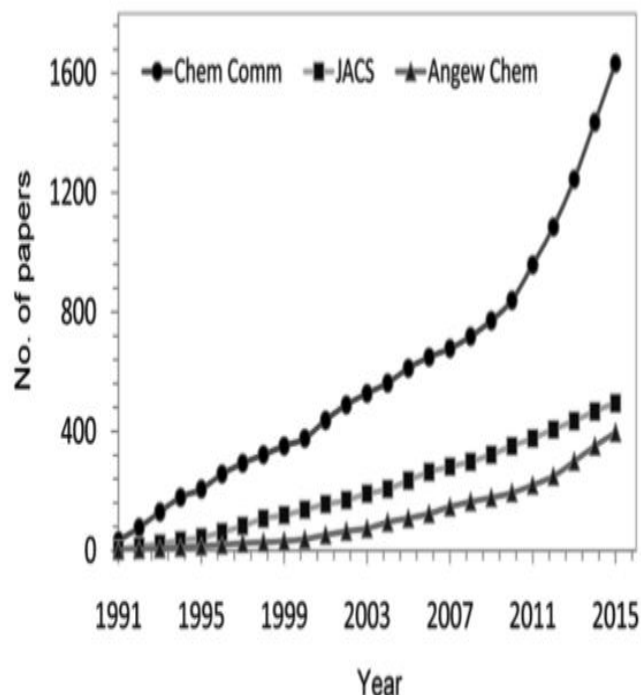


Figure 1. Number of papers published from India in three major general chemistry journals

Institution	JACS		Angew. Chem.		Chem. Commun.		Total	
	No. of papers	Sum of citations	No. of papers	Sum of citations	No. of papers	Sum of citations	No. of papers	Sum of citations
IISc, Bengaluru	107	5,779	64	4,603	202	6,280	373	16,662
CSIR-NCL, Pune	44	2,398	37	1,660	204	4,615	285	8,673
University of Hyderabad, Hyderabad	39	3,180	28	5,283	127	5,679	194	14,142
IACS, Kolkata	25	819	28	793	139	3,548	192	5,160
CSIR-IICT, Hyderabad	32	2,676	25	1,537	109	2,510	166	6,723
IIT Kanpur	43	2,571	25	1,433	73	1,507	141	5,511
JNCASR, Bengaluru	31	1,930	31	3,369	66	3,597	128	8,896
IIT Bombay, Mumbai	24	1,234	24	1,055	76	1,350	124	3,639
CSIR-NIIST, Thiruvananthapuram	46	3,997	24	2,687	44	992	114	7,676
IIT Madras, Chennai	13	382	12	471	56	918	81	1,771
IIT Kharagpur	11	730	6	95	57	1,887	74	2,712
IISER, Pune	5	98	9	407	53	683	67	1,188
CSIR-CSMCRI, Bhavnagar	7	545	5	236	40	986	52	1,767
Bhabha Atomic Research Centre, Mumbai	17	1,016	8	765	23	421	48	2,202
IISER, Kolkata	7	52	5	196	33	543	45	791
Guru Nanak Dev University, Amritsar	2	51	1	11	38	736	41	798
IIT Guwahati	3	51	9	425	28	688	40	1,164
IISER, Thiruvananthapuram	12	216	11	169	9	89	32	474
University of Delhi, Delhi	2	255	3	244	23	564	28	1,063
CSIR-CDRI, Lucknow	5	247	8	162	13	214	26	623
Jadavpur University, Kolkata	3	340	4	228	19	537	26	1,105
IISER, Bhopal	1	12	3	30	17	295	21	337
TIFR, Mumbai	5	103	5	137	11	80	21	320
University of Pune, Pune	7	214	2	47	12	157	21	418
Panjab University, Chandigarh	4	151	2	283	10	83	16	517
University of Calcutta, Kolkata	2	41	2	10	12	133	16	184
CSIR-IICB, Kolkata	1	28	2	14	10	75	13	117
NIPER, Mohali	2	137	1	27	10	365	13	529
CSIR-CCMB, Hyderabad	5	215	1	37	5	124	11	376
CSIR-IGIB, New Delhi	3	76	3	107	4	28	10	211
Tezpur University, Tezpur	1	28	7	77	2	15	10	120
CSIR-CLRI, Chennai	4	123	4	117	1	17	9	257
CSIR-NPL, New Delhi	4	457	1	4	2	11	7	472
BB Ambedkar University, Lucknow	1	14	2	40	3	60	6	114
S.N. Bose National Centre for Basic Sciences, Kolkata	1	16	3	110	1	5	5	131

Table 2. Distribution of papers published in all three general chemistry journals during 1991–2015 by institution

IACS (192), IICT (166), IITK (141), JNCASR (128), IITB (124), NIIST (114), NCL (285), UoH (194), IICL (373), and IITB (685). Here you can find the list of byline associations. Some of these establishments predate 1991. B. R. Ambedkar University, Tezpur University, and IISERs all came into being after 1991. According to Arunanet al.¹, very few organizations put out scholarly works of excellent quality. Seeing several lesser-known colleges included on this list is encouraging.

