100 years of *Chemical Reviews*: contribution of the Indian chemists

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Chemical Reviews, a leading scientific journal published by the American Chemical Society in the field of chemistry is going to complete its 100 years of journey. On that note, this study aims to conduct a scientometric analysis of the contributions made by the Indian chemists to that journal. The analysis is based on scientometric indicators such as the number of publications, citation count and authorship patterns to provide a comprehensive overview of Indian scientists' impact on the journal. The study reveals that India is among the top contributors to the journal, with a substantial increase in the number of publications over the past few years. Furthermore, Indian authors have published highly cited articles, indicating the high-quality research being conducted in the country. The analysis of authorship patterns shows that collaborations between Indian and foreign researchers are increasing, highlighting the importance of international collaboration in scientific research. A comprehensive content analysis explores the focus area transition of the published work.

Keywords: Authorship pattern, *Chemical Reviews*, international collaboration, scientometric analysis, scientific research.

CHEMICAL REVIEWS remains the flagship scientific journal of the American Chemical Society (ACS) that publishes in-depth reviews and perspectives on a wide range of topics related to chemical sciences. Over the years, the journal has published numerous articles authored by scientists worldwide, contributing to advancing knowledge and understanding in chemical sciences[1]. *Chemical Reviews* (ISSN: 0009-2665) remains the top journal in chemistry, multidisciplinary with a journal impact factor of 62.1, over 230,000 citations, and over 6.3 million downloads. It started its journey in 1924 by William Albert Noyes (University of Illinois). The mission of *Chemical Reviews* is to provide comprehensive, authoritative, critical and readable reviews of important recent research in organic, inorganic, physical, analytical, theoretical and biological chemistry (https://pubs.acs.org/journal/chreay). The journal is about to complete its 100 years of service and dissemination of knowledge in the field of chemical sciences.

India is one of the largest and fastest-growing economies in the world, with a rich history of scientific innovation and discovery[2]. Indian scientists have made significant contributions to various fields of science, including chemistry[3]. However, there is a need to assess the contributions of Indian chemists to *Chemical Reviews* over the past 100 years of its journey.

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In recent years, there has been a growing interest in analysing scientific output from the viewpoint of scientometric studies, which provides valuable insights into the research trends, impact and productivity of scientists, institutions and countries[4]. Scientometric analyses of India's contribution to the field of chemistry have revealed a prominent leadership role played by Indian scientists on a global scale[5–9]. Furthermore, scientometric studies have explored various sub-areas within chemistry, such as alkaloid chemistry[10], analytical chemistry[11], organic chemistry[12–15], physical chemistry[16] and green chemistry[17] in the Indian perspective, to understand the growth of the literature and research trends in those areas. In addition, several studies have focused on individual journals, namely the *Indian Journal of Chemistry*[18–20] and the *Indian Journal of Chemical Technology*[21], employing scientometric indicators to ascertain the scholarly impact and research.

The present study aims to conduct a comprehensive analysis of the contributions made by Indian chemists to *Chemical Reviews* over the past 100 years. The analysis will focus on various scientometric indicators, such as the number of publications, citation count and authorship pattern, along with an in-depth overview of Indian chemists' impact on the journal.

Scope and coverage

The coverage of the study includes a 100-year timeframe from the commencement of *Chemical Reviews* until the

Table 1. Contribution of Indian scientists

Year	Total publications	Indian contribution	Percentage	Percentage with respect to the total	Activity index
1924–30	115	0	0.00	0.00	0.00
1931–40	299	1	0.48	0.33	12.76
1941–50	303	2	0.97	0.66	25.17
1951–60	257	3	1.45	1.17	44.52
1961–70	286	11	5.31	3.85	146.69
1971–80	263	5	2.42	1.90	72.51
1981–90	457	15	7.25	3.28	125.19
1991–2000	995	27	13.04	2.71	103.50
2001–10	1,718	38	18.36	2.21	84.36
2011–20	2,491	77	37.20	3.09	117.90
2021–2023	711	28	13.53	3.94	150.20
Total	7,895	207	100	2.62	Mean 80.25

present time (1924 to May 2023), encompassing all published articles by Indian chemists.

