COMPARATIVE ANALYSIS OF THE RESEARCH PUBLICATIONS OUTPUT, PUBLICATION EXCELLENCE, AND COLLABORATION PATTERNS OF INDIAN CSIR- CHEMICAL SCIENCE LABORATORIES DURING 2010 – 2019

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CSIR – Chemical Science laboratories are constituent laboratories of the Council of Scientific and Industrial Research (CSIR), India. CSIR laboratories work on a wide spectrum of science and technology areas, including the chemical sciences, biotechnology, and nanotechnology, and play an important role in the field of chemical sciences by providing innovative and effective solutions to a wide range of chemical sciences problems in the country. This study tried to analyses the research publication of CSIR-Chemistry Science Laboratory from 2010 to 2019. The data of this study includes details of 20,601 publications extracted from the Web of Science Database. The extracted data were analysed on various parameters such as publication trend, the degree of collaboration and Collaborative Measures, Discipline -wise Research Output, highly reference papers, most influential authors, preferred sources and growth, most cited countries, highly cited papers and prolific keywords. This study shows that most scientists are preferred to publish research papers in collaboration and the 'RSC Advances' is the most preferred journal for publication.

Keywords: CSIR; Chemical Science Laboratories; India; Bibliometric study; Degree of Collaboration; Authorship Pattern; Collaborative Measures

INTRODUCTION

The Council of Scientific & Industrial Research (CSIR, n.d.), founded in 1942 is an autonomous institution known for its outstanding performance in R&D and technological innovation. Through its network of 38 national laboratories, CSIR conducts focused basic and applied research in different scientific and technical fields, and has a wide presence in India. CSIR covers a wide range of scientific and technical fields and provides important technical interventions in many areas in social efforts. Through its technical intervention, CSIR not only provides solutions and innovations for the industry but has also proven to be a catalyst for improving the quality of life of millions of people across the country. CSIR's R&D expertise and experience are reflected in approximately 4,000 active scientists, supported by 7,000 scientific and technical personnel. CSIR on average files about 200 Indian patents and 250 foreign patents annually. In the CSIR meeting (Singh, 2020), Prime Minister Narendra Modi praised the Institute's work and advised the Scientists should work on topics such as the 5G, artificial intelligence, water conservation, malnutrition, promoting farmers' prosperity through science and technology, and the production of cheap and sustainable batteries for energy storage. On average, CSIR issues 200 Indian patents and 250 foreign patents annually.

The current bibliometric study attempts to analyse the impact of the research excellence, quality, and research output of the Chemical Science Laboratories. With their expertise in chemistry and chemical technology, these technologies are providing solutions to the challenges faced by the industry, government departments, and entrepreneurs through basic and applied research and process development. These results will help to understand the research priorities and contributions of the Chemical Science Laboratories and provide insights and guide for the development of Indian industry, government departments, and entrepreneurs.

LITERATURE REVIEW

Previously few Scientometric studies were conducted on research institutes and in particular on CSIR Laboratories, India. Garg et al., 2020 examines the research output of CSIR-Institute of Himalayan Bioresource Technology (IHBT) during 1990-2019. Studied the citation impact, authorship and communication patterns, international collaborations. (Mukherjee, 2017; Nagarkar et al., 2015) studied the quality and quantity of research output CSIR laboratories using Web of Science and Scopus from 2010 to 2015. The study covers year-wise output, authorship trend, and citation analysis.Gupta et al., (2015) analysed the performance of 37 CSIR at the comprehensive level and at the laboratory level based on various indicators in 2007-11 using the Scopus database. Identify overall CSIR strengths and weaknesses. CSIR institutes contributed significantly to chemistry. (Nayak et al., 2020) Analysed 5372 publications of CSIR-NCL, Pune using Scopus database during 2010 – 2019. (Suma & Sudhier, 2014) Conducted the study on CSIR- National Institute of Interdisciplinary Science &Technology (NIIST) during 2007 – 2011. A total of 1080 publications and 110 patents were analysed with the various indicators. Lohiya et al. (2016) Scientometric Study was conducted on CSIR, National Environmental Engineering Research Institute (NEERI) during 1989 to 2013 using WoS database and analysed 1236 papers. Study covers the publication pattern, highly cited papers and authors, authorship pattern and collaboration trends and so on.