Accounts of Chemical Research

Among the 3,497 papers published in Acc. Chem. Res. between 1991 and 2015, with an average of 127.15 citations per paper (CPP), 72 (or 57.39 percent) were from India and 299 (or 107.14 percent) were from China. Out of the 72 papers published in India, 25 have garnered 100 citations or more, while 3 have received 1000 citations or more. Institutions and researchers such as UoH, JNCASR, NIIST, and IISc, as well as Desiraju, Rao, Nair, and Ajayaghosh, are accountable for the high average citations.

Two journals that started publishing in the last decade have had articles written by Indians.

Nature Chemistry

With a CPP of 45.26, Nature Chem. published 1621 papers between 2009 and 2015. Of these, 11 papers (CPP 23.45) are contributed by India, whereas 57 papers (CPP 66.82) are from China.

Chemical Science

The first year that India contributed more than 10 articles to this journal was 2014, even though it began publishing in 2010. In comparison to China's 591 papers (CPP 22.69), Indian scientists published just 28 papers (CPP 13.89) by year's end 2015. A number of institutions, including NCL, JNCASR, NIIST, and IISER Kolkata, have contributed to these works.

Multidisciplinary journals

Chemists contribute to both standard scientific journals and more interdisciplinary ones. Of particular note are Science, Nature, and PNAS. For contributions to Indian Nature from 2010 to 2015, a WoS-SCIE search returned 80 results. There might be room for two pieces of original chemistry—one in materials and one in biochemistry—if we exclude things like broad news articles, policy comments, book reviews, etc. In the period from 2010 to 2015, 92 papers were published in Indian Science. The chemistry-related six-paper set consists of four articles, an editorial, and a review. A search of the PNAS chemical division turned up twelve articles written by Indians. It is apparent that these publications do not publish any papers written by Indian chemists.

Highly cited papers

A large number of chemists like publishing in specialized, high-impact journals. According to a WoS-SCIE search, out of the more than 1.18 million chemical publications published between 2009 and 2014, 1.29 percent have been cited 100 times or more. In China, the similar values for over 240,000 papers are 1.65%. By the end of September 2016, 388 out of 68,300 Indian papers (or little more than 0.5%) have received 100 citations or more. Notable among the 103 journals that have published these 388 papers are J. Phys. Chem. C (15 papers from India between 2009–2014), Colloids and Surfaces B (15 papers), and Org. Lett. (12 papers). It is possible that young Indian chemists can get to the position of opinion maker by publishing regularly and extensively in class specialist publications.

4. INTERNATIONAL COLLABORATION

The percentage of Indian papers with co-authors from outside the country rose from 15.4% in 2005 to 20.7% in 2014, a compound annual growth rate (CAGR) of 3.34%, according to data on Indian publications in journals categorized as "Chemistry" and "Electrochemistry" by WoS-SCIE. During this time, India's number of cooperating nations rose from 56 in 2005 to 65 in 2008, 75 in 2011, and 95 in 2014.

DISCUSSION

As part of its mission to promote science in India, Nature Index is working to debunk the stereotype that the country undertakes little research. Nanoscience and chemistry, according to India's Minister of Science and Technology Harsh Vardhan, are driving innovation at the country's academic institutions.

Nature Index only keeps tabs on eighteen chemistry journals. By comparison, SCImago (powered by Scopus) records 857 journals, out of which 468 were accessible to Indian academics in 2014, whereas WoS-SCIE

indexes 600 chemical journals. India is ranked third in chemical research, following the US and China, according to Thomson Reuters, Elsevier, and SCImago. Scopus is used by Elsevier and WoS-SCIE by Thomson Reuters. At number eight on the Nature Index is India. With a one-order-of-magnitude increase in the number of articles evaluated, India moves up the rankings. This begs the question, "Are we publishing mediocre stuff?" since the ranking falls when only high-quality journal papers are considered.

Is it possible to maximize the potential of the scientific endeavor by extending it? The following statement by Chairman Mao is often cited as the most apt: "Every quality manifests itself in a certain quantity, and without quantity there can be no quality." In spite of the millions, Feng¹⁸ was able to leave the system and gain Earth recognition through "quantum fluctuation" after his visit to Israel. Although expanding the base may be challenging, several Indian specialists have emphasized its necessity^{19, 20}. Even though "educating, recruiting, and supporting its next generation of scientists will be India's greatest challenge," Vale and Dell²¹ argue that "the brightest students in India are simply not coming to graduate school."