Method used

The first step of this study was to collect data from the Scopus database (https://www.scopus.com/). The data included all published articles in *Chemical Reviews* by Indian scientists, along with their bibliographic details such as author names, affiliations, publication year, times cited, etc. We have considered authors who have an institute affiliation with India.

Subsequently, the collected data were downloaded into an MS Excel file (.csv), cleaned, and prepared for analysis, including removing duplicates, correcting author names and affiliations, and standardizing the data to ensure consistency. Finally, 7895 articles were considered to be published in *Chemical Reviews* from 1924 to May 2023, of which 207 were published by Indian scientists.

Then, a scientometric analysis was conducted using the aforesaid data identifying the key trends and patterns such as publication growth, distribution of publications, citations, authorship trend, research trend, etc. Some statistical indicators were employed, such as activity index, author productivity, degree of collaboration (DC), collaborative index (CI), collaborative coefficient (CC), etc. VOSviewer (https://www.vosviewer.com/) for network visualization and OriginPro 8.5 (https://www.originlab.com/origin) for data plotting were used. Content analysis method was used to analyse the thematic growth, subject-wise development and research trend of these publications.

Analysis and findings

Publication trend of Chemical Reviews

Table 1 shows the distribution of research publications in *Chemical Reviews* from its commencement to the present time over the span of 100 years. The journal started its publication journey in 1924, and since then, it has published 7895 papers that have been considered for the present study. Figure 1 *a* shows the publication trend. Two distinct regions are evident from the plot. First, a plateau region from 1924 to the 1990s with an average of 30 publications per year, followed by regions of steep rise after the 1990s. This rise may be attributed to economic growth, institutional expansion, rapid growth in the number of research groups, the facile publication process and a positive attitude towards scholarly communications.

Most productive countries in Chemical Reviews

Table 2 shows the ranks of countries based on the number of papers published, with the corresponding percentage over 100 years. From the table, it can be seen that with 4050 papers, the United States of America holds the top position, accounting for 51.30% of the total papers, followed by Germany (9.02%), the United Kingdom (8.65%) and China (7.71%). India is positioned tenth with 207 papers, representing 2.62% of the total. This indicates that India actively contributes to research publications in *Chemical Reviews*.

Contribution of Indian chemists

Table 1 shows the growth of research papers in *Chemical Reviews* both overall publication-wise and by Indian scientists over time. From 1924 to 1960, only six papers have been contributed by Indian authors with respect to a total of 974 papers in the journal. The first article from an Indian author appeared way back in 1932. The number of published papers from India has increased over time. During 1961–80, there were 16 papers representing 7.73% of the total publications. From 1981 to 2020, there was a steady rise in the number of papers from India, and the percentage of publications varied between 7.25 and 37.20. The most recent data show that from 2011 to 2020, India contributed 77 papers, accounting for 3.09% of the total. As of the latest

