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Research Article

Research Emphasis of IISERs in Chemical Sciences from 2006 to 2020: A Scientometric Assessment

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ABSTRACT
The mission of setting up of Indian Institutes of Science Education and Research (IISERs) was to create Science University of international standards in which quality education and research in basic sciences will be integrated. The present study focuses on the contribution of the faculty members of five IISERs in chemical sciences during the 15 years period from 2006 to 2020 to identify the research trend, publication pattern and scholarly impact. Chemistry was the most productive research area of selected IISERs and the faculty members contributed 3,973 articles of which 18.52% were internationally collaborated articles. The articles were analysed on the basis of different parameters like chronological distribution, communication pattern, areas of research emphasis, contribution of different institutes under IISERs and areas within Chemistry where they show strong presence, collaborating institutions and countries, leading authors and their citation impact. The study highlighted the important role of IISERs in strengthening Chemistry research in India. They have also established collaborative partnership among different countries as reflected in research publications. The publishing outputs demand more priority on other areas of fundamental sciences as well and the study may be helpful to policy makers/ authorities in determining allocation of resources of group of IISERs to augment more quality research.

Keywords: Indian Institute of Science Education and Research, IISERs, Chemical Sciences, Scientometrics, India.

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INTRODUCTION

India has a remarkable historic tradition with chemistry and according to the Thomson Reuters; chemistry research in India is growing rapidly.[1] The Nature Index also reported that chemistry produced more than half of the country's output.[2,3] In 1997–2001, India ranked 10th with 3.8% of world's papers in chemistry whereas in 2011–15, India contributed 6.9% of the world's papers and was behind only China (25%) and the USA (17%).[4] The Derwent Innovations Index[5] also reported that 71% patents granted to Indian innovators resulted from the field of chemistry. Furthermore, India's leading institutions are competitive in chemistry with those in Europe, the USA and Asia, and are also counted among the world's leading countries.[3] Most of the prestigious Indian institutions under different scientific agencies like CSIR (Council of Scientific and Industrial Research), Department of Atomic Energy (DAE), Department of Science and Technology (DST), Central or State universities and institutions under the Ministry of Education (earlier known as Ministry of Human Resource Development) are involved in chemistry research and perform reasonably well mirroring country's focus on research.[4]

With the primary aim of integrating high quality research with undergraduate teaching, five Indian Institutes of Science Education and Research (IISERs) as autonomous institutions under the Ministry of Human Resource Development, India were founded between 2006 and 2008.[6] Subsequently, two new IISERs were set up in Tirupati (2015) and in Berhampur (2016).[7] The basic objective of setting up these IISERs was to gain excellence in the area of basic sciences. The IISER Pune became the first institute in India to receive the Royal Society of Chemistry Accreditation for the Chemistry BS-MS Programme.[8] Also in the year 2018, two scientists (Dr. Swadhin K Mandal and Dr. Rahul Banerjee) from the Department of Chemical Sciences of the IISER Kolkata were awarded the prestigious Shanti Swarup Bhatnagar Prize.[9] Collectively, IISERs became the fourth-ranked Indian organization in chemistry as reflected in the Nature Index, 2015 and further improved to second rank after the IITs as reported in Nature Index for the period November 2017 to October 2018.[3] Hence, within a short span of time, the institutes achieved significant milestones and recognition. Therefore, the present study focuses on the research trend and impact of selected IISERs in the field of chemical sciences.

REVIEW OF THE RELATED LITERATURE

Literature review summarizes and highlights India's status in chemical sciences research and group of IISER's contribution to scientific research. For instance, during 1987-2007 Indian chemical research activity indicated that India's research effort in chemical science was more as compared to the world average and Indian authors contributed 6.03% to the world output.[10] In another study,[11] it was found that organic, inorganic and applied chemistry were the priority areas of research. Indian Institute of Science Bangalore received maximum average citations per paper while Indian Institute of Technology Kanpur had the highest PEI (publication effective index) score. From the year 2011 to 2015, Indian scientists published 62,448 papers in chemistry with 14.68 average citations per paper. This research effort helped India to secure 3rd rank accounting 6.9% share. Here three IISERs, viz. IISER Thiruvananthapuram, IISER Pune and IISER Bhopal performed well in producing highly cited papers in chemistry.[4]

In organic chemistry,[12,13] India's research output was 5.98% of the world contributions and ranked 9th while the USA, Germany and China secured first, second and third positions. Among the Indian institutes, three CSIR research institutes namely Indian Institute of Chemical Technology (CSIR-IICT) Hyderabad, National Chemical Laboratory (CSIR-NCL) Pune and Central Drug Research Institute (CSIR-CDRI) Lucknow were found to be the most productive institutes. In another attempt,[1] India's contribution was identified in three leading multidisciplinary chemistry journals during 1991-2005. Among the journals, Chemical Communications was the most preferred journal followed by Journal of the American Chemical Society.