Sengar (2014) analysed the degree of collaboration, authorship pattern of the CSIR Institute for Microbiological Technology, Chandigarh. The study suggests, to increase collaborative authorship, to improve the quality of research. Sengar (2012) conducted scientometric study on CSIR Institute of Microbial Technology, Chandigarh during 1991-1995 and 2005- 2009. The study found that the results of the CSIR-ImTech Chandigarh research on publishing articles in high-impact journals increased significantly, with each article cited during the research period. (Ramalingam et al., 2011) reviewed 1,282 research papers published by scientists at the CSIR-Central Electrical Research Institute between 2000 and 2009. The collaborative research was dominant with the highest degree of collaboration (0.98). (Kumar, 2010) studied the applicability of Loka's law as a general inverse square power relationship between 1988-92 and 2004-08 and the applicability of India's CSIR research on productivity distribution. (B. M. Gupta, Kumar, & Khanna, 1999; B. M. Gupta, Kumar, Khanna, et al., 1999; Kumar, 2010) analyzed the application of Lotka's inverse power law (general and square) and other statistical distributions to the productivity distribution of CSIR scientists at various levels and studied the research achievements of CSIR scientists in various programs and working ages in engineering laboratories. (B. M. Gupta, Kumar, & Aggarwal, 1999; Lemoine, 1992) Considering the gender of scientists, both, examined Lotka's law to distribution to the scientific productivity distribution of 7000 Indian scientists in the CSIR and male and female scientist's productivity at the overall agency level and at the group of laboratories level with a wide range of topics. (Shivaram et al., 2016) conducted a scientometric study on CSIR-NAL 1002 papers using the SCOPUS database during 2005 – 2014. These papers were divided into Engineering and Science groups. Study found that science group have published more papers than engineering. Among, 712 papers were published in good impact factor journals.

OBJECTIVES

The key objective of this study is to evaluate the contribution and citation impact of Indian CSIR – Chemical Science Laboratories during 2010 – 2019. In this regard, the study is intended to:

1. Eximine the research output of Chemical Science Laboratories during 2010 – 2019;
2. Identify the Authorship pattern and degree of collaboration among authors;
3. Study the overall performance of Chemical Science Laboratories during the study;
4. Determine the most important subject areas of Chemical Science Laboratories; and
5. Identify the highly prolific authors, sources and highly cited papers.

SCOPE OF THE STUDY

Over the years, these Chemical Science Laboratories have contributed research output significantly and built an impressive collection. The main purpose is to analyse the research output of these Chemical Science Laboratories on various parameters and to compare them with the research performance in terms of both quantity and quality. Further, identified disciplinary research strengths of Chemical Science Laboratories during 2010 – 2019.

SIGNIFICANCE OF THE STUDY

This is an attempt to analyses the research performance of 9 Chemical Science Laboratories using various bibliometric indicators. This study may helps to students, researchers and scientists to identify the best laboratory for their study.

METHODOLOGY

The web of science database was used to collect the data of these Chemical Science laboratories from 2010 – 2019. The data has been collected in mid of April 2021 using the advanced search: Organization-enhanced (OG) and Indexes=SCI-EXPANDED Timespan=2010-2019.

All the Bibliographical details were transferred into MS Excel. The VOSviewer (van Eck & Waltman, 2010) software and Bibliometrix (Aria & Cuccurullo, 2017) R package were used to classify the collaborative network of organizations, countries, keywords plus, source growth. After validation, the data were analysed according to the objectives of the study. Table 1 shows the search results.

ANALYSIS AND RESULTS

Data Description

Research Output of Chemical Sciences laboratories (2010 – 2019)

The Table 2 shows the Chemical Sciences laboratories' research publications and have experienced steady growth over the years. These Chemical Science laboratories were published in high-quality journals, it shows the strength of these laboratories. In 2015, 2462 papers were published, followed by in the year 2014, 2426 papers were published. The research productivity (total citations and average citation per article) was found highest for CSIR-IICT, Hyderabad (TP