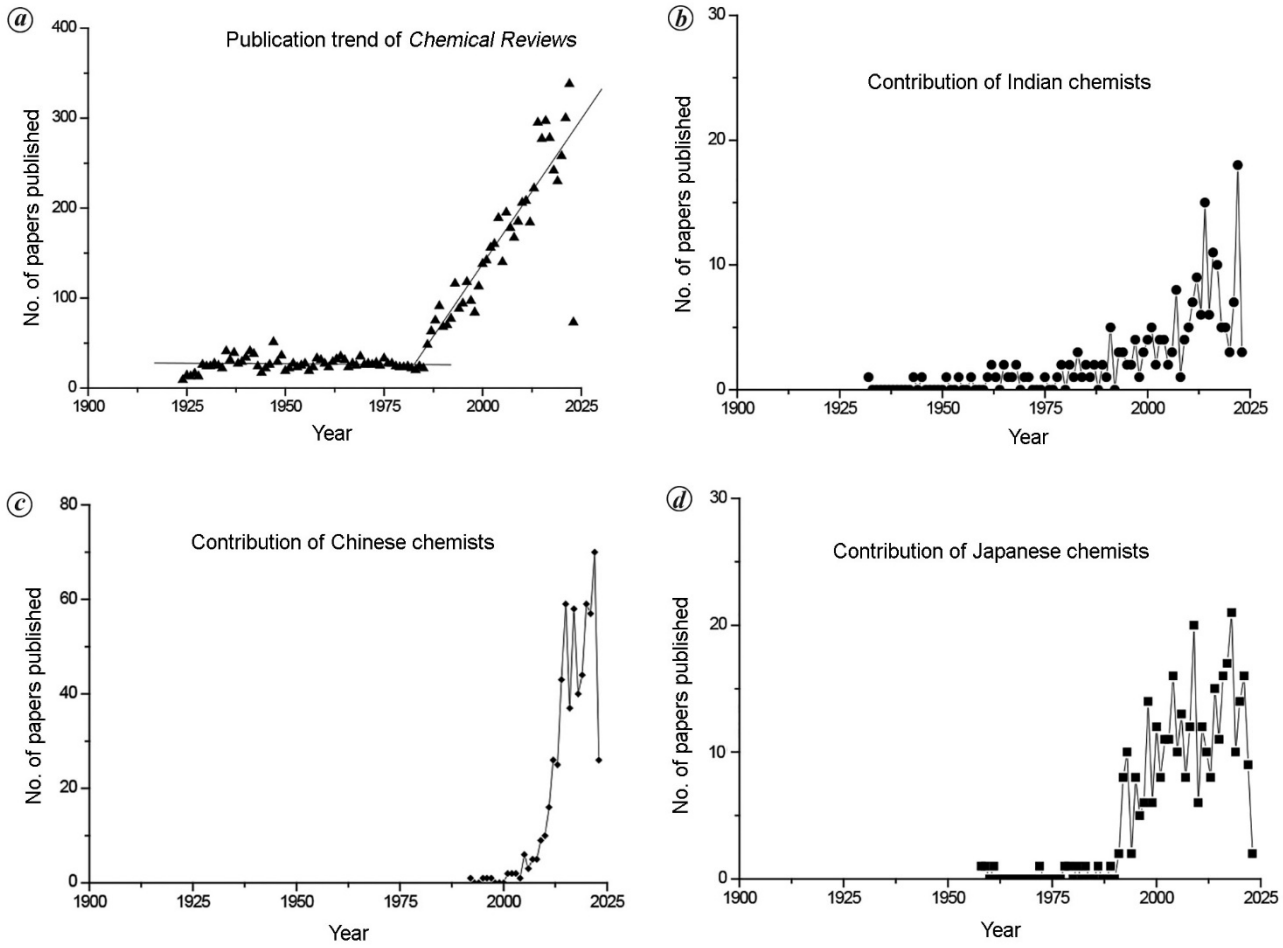

Figure 1. Publication trend and scholarly comparison with Asian countries.

Table 2. Top 10 most productive countries in *Chemical Reviews*

Country	No. of papers	Percentage	Rank
United States of America	4,050	51.30	1
Germany	712	9.02	2
United Kingdom	683	8.65	3
China	609	7.71	4
France	472	5.98	5
Canada	367	4.65	6
Japan	357	4.52	7
Spain	272	3.45	8
Italy	258	3.27	9
India	207	2.62	10

recorded year (2021–23), there have been 28 publications from India out of 711 papers, with 3.94% of the overall publication. The enhanced publication rate may be attributed to growth in research institutions, more research group involvement and global exposure. Moreover, economic liberalization in the 1990s lifted the ban on the procurement of chemicals and equipment from abroad, thus facilitating the research infrastructure.

Indicators like the activity index[10] indicate the relative research contribution of a particular country in any specific subject with respect to global or overall publications.

$$\mathrm{AI} = \{(I_i/I_0)/(W_i/W_0)\} \times 100,$$

whereas I_i is India's output in year i, I_0 is India's total output, W_i the world output in year i and W_0 is the total output.

In the present study, the mean of activity index was recorded as 80.25, which is good in terms of total publications. Overall, the data highlight a growing trend of research papers by India over the years, with varying levels of participation in different time periods. This indicates an increasing recognition of the importance of scholarly engagement.

Types of publication

Figure 2 showcases the types of publications and the corresponding number of papers in each category. Reviews (116) and articles (90) constitute the majority of the publications,

with reviews being the most prevalent. This indicates that the authors have conducted in-depth analyses of specific research areas, potentially synthesizing existing knowledge in their respective fields.