A few scientometric studies also examined the performance of IISERs. During 2010-2014, five IISERs produced total 2,542 publications comprising 30.80% share of international collaborative output. Further, chemistry and physics were the priority areas of research among the scientists of IISERs.[14] Among IISERs, IISER Kolkata produced largest share of publication followed by IISER Pune and IISER-Mohali. Furthermore in short time of their existence, most of the IISERs achieved wider international collaborative efforts and also made a high scholarly impact.[15] Furthermore, the pattern of highly cited papers of the IISERs in Chemistry during 2008-2015[16] revealed that the scientists of IISERs contributed 42.96% of their total publications output in the area of Chemistry. IISER Pune contributed largest number of highly cited papers (20) followed by IISER Bhopal (17 papers) and IISER Kolkata (16 papers). Additionally, among attached collaborating institutions, IIT-Kanpur produced highest number of publications followed by National Physical Laboratory, New Delhi.

The review of literature shows that no study has been published which compared the research performance of the group of IISERs in chemical sciences research. Hence, the present study fills this research gap. The study examines the research output and its impact in terms of citations of the five established IISERs in the area of chemical sciences over the past 15 years from 2006 to 2020.

OBJECTIVES OF THE STUDY

The main aim of the study is to determine the research status and publication behavior of the scientists of IISERs in the area of chemical sciences. The study especially focuses on research profile, growth of publications over time, leading authors, scholarly impact, emphasis areas, scholarly communication patterns, partnering institutions and collaborating countries. The paper seeks answers to the following questions:

- What are the performances of IISERs to chemical sciences research over last 15 years?
- What is the scholarly publication behaviour of IISERs faculty members?
- What are research focus areas in the field of chemical sciences?
- What are the primary collaborating countries and participated institutions?

METHODOLOGY AND DATA SOURCE

The present study examines the publication output of the faculty members of five selected Indian Institutes of Science Education and Research (IISERs) in the area of Chemical Sciences over last 15 years period, 2006- 2020. The five IISERs are IISER Kolkata (IISER-K), IISER Pune (IISER-P), IISER Mohali (IISER-M), IISER Bhopal (IISER-B) and IISER Thiruvananthapuram (IISER-TVM). The other two IISERs i.e., IISER Tirupati and IISER Berhampur are in the early days of development. Therefore, these two newly IISERs have been excluded from the study.

For this purpose, the Web of Science (WoS) - core collection citation database (www.webofknowledge.com) of Clarivate Analytics was accessed during the 3rd and 4th week of April, 2021. The full record of research articles of individual IISER as well as group IISERs were searched using 'Organization-Enhanced' field tag and then the results were refined further implementing the following strategies:

Document Types: Article

Research Areas: Chemistry

Time span: 2006-2020

The search query resulted in 4,244 records including article (3,973), review (132), meeting abstract (86), editorial material (28), correction (23), proceedings paper (13), early access (4), book chapter (3), letter (2) and news item (1). Of these, only journal articles (3,973) were selected and exported in three different formats i.e., Excel, plain text and tab-delimited (win) for further analysis to get desired output as specified in the objectives of the study. Meanwhile, impact factor (IF) and quartile category of source journals were also identified from the database. Additionally, the Biblioshiny web-interface of Bibliometrix package of R software and VOSviewer software tool have also been used for mapping the network visualisation. Here, different scientometric indicators like average citations per paper (ACPP),[17] *h*-index,[18] *g*-index,[19] *hg*-index,[19] *p*-index[20] and highly cited papers have been applied for assessing the scholarly citation impact.

RESULTS

Research Profile of IISERs

Table 1 depicts the data related to research contributions, focus area and chemistry research output of corresponding IISERs. Out of total 10,495 research articles of five IISERs, Chemistry was found to be the most productive research area having 3,973 (37.85%) share of research articles. In terms of research articles in chemistry discipline, IISER-K and IISER-P contributed largest number of 1,112 and 1,063 articles respectively. However, two younger IISERs i.e., IISER-B and IISER-T shared highest percentage of 44.02% and 40.27% research articles respectively in the area of chemistry. According to the Nature Index data,[21] among Indian academic institutions IISER-K ranked 4th followed by IISER-P ranking 6th and IISER-B with 11th rank in the field of chemistry. It is observed from the dataset that Chemistry was the primary research area for all the IISERs except IISER-P where Physics was the most productive area.