Table 1: Data Description

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2010:2019
Sources (Journals, Books, etc)	1766
Documents	20601
Average years from publication	6.24
Average citations per documents	19.96
Average citations per year per doc	2.761
References	1
DOCUMENT TYPES	
article	19227
book chapter	5
proceedings paper	300
retracted publication	10
biographical-item	9
correction	102
editorial material	119
letter	29
meeting abstract	172
news item	2
reprint	1
retraction	6
review	607
review; book chapter	12
DOCUMENT CONTENTS	
Keywords Plus (ID)	34096
Author's Keywords (DE)	33794
AUTHORS	
Authors	26324
Author Appearances	98760
Authors of single-authored documents	153
Authors of multi-authored documents	26171
AUTHORS COLLABORATION	
Single-authored documents	237
Documents per Author	0.783
Authors per Document	1.28
Co-Authors per Documents	4.79
Collaboration Index	1.29

6375; TC 117177; ACPA 18.38), followed by CSIR-NCL, Pune (TP 4959; TC 104886; ACPA 21.15) and CSIR-NIIST, Thiruvananthapuram (TP 2035; TC 45519; ACPA 22.37). Quality research utility in these institutes could be attributed to measures taken to facilitate the execution of research initiatives and to increase knowledge products. The Chemical Sciences Laboratories are the oldest National Laboratories, undertakes research in various areas and its research outputs also include publications made as a part of students' research.

The SciVal-based data on the publications in the top 10 percentile is extensively used as an indicator to measure the quality of the research (Rajan et al., 2018). Publications in top journals, citations or views percentiles represent the number of publications of a selected article that have been published in the global topmost journals or those which are highly cited or viewed, having reached a threshold, respectively. The proportion of publications in top journal and citation percentiles was the highest for Chemical Sciences Laboratories, while the highest visibility as it topped among the institutes in terms of maximum outputs. Figure 1 displays the authors' collaboration network.