Scholarly comparison with Asian countries

In terms of the number of publications in *Chemical Reviews*, three Asian countries have been ranked. Presently, China occupies the fourth position; Japan is in the seventh position, followed by India in the tenth position. India had started earlier (1932) than its Asian counterparts, followed by Japan (1958) and China (1992). Publication trend lines show that although China started late in the 1990s, it has the highest growth rate among the Asian countries (Figure 1 *b*–*d*). This trend of publication in *Chemical Reviews* is in accordance with the overall publication trend. According to the World Bank data 2020 (https://data.worldbank.org/indicator/SP.POP.SCIE.RD.P6), India has 253 researchers per million, whereas China has 1585 and Japan has 5455. So, the lower rate of growth in India is directly related to the skilled workforce in the field.

Content analysis of Indian publications

Publications in the pre-independence period and thereafter in India

Although *Chemical Reviews* started its publication in 1924, the first article from the Indian affiliation appeared way back in 1932 when India was under British rule. Doja[22] (Patna University) worked on the synthesis of cyanine dyes. In 1943, another article appeared on the topic of 'Reaction between ethylene derivatives and the halogens' from Anantakrishnan and Venkataraman[23] (Annamalai University). The last article of the pre-independence period appeared in 1945, authored by Sethna and Shah[24] (Elphinstone College, Bombay and M. R. Science Institute, Ahmedabad). Their review entitled 'Chemistry of coumarins' described synthesising different types of coumarin dyes and their physiological applications. This domain of work is still relevant, as evidenced by from several publications in recent times.

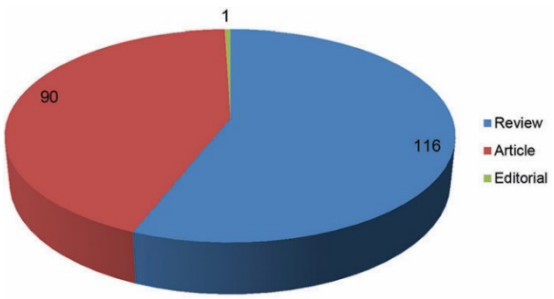

Figure 2. Types of publications.

Focus area of top 20 cited papers

Table 3 highlights the focus area of the top 20 most cited publications by Indian authors[25–44]. It is evident that the major area of work ranges from organic chemistry/natural products chemistry as applied to drug synthesis, catalysis, photochemistry and electrochemistry to modern areas like computational chemistry, organometallic chemistry and nano-chemistry. Experimental as well as theoretical works are cited. Moreover, areas with potential industrial applications are highly cited in accordance with the overall trend.

Most productive authors

Table 4 lists the most productive authors (with at least three papers), their number of papers, and their respective *h*-index and citation counts. S. P. Gupta (Meerut Institute of Engineering and Technology) has the highest number of published reviews (9) among Indian authors from 1987 till date. The domain of his work is mainly theoretical and computational chemistry involving quantitative structure–activity relationship studies of different types of drug molecules. P. K. Chattaraj and G. Mehta are also on the list, with three published papers each. Chattaraj's area of work is theoretical and computational chemistry, especially on the development of the electrophilicity index. Mehta has published in the field of synthetic natural products chemistry. It is worth mentioning that setting a limit of at least two publications per author adds another 43 authors to the list.

Authorship pattern

About 11.59% of the total papers have been published by a single author, and the remaining are published through joint or collaborative authorship. From Figure 3, it can be observed that two-author papers (30.43%) are the most common, followed by three-author papers (24.64%). This analysis shows a trend towards collaborative research and a preference for smaller authorship groups. However, there is also a significant presence of papers (11.59%) with more than five authors, indicating the involvement of larger research groups. The authorship pattern in this study reflects a diverse range of research groups, highlighting the importance of teamwork and collective contributions in research. Table 5 summarizes different measurements related to the authorship pattern. The degree of collaboration is calculated using the simple formula

$$\mathrm{DC} = \frac{N_\mathrm{m}}{N_\mathrm{m} + N_\mathrm{s}},$$

where N_m is the number of multi-authored papers, and N_s is the number of single-authored papers[45]. A DC value of 0.88 indicates a high degree of collaboration, implying that