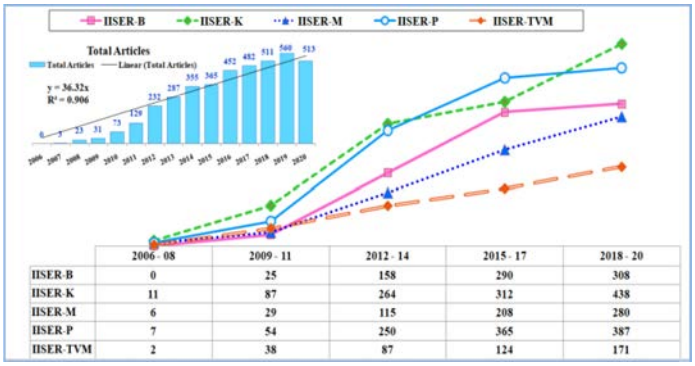
Table 1: Research status of five selected IISERs during 2006-2020.

IISERs	Total Research Articles	Most productive area	Ranking of IISERs in Chemistry*	Research output in Chemistry by IISERs	
				No. of Articles	Share of total articles
IISER-B	1,774	Chemistry	11	781	44.02%
IISER-K	3,025	Chemistry	4	1,112	36.76%
IISER-M	1,797	Chemistry	14	638	35.50%
IISER-P	3,218	Physics	6	1,063	33.03%
IISER-TVM	1,048	Chemistry	13	422	40.27%
Total =	10,495	Chemistry	-	3,973	37.85%

*data source- The Nature Index-2021 Table[20]

Chronological distribution of research articles

Figure 1 illustrates the year-wise distribution of research articles of five IISERs in chemistry. Two oldest IISERs i.e., IISER-K and IISER-P were predominant in chemistry research productivity among IISERs and showed a consistent growth over the last 15 years. On the contrary, IISER-T produced minimum number of articles. The research journey of the faculty members of chemistry began with 3 articles in the year 2007 while highest 560 articles were produced in 2019 followed by the year 2020 with 513 papers. It is clearly seen from the Figure that a sharp increasing research trend has been witnessed since 2016 and the value of R- squared (R^2 = 0.906) on the Figure 1 also confirmed the fact that a linear trend has been evidenced in the research growth of papers in chemical sciences. Further, some articles may appear in more than one IISER category due to their inter-institutional level collaboration.



	2006 - 08	2009 - 11	2012 - 14	2015 - 17	2018 - 20
IISER-B	0	25	158	290	308
IISER-K	11	87	264	312	438
IISER-M	6	29	115	208	280
IISER-P	7	54	250	365	387
IISER-TVM	2	38	87	124	171

Figure 1: Pattern of growth of papers of IISERs in chemistry during 2006-2020.

Contribution of Review Articles and Proceedings Paper

Figure 2 shows the contribution of review articles and proceedings paper. The scientists of selected IISERs produced total 132 review articles and 13 proceedings paper. Of these, IISER-K shared the highest number of 46 review articles followed by IISER-P with 37 reviews and IISER-B with 29 reviews. Alternatively, IISER-P contributed a maximum of 6 proceedings paper followed by IISER-M with 3 proceedings.

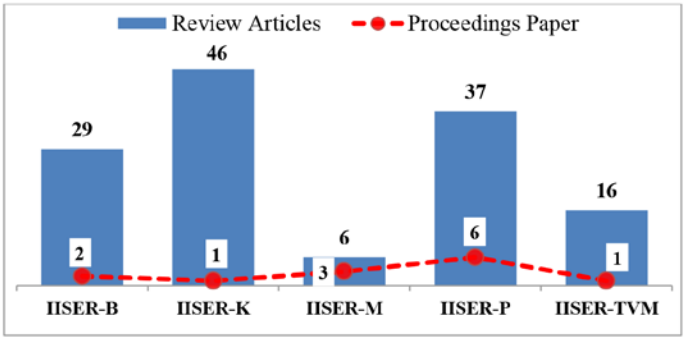


Figure 2: Contribution of Review Articles and Proceedings Paper.