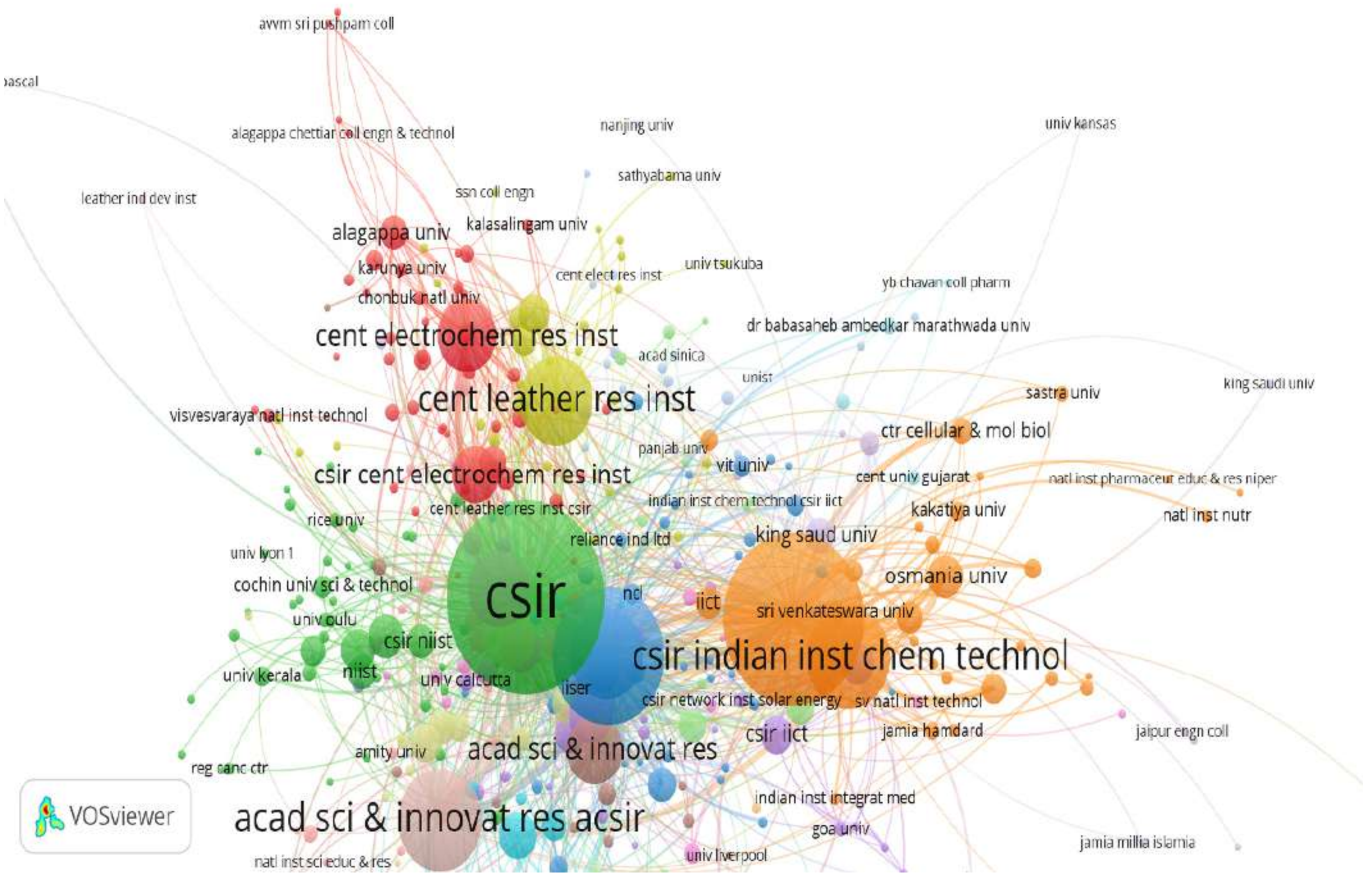

Figure 1: CSIR- Chemical Sciences laboratories collaboration network

Table 2: Research Output of CSIR- Chemical Sciences Laboratories (2010 – 2019)

Name	Est	Place	2010-2019	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	h-index	TC	ACPA
			No of Publications													
Indian Institute of Chemical Technology	1977	Hyderabad	6375	525	573	635	592	796	759	703	654	587	551	96	117177	18.38
National Chemical Laboratory	1950	Pune	4959	318	369	435	463	577	603	600	607	512	475	116	104886	21.15
Central Electrochemical Research Institute	1953	Karaikudi	1926	115	150	122	150	209	176	202	256	276	270	73	39987	20.76
National Institute for Interdisciplinary Science and Technology	1975	Thiruvanan thapuram	2035	187	194	152	180	220	224	211	245	228	194	81	45519	22.37
Central Salt Marine Chemicals Research Institute	1954	Bhavnagar	1994	196	214	167	175	199	230	209	205	213	186	79	44841	22.49
Central Leather Research Institute	1965	Chennai	1704	155	176	193	184	209	213	157	138	128	151	67	29823	17.50
North - East Institute of Science and Technology	1961	Jorhat	883	43	62	55	75	85	99	98	111	130	125	54	15571	17.63
Indian Institute of Petroleum	1960	Dehradun	697	31	36	50	57	82	121	96	77	70	77	56	15399	22.09
Central Institute of Mining and Fuel Research	2007	Dhanbad	430	20	23	28	40	49	37	56	46	65	66	43	7449	17.32
				1590	**1797**	**1837**	**1916**	**2426**	**2462**	**2332**	**2339**	**2209**	**2095**		**420652**	**19.97**

Authorship Pattern, Degree of Collaboration (DC), Collaboration Index (CI), Collaboration Coefficient (CC), and Modified Collaboration Coefficient (MCC)

a) Degree of Collaboration (DC)

In recent years, most countries have realized the importance of scientific research to their socio-economic growth, and have begun to implement programs to encourage and support the cooperation of researchers and scientists at the national and international levels. It can be defined as the number of multi-author publications in a subject published in a year and the total number of papers published in a year. Degree of Collaboration proposed by (Subramanyam, 1983) as below:

$$C = \frac{Nm}{Nm + Ns}$$

Using data in Table 3, during 2015;

$$C = \frac{2418}{2418 + 30}$$

$$C = 0.988$$

Where C is the degree of collaboration, Nm is the number of multi-authored papers, and Ns is the number of single-authored papers. In the current study, the value of DC for the year 2019 is 0.994, followed by 2018 (0.993), 2016, 2017 is 0.991 and 2010 (0.989). In 2019 the value of DC of 0.994, which is the highest value of all the years and the average value of DC, is 0.989.

b) Collaboration Index (CI)

(Lawani S.M, 1980) was suggested the Collaborative Index (CI) method. CI is the average number of authors per paper. It can be easily calculated, but it cannot be interpreted as a degree because it has no upper limit. The formula is as follows:

$$\mathrm{CI} = \frac{\sum_{j=1}^{k} j(fj)}{N}$$

In simpler terms,

$$CI = \frac{(\mathrm{f1})1 + (\mathrm{f2})2 + (\mathrm{f3})3 + \cdots + (\mathrm{fn})\mathrm{n}}{\mathrm{N}}$$