Using data collected from WoS-SCIE over a six-year period, we determined the compound annual growth rate of Indian papers published in high-quality journals across most fields (Box 1), in order to test the premise that more researchers and research papers will result in higher-quality articles. From 1064 in 2010 to 1742 in 2015, the chosen journals published Indian papers at a CAGR of 10.4 percent. Publications pertaining to chemicals increased at a rate of 7.1% over that time. Indian chemical research is on the upswing, with more publications published in general and in higher-quality journals, but the country's studies aren't exactly leading the pack²². Indian researchers cited less chemical publications between 2005 and 2014 compared to global averages and both affluent and developing nations, according to a Thomson Reuters study⁸ that the DST commissioned. Out of the top ten most-cited chemical studies published between 2003 and 2012, India ranked fourth to ninth, despite an increase in higher-quality publications (ref. 23). The number of research papers published in China and those with many citations has grown significantly in the last several years. This chemical article has the most citations from the United States, China, Germany, and Japan. When looking at the top one percentile of the most referred papers, China had a little advantage over India in 2000 (Figure 2), but by 2014, it had risen considerably. Once held by the United States, China took the lead in 2013 in terms of paper citations (one percentile). The OECD's 2015–23 STI Scoreboard shows that out of twenty-seven disciplines, eleven had publications citing Chinese sources, putting China in the top four nations overall. Rather, chemical engineering is where India is represented.

Among the 35 Indian institutions that contributed to the journals JACS, Angew. Chem., and Chem. Commun. between 1991 and 2015, 21 are universities and colleges. There are 10 CSIR laboratories, two DST laboratories, and two DAE institutes included, in addition to four state universities (Calcutta, Punjab, Jadavpur, and Pune). Co-authors from outside the country make up 44% of JACS articles and 38% of.

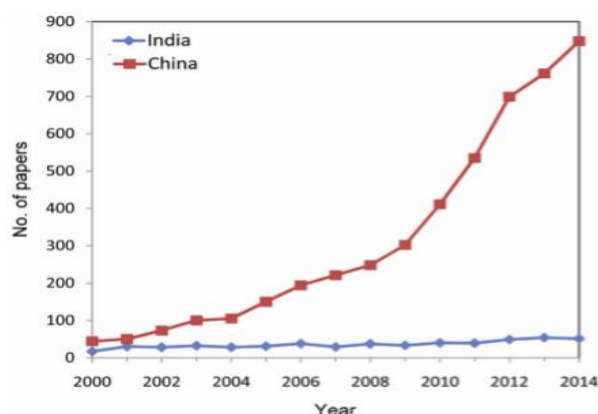


Figure 2. Nearly a quarter of all cited chemical research on Chemical Communication and Web of Science originates from China and India. With NCL and IISc in the forefront, this collection features articles from nine different universities. The low level of participation, particularly from public schools and other institutions, is deeply troubling.

Nature & Science and JACS have never published any work by Indian researchers. Publications like JACS, which

publishes work in every branch of chemistry, encourage and welcome papers from a wide range of academic fields. Chemical biology and materials science are rapidly expanding fields, but unfortunately, most academic departments still divide chemistry into physical, organic, and inorganic subfields^{25–26}. The fact that Indian laboratories are sluggish to embrace new approaches to chemical research is a major problem. The legacy of inorganic and natural product chemistry in India has also been disregarded²⁵.

According to Thomson Reuter's ranking of the 100 most powerful scientists worldwide, not a single Indian scientist hailing from an Indian university made the cut. This ranking was impacted by scientific articles published between 2000 and 2010. Rather, the roster had three South Koreans as well as a single Brazilian and a single South African. Assisting talented individuals who are part of fringe organizations is an excellent first step. Raise the bar for education and encourage more people to get degrees and participate in research. According to Ganesh²⁸ and Arunan *et al.*⁽¹⁾, foreign teachers will enhance science education in India.

As a means to "reverse the brain drain from the country" and entice talented scientists, the government has established multiple fellowships. According to K. S. Jayaraman (*pers. commun.*), comparable initiatives in China have been successful, but this one has not. Modern students often choose for less prestigious institutions. Over 60% of IISER grads go on to graduate school overseas, as Desiraju²⁹ predicted in 2008 and Ganesh²⁸ confirms. But a worried professor at a famous Indian university points out that not all people with a Ph.D. end up working as professors or researchers.

5. CONCLUSION

In conclusion, the landscape of chemistry research in India reflects promising strides toward advancement, albeit not at an accelerated pace. The nation has made commendable progress, evidenced by the growth of academic institutions, collaborative research endeavors, and contributions to various fields of chemistry. Despite these achievements, challenges like limited funding, infrastructure gaps, and retention of skilled talent persist, impeding rapid growth. Nevertheless, with a steadfast commitment to addressing these hurdles, fostering innovation, and promoting interdisciplinary collaborations, India's chemistry research can chart a more rapid and impactful trajectory, further enriching global scientific endeavors. Continued efforts and investments in nurturing talent, fostering collaborations, and bolstering infrastructure will be pivotal in propelling India's chemistry research toward greater heights in the years to come.

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