Most prolific authors

Table 2 exhibits the 14 most prolific authors who have published minimum 55 or more papers during the study period. Of the 14 most productive authors, 8 authors were from IISER-K, 3 from IISER-M, 2 from IISER-B and 1 from IISER-P. Among all the authors listed in Table 2, Dr. Deepak Chopra of IISER-B contributed highest number (96) articles followed by Dr. Sanjit Konar of IISER-B with 86 articles and Dr. Sanjay K. Mandal of IISER-M with 82 articles. In terms of citations impact, 70 articles of Dr. Sujit K. Ghosh of IISER-P had the highest value of average citations per paper (63.5) and *h*-index score of 31. Additionally, co-authorship pattern of Dr. C. Malla Reddy of IISER-K is the highest with 7.72 average co-authors per paper followed by Dr. Angshuman Roy Choudhury of IISER-M. The co-authors per paper describe the linkage of research collaboration with other co-authors by an individual scientist.

Citation report

Table 3 depicts data related to scholarly impact of the chemistry research output of IISERs based on different scientometric indicators. The scientometric indicators determine the relative research efforts of an individual/ institution or country. Every indicator has its own merits along with its demerits. Hence, to get an unbiased and comprehensive view of performances, several indicators have been applied for evaluation of scholarly impact. The publications of IISER-P attracted the largest citation impact in terms of average citations per paper, *h*-index, *g*-index, *hg*-index and *p*-index. In terms of *hg*-index, IISER-P received the highest score of 82 followed by IISER-K with 63.9 and IISER-B with 63.64. Alternatively, in terms of *p*-index, IISER-P had the highest score with 78.1 followed by IISER-B with 65.91 and IISER-K with 63.01. Meanwhile, IISER-P produced maximum 27 papers which cited at least 100 or more times and 98 papers with at least 50 or more citations followed by IISER-B, IISER-K and IISER-TVM. Hence, among the five IISERs, the publications of IISER-M received the least citation impact. The details about the used indicators are mentioned below:

Jorge Hirsch in 2005 suggested *h*-index to indicate[18] that out of an author's total *Np* papers, *h* papers received at least

Table 2: Prolific authors who have contributed 55 or more papers during 2006-2020.

Rank	Author	Affiliation	Total Articles	ACPP	*h*-index	Co-authors per paper
1	Dr. Deepak Chopra	IISER-Bhopal	96	17.75	23	4.24
2	Dr. Sanjit Konar	IISER-Bhopal	86	28.22	29	4.27
3	Dr. Sanjay K. Mandal	IISER-Mohali	82	10.2	16	3.83
4	Dr. Santanu K. Pal	IISER-Mohali	75	13.44	17	4.91
5	Dr. C. Malla Reddy	IISER-Kolkata	71	41.56	26	7.72
6	Dr. Sujit K. Ghosh	IISER-Pune	70	63.5	31	5.03
7	Dr. Angshuman Roy Choudhury	IISER-Mohali	69	21.07	19	6.68
8	Dr. Debasish Haldar	IISER-Kolkata	67	9.16	15	4.06
9	Dr. Swadhin K. Mondal	IISER-Kolkata	65	23	23	6.03
10	Dr. Balaram Mukhopadhyay	IISER-Kolkata	60	10.07	13	2.92
11	Dr. Debasis Koley	IISER-Kolkata	58	18.50	19	6.74
12	Dr. Sayan Bhattacharyya	IISER-Kolkata	57	14.88	18	4.33
13	Dr. Pradipta Purkayastha	IISER-Kolkata	56	6.84	11	3.68
14	Dr. Venkataramanan Mahalingam	IISER-Kolkata	55	14.64	17	4.07

ACPP= Average citations per paper

Table 3: Scholarly impact of the articles in Chemistry of IISERs.

Name of the IISER	Total Publications	TC	ACPP	*h*-index	*g*-index	*hg*-index	*p*-index	AC_{100}	AC_{50}
IISER-B	781	14956	19.15	54	75	63.64	65.91	15	67
IISER-K	1112	16684	15	53	77	63.9	63.01	13	60
IISER-M	638	8867	13.9	40	62	49.8	49.76	6	22
IISER-P	1063	22498	21.16	64	105	82	78.1	27	98
IISER-TVM	422	8321	19.72	45	71	56.52	54.75	11	41
Total=	3,973	70,093	17.64	88	133	108.18	107.33	71	280

TC= Total times cited; ACPP= Average citations per paper; AC100= Articles that received at least 100 or more citations; AC50= Articles that received at least 50 or more citations

h citations each and remaining papers have fewer (≤*h*) citations each.

In 2006, Leo Egghe proposed *g*-index[19] to define that the top *g* cited papers received together at least g^2 citations.