Table 3. Focus area of top 20 cited papers

Authors	Domain of work	Authors	Domain of work
Kumar *et al.*[25]	Natural products, pharmaceuticals applications	Babu *et al.*[35]	Polymer chemistry, π-gelators
Ali[26]	Adsorbents, water treatment	Mishra *et al.*[36]	Fluorescent dyes, synthesis and spectroscopy
Shaikh and Sivaram[27]	Organic carbonates	Izatt *et al.*[37]	Theoretical chemistry, cation-macrocycle interaction
Patel *et al.*[28]	Pharmaceutical wastage, removal methods	Braga *et al.*[38]	Organometallics, crystal engineering
Petr *et al.*[29]	Electrochemistry, rechargeable batteries	Chen *et al.*[39]	Nanochemistry, nanomedicine
Chakraborty *et al.*[30]	Supramolecular chemistry, two- and three-dimensional ensembles	Patani and LaVoie[40]	Organic chemistry, drug design
Punniymurthy *et al.*[31]	Catalysis, oxidation process	Chattaraj *et al.*[41]	Theoretical chemistry, electrophilicity index
Sudesh Kumar and Neckers[32]	Photochemistry, azobenzene polymers	Chakraborty and Pradeep[42]	Cluster formation
Ghosh Chaudhuri and Paria[33]	Nanoparticles – synthesis and applications	Prateek Thakur and Gupta[43]	Nanocomposite
Ghosh and Pal[34]	Nanoparticles – spectroscopy	Basavaich *et al.*[44]	Organic chemistry, Bayer–Hillman reaction and its applications

Table 4. Most productive Indian authors

Authors	Institution	*h*-Index	No. of papers	Citation
S. P. Gupta	Meerut Institute of Engineering and Technology	21	9	750
P. K. Chattaraj	Indian Institute of Technology, Kharagpur	62	3	1,652
G. Mehta	University of Hyderabad	46	3	790

Table 5. Different measurements related to authorship pattern

Authorship measurement	Relevant score
Average authors per paper	3.28
Productivity per author	0.31
Degree of collaboration	0.88
Collaborative index	3.28
Collaborative coefficient	0.58

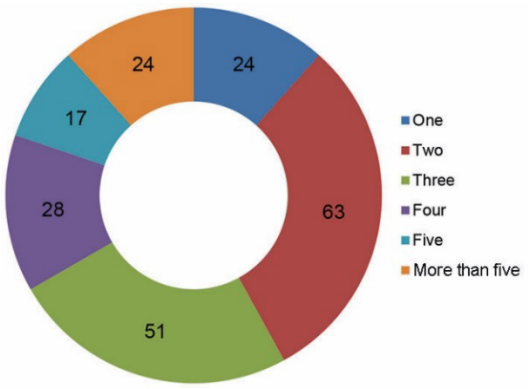

Figure 3. Authorship pattern.

most papers in the dataset involve multiple authors working together.

The collaborative index is a measure of the mean number of authors[46], and the collaborative coefficient is the mean number of authors per paper[47]. The mathematical formulae to estimate CC and CI are

$$\mathrm{CC} = 1 - \frac{\sum_{j=1}^{K}\left(\frac{1}{j}\right) f_j}{N},$$

where f_j is the number of j-authored research papers, N is the total number of research papers, and K is the maximum number of authors per paper.

$$\mathrm{CI} = \frac{\sum_{j=1}^{K} j f_j}{N}.$$

The values of CC and CI were 3.28 and 0.58 respectively, indicating the authorship pattern towards joint or collaborative research.

The average authors per paper indicates the average number of authors involved in each paper. In the present study, the average number of authors is 3.28, which suggests that the papers analysed typically have multiple authors. Productivity per author, measured by the number of papers per author, was found to be quite low (0.31). The metrics in Table 5 indicate a high level of collaboration among authors in the analysed papers.

Table 6. Most productive Indian institutions

Institution	Number of papers	Percentage (N = 207)	No. of times cited
Indian Institute of Technology, Kanpur	17	8.21	4,857
Indian Institute of Science, Bengaluru	15	7.25	6,685
Indian Institute of Technology, Kharagpur	12	5.80	7,112
Indian Institute of Technology, Bombay	11	5.31	2,541
Indian Institute of Chemical Technology, Hyderabad	10	4.83	4,500
University of Hyderabad	9	4.35	5,082
Birla Institute of Technology and Science, Pilani	7	3.38	844
Indian Association for the Cultivation of Science, Kolkata	7	3.38	1,823
Indian Institute of Technology, Madras	7	3.38	3,201
Banaras Hindu University, Varanasi	6	2.90	1,009
National Chemical Laboratory, Pune	6	2.90	2,655
University of Delhi	5	2.42	2,340