Where, f1, f2, f3…. = number of authors

N= Total no of papers

Using data in Table 3, during 2015

$$CI = \frac{(30 + 247 * 2 + 488 * 3 + \cdots + 65 * 10)}{2418}$$

$$CI = \frac{11353}{2416}$$

$$CI = 4.695$$

In table 3 shows that the CI value is highest (4.922) in the year 2019 and the CI value is lowest (4.222) in the year 2010. The average CI value is 4.835 during the study period.

c) Collaborative Coefficient (CC)

The CC is defined by (Ajiferuke et al., 1988) It aims to eliminate the shortcomings associated with CI and DC. CC is between 0 and 1 (0d"CC>1). Since the number of individual authors dominates, CC0. CC distinguishes single author, two authors, three authors, etc. The problem with CC is that it does not give a maximum collaboration value of 1 unless the number of authors is unlimited. The formula as below:

$$\mathrm{CC} = 1 - \frac{\sum_{j=1}^{A}\left(\frac{1}{j}\right) fi}{N}$$

Using data in Table 3, during 2015

$$\mathrm{CC} = 1 - \frac{[(1 * 30) + \left(\frac{1}{2} * 247\right) + \left(\frac{1}{3} * 488\right) + \left(\frac{1}{4} * 483\right) + \cdots + \left(\frac{1}{10} * 65\right)]}{2418}$$

$$\mathrm{CC} = 1 - \frac{629.652}{2418}$$

$$\mathrm{CC} = 0.740$$

The values of CC for year 2018 is 0.752; 2019 is 0.750 and 2016 & 2017 is 0.744 respectively. The average value of CC is 0.751 during the study period.

d) Modified Collaborative Coefficient (MCC)

Savanur & Srikanth (2010) were proposed the formula for the calculation of MCC. For single-author papers, CC gives 0, but it does not give the maximum collaboration value of 1. This is taken care of by MCC and the formula is as below:

Table 3 is calculated MCC for distribution of authorships and below is the example for the year 2015:

$$\kappa = \frac{A}{A-1}\left\{1 - \frac{\sum_{j=1}^{k}(1/j)fj}{N}\right\}$$

$$\kappa = \left(\frac{2418}{2418-1}\right)\left\{1 - \frac{(30 * 1) + \left(\frac{1}{2} * 247\right) + \left(\frac{1}{3} * 488\right) + \left(\frac{1}{4} * 483\right) + \left(\frac{1}{5} * 437\right) + \cdots + \left(\frac{1}{10} * 65\right)}{2418}\right\}$$

$$\kappa = (1.000414)\left(1 - \frac{629.652}{2418}\right)$$

$$\kappa = (1.000414)\,(0.740)$$

$$\boldsymbol{\kappa = 0.740}$$

The highest value of MCC are 0.752 in 2018, 0.750 in 2019, and 0.745 in the year 2016 and 2017 respectively and the average MCC value 0.752 during the study period.

Table 3: Authorship Pattern and Collaborative Measures (DC, CI, CC, and MCC) of CSIR- Chemical Sciences Laboratories

Year	Single	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten or More	Total	DC	CI	CC	MCC
2010	17	216	367	400	254	155	77	40	27	18	**1571**	0.989	4.222	0.717	0.717
2011	33	255	371	416	294	181	114	46	27	37	**1774**	0.982	4.315	0.715	0.715
2012	23	250	404	367	320	178	123	73	26	45	**1809**	0.987	4.422	0.722	0.723
2013	22	268	382	435	315	204	100	60	47	43	**1876**	0.988	4.412	0.723	0.723
2014	44	320	480	499	413	268	134	104	55	53	**2370**	0.982	4.468	0.722	0.722
2015	30	247	488	483	437	301	200	111	56	65	**2418**	0.988	4.695	0.740	0.740
2016	20	261	408	426	394	301	189	119	67	81	**2266**	0.991	4.825	0.744	0.745
2017	20	280	373	444	401	308	198	124	60	80	**2288**	0.991	4.828	0.744	0.745
2018	15	229	330	460	374	310	197	118	66	67	**2166**	0.993	4.903	0.752	0.752
2019	13	232	341	402	372	248	183	124	54	94	**2063**	0.994	4.922	0.750	0.750
2010-2019	**237**	**2558**	**3944**	**4332**	**3574**	**2454**	**1515**	**919**	**485**	**583**	**20601**	0.989	4.601	0.733	0.733

DC=Degree of Collaboration, CI=Collaboration Index, CC=Collaboration Coefficient, MCC=Modified Collaboration Coefficient.