The *hg*-index[19] is a combined index of both *h*-index and *g*-index. The *hg*-index can be determined by using following formula:

$$hg\text{-index} = \sqrt{h \times g}$$

The composite performance index (*p*-index or mock *h*-index) was introduced by Prathap[20] and can be formulated as follows:

$$p\text{-index} = \left(C \cdot \frac{C}{P}\right)^{1/3}$$; Where, C = total number of citations; P = total number of papers

Communication pattern of IISER scientists

Distribution of articles for publication of research results

Table 4 assesses the data related to distribution of journal articles in terms of quartile category and impact factor (IF) of journals. The scientists of IISER-K considered maximum 149 journals for publication of 1,112 articles having 7.46 average articles per journal while IISER-T preferred a minimum of 88 journals for publication of 422 articles having 4.8 average articles per journal. Besides, the scientists of IISER-B and IISER-P published lion's share of articles i.e., 59.8% and 59.55% respectively in the first quartile (Q1) category journals. Additionally, IISER-M and IISER-K shared majority of articles i.e., 43.42% and 40.65% respectively in the second quartile (Q2) category journals. Overall, the faculty members of IISERs used 235 journals as scholarly communication channels accounting 16.90 average articles per journal and altogether it published 51.37% articles in Q1 journals and 36.3% journals in Q2 journals. It is worthy to note that only 12.11% articles were published in the Q3 and Q4 journals. Very few articles were published in the non-quartile category journals.

Meanwhile, it is evident from the dataset that the faculty members of IISER-T accounted largest share of 16.11% articles in the very high IF (>9) journals whereas IISER-P contributed maximum of 28.6% articles in high IF (6> - ≤9) journals. On the contrary, IISER-M (32.60%) followed by IISER-K (25%) contributed their maximum papers in low IF (0 - ≤ 3) journals. Overall, the selected IISERs published 21.52% of their total articles in low IF journals followed by medium IF journals with 51.1% articles, high IF journals with 17.44% articles and very high IF journals with 10% articles.

Most preferred journals

Table 5 depicts the top 15 most preferred journals for publishing research results. Of these, Chemical Communications having impact factor of 6.222 published highest numbers of articles i.e., 261 followed by RSC Advances with 168 articles and Journal of Physical Chemistry-C with145 articles. Further, in terms of *h*-index, Chemical Communications journal received maximum score of 41 followed by Organic Letters with 38. It is evidenced from the dataset that the UK and USA originated journals were the most popular journals. In addition, American Chemical Society followed by Royal Society of Chemistry and Wiley were the most popular publishers among chemistry faculty members of IISERs for dissemination of their research findings.

Research emphasis areas in chemical sciences

Table 6 shows the data related to research emphasis areas and the share of corresponding IISERs. IISER-B contributed majority of 209 articles in the 'Organic Chemistry' area

Table 4: Scattering of articles by Quartile category and Impact factor.

IISERs	Articles published in Quartile category journal			Impact Factor (JCR, 2021) wise distribution of articles with share			
	Q1	Q2	Q3-Q4	0 - ≤ 3	3> - ≤6	6> - ≤9	9> --
IISER-B (N=781)	467 (59.8%)	230 (29.45%)	84 (10.75%)	138 (17.67%)	421 (53.9%)	170 (21.76%)	52 (6.66%)
IISER-K (N=1112)	504 (45.32%)	452 (40.65%)	152 (13.67%)	278 (25%)	598 (53.8%)	127 (11.42%)	109 (9.8%)
IISER-M (N=638)	230 (36.05%)	277 (43.42%)	131 (20.53%)	208 (32.60%)	329 (51.57%)	59 (9.25%)	42 (6.6%)
IISER-P (N=1063)	633 (59.55%)	344 (32.36%)	83 (7.81%)	204 (19.2%)	459 (43.2%)	304 (28.6%)	96 (9.03%)
IISER-T (N=422)	237 (56.16%)	149 (35.31%)	34 (8.05%)	64 (15.16%)	214 (50.71%)	76 (18%)	68 (16.11%)
Total (N=3973)	2041 (51.37%)	1442 (36.3%)	481 (12.11%)	855 (21.52%)	2029 (51.1%)	693 (17.44%)	396 (10%)

Table 5: Most productive journals of research communication.