Table 7. Major collaborative countries

Country	Paper	Percentage	Citation
United States of America	41	19.81	16,712
Germany	18	8.70	6,431
China	7	3.38	2,423
France	7	3.38	2,356
Israel	7	3.38	4,690
Japan	7	3.38	4,135
Italy	6	2.90	5,779
Spain	6	2.90	1,577
South Korea	5	2.42	1,354
United Kingdom	5	2.42	1,305

Most productive Indian institutions

Table 6 provides the most productive institutions based on the number of papers that they have published, along with their respective percentages and citation counts. The table shows that the Indian Institutes of Technology (IITs) outperform other institutions. IIT Kanpur ranks first with 17 papers (8.21% of the total) and has many citations (4857). Other notable institutions are the Indian Institute of Science (7.25%), IIT Kharagpur (5.80%), IIT Bombay (5.31%), Indian Institute of Chemical Technology (4.83%) and University of Hyderabad (4.35%). These institutions have made notable contributions to *Chemical Reviews*, showcasing their research output and influence in their respective fields.

Most collaborative countries

Table 7 showcases the countries engaged in collaborative research based on the number of papers published, the percentage of collaboration, and the corresponding citation counts. From the table, it can be seen that with 41 collaborative papers, the USA holds the top position in terms of collaboration (19.81% of the total papers) and has received a substantial citation count of 16,712. The other countries are Germany (8.70%), followed by China, France, Israel and Japan, with seven papers each (3.38%). The citation counts indicate the impact and recognition of collaborative research conducted by these countries. Figure 4 showcases the collaborative network.

Top 10 most cited journals

The articles published by Indian chemists in *Chemical Reviews* have been cited by top journals from renowned publishing houses like ACS, Wily-Blackwell, Royal Society of Chemistry, Elsevier, etc. (Table 8). These journals are widely recognized and highly cited within the field of chemistry, indicating their significance and influence among the scientific community. With 1791 publications cited, the *Journal of the American Chemical Society* (*JACS*) is the most cited journal. The high impact factor of *JACS* (16.383) indicates the influence and importance of the published papers.

Research area transition over 100 years

To study the research area transition in *Chemical Reviews* as published by the Indian authors, we have divided the whole span into four quarters (Box 1). In the initial quarter (1924–49), the number of published articles was low, and the area of research encompassed the study of organic reaction and dye synthesis (specifically cyanines and coumarins) and their properties. Organic synthesis, natural products chemistry, adsorption, electrochemistry, thermodynamics and polymers were the main research topics in the second quarter (1950–75). Catalysis, natural products, organic synthesis, organometallics, QSAR studies, solvatochromism, photochemistry, computational chemistry, solvation dynamics, polymers and thermodynamics were the focus areas during 1976–2000. After 2000, areas like nanoparticles – their synthesis and applications, graphene chemistry, metal-organic framework, green method of synthesis, chemical sensors, energy storage, etc. have been explored in detail. However, synthetic organic chemistry, natural product chemistry and catalysis remain the focus areas across almost all quarters.