Name of the Journal with IF, 2021	Country	IISER-B	IISER-K	IISER-M	IISER-P	IISER-T	Total Papers (P)	*h*-index
Chemical Communications, 6.222	UK	65	65	15	92	24	261	41
RSC Advances, 3.361	UK	30	67	23	30	19	168	26
Journal of Physical Chemistry C, 4.126	USA	11	45	7	51	32	145	26
Chemistry – A European Journal, 5.236	Germany	40	39	15	36	12	140	27
Journal of Organic Chemistry, 4.354	USA	39	26	24	34	9	131	25
Organic Letters, 6.005	USA	67	4	12	43	4	130	38
Dalton Transactions, 4.390	UK	29	40	25	20	10	123	24
Physical Chemistry Chemical Physics, 3.676	UK	19	28	11	34	22	114	19
Angewandte Chemie International Edition, 15.336	UK	15	23	8	35	26	106	34
Inorganic Chemistry, 5.165	USA	19	35	9	29	15	106	31
Journal of Physical Chemistry B, 2.991	USA	16	20	15	49	5	105	22
Organic and Biomolecular Chemistry, 3.876	UK	28	16	16	37	7	102	24
ChemistrySelect, 2.109	UK	16	39	24	17	5	101	10
CrystEngComm, 3.545	UK	31	30	13	9	12	92	22
Crystal Growth and Design, 4.076	USA	32	25	15	12	8	90	29

Table 6: Distribution of research focus areas according to WoS categories.

Research Area	Research output of the IISERs with Activity Index (AI)					Total articles	%articles
	IISER-B	IISER-K	IISER-M	IISER-P	IISER-T		
Chemistry Physical	156 (64)	330 (95)	219 (110)	382 (115)	170 (129)	1244	31.31%
Chemistry Organic	209 (150)	154 (78)	120 (106)	197 (104)	35 (47)	707	17.8%
Materials Science Multidisciplinary	100 (72)	180 (92)	76 (67)	243(129)	113(151)	702	17.67%
Physics Atomic Molecular Chemical	50 (54)	122 (92)	100 (131)	135(106)	70(139)	474	12%
Chemistry Inorganic Nuclear	76 (89)	149 (123)	90 (130)	79(68)	43(94)	432	10.87%
Nanoscience Nanotechnology	30 (42)	86 (86)	25 (43)	145(151)	78(204)	359	9.04 %
Crystallography	75 (152)	72 (102)	64 (159)	26(39)	20(75)	251	6.32%
Biochemistry Molecular Biology	11 (51)	45 (147)	11 (63)	38(130)	4(34)	109	2.74%
Physics Applied	8 (38)	18 (61)	14 (82)	50(176)	17(151)	106	2.67%
Energy Fuels	10 (60)	20 (84)	8 (59)	37(163)	11(122)	85	2.14%
Others	270 (104)	419 (114)	162 (76)	340 (96)	140 (100)	1318	33.17%
Total=	781	1112	638	1063	422	3,973	100%

whereas other remaining IISERs emphasized on the 'Physical Chemistry' area for their research. Overall, the chemical scientists of five IISERs focused towards the field of 'Physical Chemistry' having 1244 articles which accounted 31.31% share followed by 'Organic Chemistry' having 707 articles (17.8%) and 'Materials Science' having 702 articles (17.67%). Very few research articles were found in the areas of 'Medicinal Chemistry', 'Applied Chemistry' and 'Electrochemistry'.

In case of 'Physical Chemistry', IISER-M, IISER-P and IISER-T have higher AI (Activity Index) values which indicate that a higher proportion of papers were produced by these institutions. Alternatively, the AI value of IISER-B, IISER-M and IISER-P were more than 100 in the area of 'Organic Chemistry' while in 'Materials Science multidisciplinary', IISER-P and IISER-T had higher values of AI. Activity Index (AI) indicates the relative research effort of an institution to a defined subject field. It can be determined by using following formula.[22,23]

$AI = \{(N_i / N_{io}) / (N_o / N_{oo})\} \times 100$ where,

N_i = Number of papers in a particular research area by an institution;

N_{io} = Total number of papers in a particular research area by all institutions;

N_o = Total number of papers in all research areas by an institution;

N_{oo} = Total number of papers by all institutions

The value of AI = 100 indicates that research effort of an institution corresponds to the total average, AI > 100 reflects research output higher than the total average, while AI < 100 reflects research output less than the total average.

Country-wise distribution of collaboration output

Table 7 reveals the country wise collaboration output of five IISERs. Out of 59 collaborating countries, the USA produced maximum number of 204 papers followed by Germany with 156 papers and England with 68 papers. All the IISERs preferred to collaborate with their USA partners unlikely IISER-K that produced maximum 82 papers collaborating with Germany. Additionally, the collaborating publications with Sweden attracted highest average citations of 33.5 per paper followed by Japan reporting 26.44 average citations per paper. Conversely, the collaborated publications with the USA produced largest number of 8 highly cited papers that received at least 100 or more citations. Further, in terms of *p*-index score, USA publications received highest score of 44.25 followed by Germany having 38.53. Figure 3 sketches the leading countries' collaboration network.