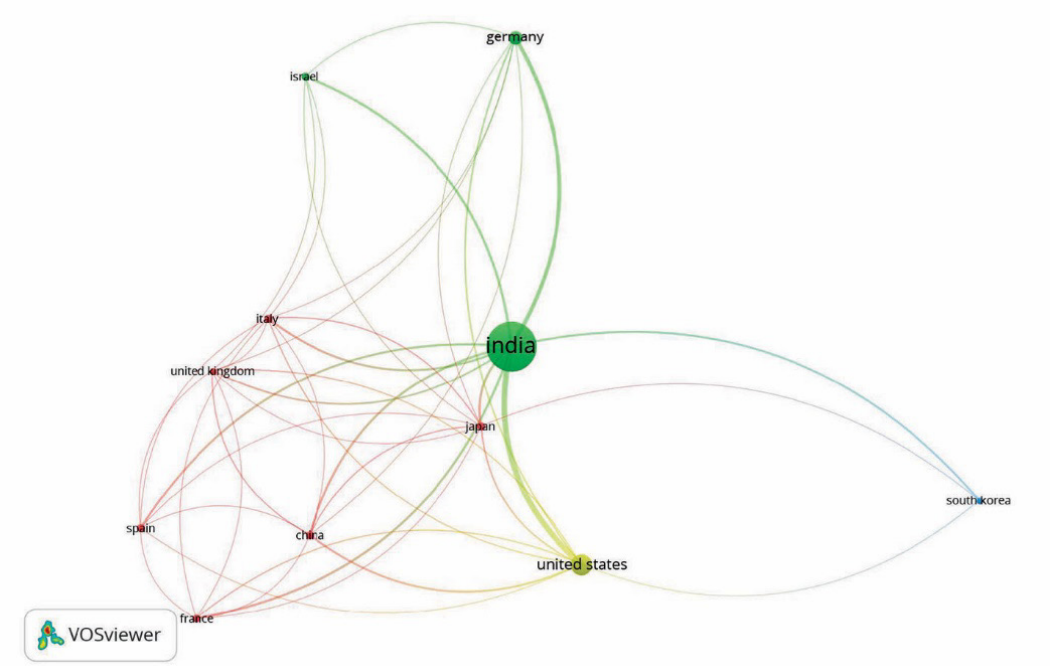

Figure 4. Collaborative of countries.

Table 8. Top 10 most cited journals in *Chemical Reviews* by Indian authors

Source	Documents	Publisher	Impact factor
Journal of the American Chemical Society	1791	American Chemical Society	16.383
Journal of Organic Chemistry	1753	American Chemical Society	4.198
Angewandte Chemie International Edition	1524	Wiley-Blackwell	16.823
Chemical Communications	1480	Royal Society of Chemistry	6.065
Organic Letters	1478	American Chemical Society	6.072
Chemistry – A European Journal	1396	Wiley-Blackwell	5.02
Tetrahedron Letters	1248	Elsevier	2.032
RSC Advances	1156	Royal Society of Chemistry	4.036
Tetrahedron	1062	Elsevier	2.388
Inorganic Chemistry	1016	American Chemical Society	5.436

Box 1. Research area transition over 100 years

1950–75 Organic synthesis, natural products, adsorption, electrochemistry, thermodynamics, polymers	1976–2000 Catalysis, natural products, organic synthesis, QSAR studies, solvatochromism, photochemistry, organometallics, computational chemistry, solvation dynamics, polymers, thermodynamics
1924–49 Organic reactions, cynanine dyes, coumarin chemistry	2001–23 Natural products, catalysts, graphene, metal organic framework, scaffolds, porphyrins, chemical sensors, nanoparticles, green synthesis, lithium-ion batteries, energy storage, computer simulation

Future trends

This study shows that Indian chemistry research is progressing well after the 1990s. However, in terms of the number of publications, it needs to catch up to the major global players. Only a few premier institutions like the IITs are found to be highly productive. Thus, the hour needs to include more institutions, specifically the Central and State Universities. As universities are the backbone of the Indian educational system, in order to increase the number of high-quality

publications, they must also contribute effectively. Funding agencies must support such institutions to improve the research environment[7,9]. The lack of jobs also prevents dedicated researchers in the field[48]. Goal-based fundamental research work may catalyse the rate of publications in journals like *Chemical Reviews*.

Conclusion

This scientometric analysis on a contribution made by Indian chemists to *Chemical Reviews* has shed light on the significant impact that they have had on the journal. The analysis reveals that India is among the top 10 contributors to the journal in terms of the number of publications. The initial sluggishness phase has been replaced with a substantial increase in publications after the 1990s. It is also found that the Indian authors have produced highly-cited articles, indicating the high quality and relevance of their research work. The authorship pattern in this study reflects a diverse range of research groups, with nearly about three authors per paper. Additionally, it reveals that a few Indian institutions are leading the research output, and there is further scope for improvement in the participation of other institutions. The research area analysis shows that organic synthesis, natural products and thermodynamics are the incessant areas, whereas areas like organometallics, photochemistry and polymer chemistry have gained attention after the 1970s. Nanoparticles, graphene, metal-organic framework, lithium-ion batteries, energy storage and computer simulation are the emerging fields in the new millennium.

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