Leading collaborating affiliations

Table 8 explores the data related to leading collaborating partners of individual IISER. The scientists of IISER-P and IISER-K contributed the highest papers i.e., 130 and 50 respectively collaborating with CSIR-National Chemical Laboratory, Pune. In the case of IISER-B, Indian Institute of Technology Kanpur produced the highest of 59 collaborated papers while IISER-M co-authored a maximum of 40 papers with Panjab University. Also the Indian Institute of Science Bangalore plays a crucial role for IISER-TVM with 50 papers.

Overall, the CSIR-National Chemical Laboratory Pune played dominant role by contributing 208 articles that also received *h*-index of 33 and maximum 7 articles cited at least 100 or more times. This is followed by Indian Institute of Science Bangalore with 125 articles, Indian Institute of Technology Kanpur with 112 articles and Academy of Scientific Innovative Research Chennai with 92 articles. In terms of average citations

Table 7: Country-wise collaboration output of IISERs' scientists.

Country/ region	IISER-B	IISER-K	IISER-M	IISER-P	IISER-TVM	Total Papers (P)	TC (C)	ACPP	AC_{100}	*p*-index
USA	24	50	33	62	38	204	4204	20.61	8	44.25
Germany	19	82	14	30	11	156	2988	19.15	3	38.53
England	3	26	7	22	10	68	1354	19.91	2	30
Peoples R. China	3	33	4	12	3	55	984	17.89	2	26
Spain	7	19	15	5	2	47	951	20.23	0	26.8
France	1	9	7	17	6	40	1032	25.8	1	29.9
Japan	7	4	6	3	12	32	846	26.44	4	28.17
Canada	5	4	2	13	0	24	381	15.88	0	18.22
Sweden	3	8	2	11	0	24	804	33.5	2	30
South Korea	6	2	1	12	2	22	305	13.86	0	16.17

TC= Total Cited; ACPP= Average citations per paper; AC100= Articles that received at least 100 or more citations

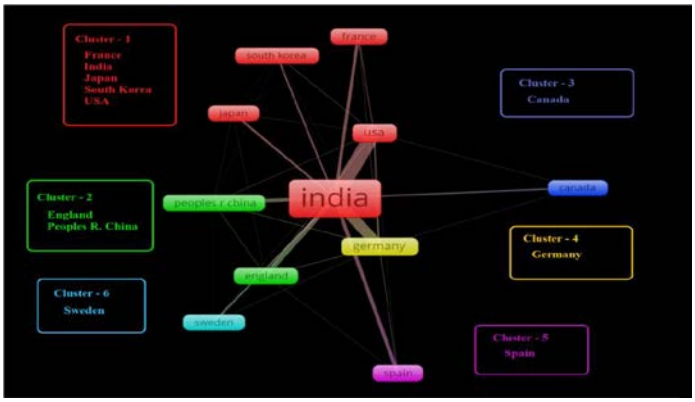


Figure 3: Collaboration linkages with foreign countries.

Table 8: Leading collaborating institutions of IISERs.

Institution	IISER-B	IISER-K	IISER-M	IISER-P	IISER-TVM	Total papers	TC	ACPP	AC_{100}	*h*-index
CSIR-National Chemical Laboratory, Pune	18	50	5	130	7	208	4575	22	7	33
Indian Institute of Science, Bangalore	21	21	7	30	50	125	3329	26.63	4	31
Indian Institute of Technology, Kanpur	59	19	26	6	2	112	2537	22.65	2	30
Academy of Scientific Innovative Research, Chennai	20	26	7	30	10	92	1819	19.77	3	22
Indian Association for the Cultivation of Science, Kolkata	15	36	6	3	11	71	1562	22	2	24
Indian Institute of Technology, Bombay	5	23	4	26	7	62	1285	20.73	1	15
Savitribai Phule Pune University, Pune	1	1	6	40	0	48	992	20.67	3	14
Kalyani University, Kalyani	1	31	11	2	2	47	518	11.02	0	14
Bhabha Atomic Research Centre, Mumbai	9	18	4	13	3	46	454	9.87	0	14
Panjab University, Chandigarh	5	2	40	0	0	45	424	9.42	0	12

per paper, the papers of Indian Institute of Science Bangalore followed by Indian Institute of Technology Kanpur attracted highest score of 26.63 and 22.65 respectively. In this context, it is worthy to note that among groups of institutes, CSIR Laboratories (346), IIT System (327) and DST Institutes (168) were the leading research partners for collaboration.

Citing countries based on without self-citations

Figure 4 illustrates the leading citing countries based on without self-citations of chemistry research papers of IISERs. Among citing countries, the scientists of Peoples R. China cited maximum Indian chemistry research accounting 37.30% share followed by India with 20.9%, the USA with 11.4% and Germany with 5.7%. It is interesting to state that though the scientists of IISERs had weaker collaboration linkage with China, the Chinese authors were found to cite Indian chemistry research frequently. Additionally the scientists from developed countries like Japan (4.6%), South Korea (3.6%), France (3.2%) and England (3.2%) also cited IISERs' research papers frequently.

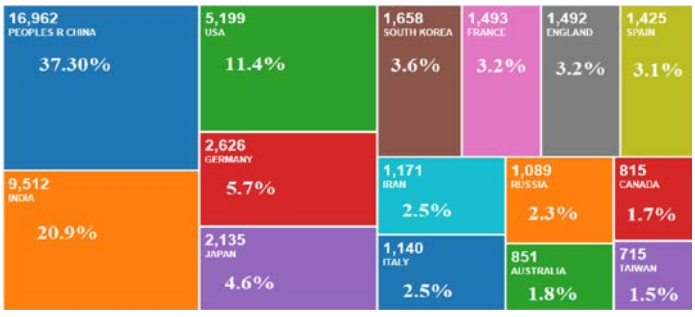


Figure 4: Tree mapping of leading 15 citing countries for chemistry research of IISERs.

CONCLUSION

Over the last 15 years, the research trend of group of IISERs showed that Chemistry was the most productive research area accounting 37.85% share of total publications output and 18.52% share of internationally collaborated articles. This fact confirmed the earlier findings of 19.86% collaboration of Indian authors with international co-authors in chemistry.[4] Hence, the scientists' of IISERs activity is in line with the country's research trend and plays a pertinent role in reinforcing India's chemistry research. From the year of 2016 (after 10 years), a steady publications growth was seen. Among IISERs, IISER Bhopal (44.02%) and IISER Thiruvananthapuram (40.27%) were overemphasized towards chemistry by sharing the largest proportion of research efforts. On the contrary, several performance indicators used in the study validate the dominancy trend of IISER-P while IISER-M received the least citation impact. Additionally, IISER-K attracted a little higher *hg*-index value whereas the IISER-B gained greater *p*-index score. Among indicators, *hg*-index is a combination of two indices which present a balanced view of highly cited papers and its citations. Alternatively, the *p*-index is highly influenced by the ACPP. In general, ACPP tends to be on the higher side when the output is low.[15] Despite being young, the IISERs at Pune, Kolkata and Bhopal performed better in terms of their productivity and impact. The other two IISERs at Mohali and Thiruvananthapuram have yet to achieve comparable levels.

Among sub-disciplinary areas of chemistry, 'Physical Chemistry' (31.31%) was the primary focus area whereas very few research articles were found in the areas of 'Medicinal Chemistry', 'Applied Chemistry' and 'Electrochemistry'. Apart from these, the publications pattern indicates that the IISERs' scientists preferred to select a few journals of repute

for publishing research findings and also published half of their total articles (51.37%) in the first quartile category (Q1) journals as compared to 38.61% for India and 53.82% for the world.[4] Hence, it is argued from the fact that the IISERs' performance was better than India in terms of sharing of papers that appeared in the quality of journals. Meanwhile, 27.44% of total articles appeared in high impact factor journals (6>) of repute. Interestingly, it is worthy to address that Chinese authors were found to cite chemistry research to the extent of 37.30% though the scientists of IISERs have a weaker collaborative network with China. This fact also corroborates the earlier findings[12] that Indian research papers in chemistry were cited mainly by Chinese authors.

This year the IISER programme is completing 15 years of existence. Possibly it is the right time to take a fresh look and review on the IISER project. But, teaching is also an important activity of IISER faculty members along with research. So, only research performance should not be counted to assess the performance of the IISER programme. However, in the end, it can be inferred that the institutions were founded to promote quality education and research in fundamental sciences, but yet an apparent biased research phenomenon was evidenced towards chemical sciences[24] followed by physical sciences. So, the authority needs to focus on other areas of fundamental sciences like mathematical sciences, biological sciences, earth and atmospheric sciences as well. Hope, the insight of the study will be helpful for authorities/ policymakers in identifying where the group of IISERs stand in Chemistry research in comparison with other conglomerates or groups of institutes like CSIRs, IITs, DSTs and DBTs etc.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

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