Discipline -wise Research Output

The total publications were divided into various sub-disciplines. Table 4 delivers the total number of publications (TP), total number of citations (TC) obtained by each discipline along with the values of Average Citation per Paper

Table 4: Discipline-Wise Research Output

Discipline-wise Research Output	TP	h-index	TC	ACPP	% of 20601
Organic Chemistry	3444	73	55585	16.14	16.718
Physical Chemistry	3199	93	78533	24.55	15.528
Chemical Engineering	1581	73	35030	22.16	7.674
Energy Fuels	1142	87	40708	35.65	5.543
Biochemistry Molecular Biology	1100	51	17440	15.85	5.340
Biotechnology Applied Microbiology	976	73	27788	28.47	4.738
Applied Chemistry	962	59	17272	17.95	4.670
Medicinal Chemistry	941	58	18042	19.17	4.568
Polymer Science	931	51	15150	16.27	4.519
Nanoscience Nanotechnology	914	80	27742	30.35	4.437
Applied Physics	845	60	19126	22.63	4.102
Environmental Sciences	797	61	18773	23.55	3.869
Inorganic Nuclear Chemistry	641	50	12779	19.94	3.111
Electrochemistry	628	53	13486	21.47	3.048
Condensed Matter Physics	522	44	9524	18.25	2.534
Analytical Chemistry	509	38	7663	15.06	2.471
Atomic, Molecular and Chemical Physics	501	44	9165	18.29	2.432
Green Sustainable Science Technology	464	58	14036	30.25	2.252
Environmental Engineering	442	58	11814	26.73	2.146
Pharmacology Pharmacy	442	41	7525	17.02	2.146

(ACPP) and h-index. The Average Citation per Paper (ACPP) for the entire output is 19.96. Among all the sub-disciplines, the value of ACPP was more than average for Energy Fuels (35.65), Nanoscience Nanotechnology (30.35), Green Sustainable Science Technology (30.25), Biotechnology Applied Microbiology (28.47), Environmental Engineering (26.73), Physical Chemistry (24.55), Environmental Sciences (23.55), Applied Physics (22.63), Chemical Engineering (22.16) and Electrochemistry (21.47). The lowest value of ACPP was for Analytical Chemistry (15.06). However, for other sub-disciplines, the value of ACPP was close to the average. The highest h index values for Physical Chemistry 93, followed by Energy Fuels with 87 and Physical Chemistry sub-discipline registered highest citations (TC=78533).

Most Influential Authors

Table 5 shows, the list of the 20 most Influential authors with 154 or more highly cited articles, surprisingly most of the authors (09)

Table 5: Most Influential authors

Author	Affiliation	NP	TC	h_index	g_index	m_index
Jhillu Singh Yadav	Indian Institute of Chemical Technology (IICT)	406	5179	32	42	2.667
Sridhar Balasubramanian	Indian Institute of Chemical Technology (IICT)	345	5068	36	48	3.000
Subba Reddy B. V	Indian Institute of Chemical Technology (IICT)	344	5144	33	51	2.750
Arvind Kumar	Central Salt & Marine Chemical Research Institute (CSMCRI)	338	10497	42	90	0.000
Kamal Ahmed	Indian Institute of Chemical Technology (IICT)	287	5940	38	53	3.167
Bajaj Hari C.	Central Salt & Marine Chemical Research Institute (CSMCRI)	232	6390	41	62	3.417
Mandal Asit Baran	Central Glass & Ceramic Research Institute (CGCRI)	227	4857	41	55	3.417
Mohan S. Venkata	Indian Institute of Chemical Technology (IICT)	207	7550	48	72	4.000
Banerjee Rahul	National Chemical Laboratory (NCL)	205	15626	64	122	5.333
Pandey Ashok	Indian Institute of Toxicology Research (IITR)	192	11202	46	103	3.833
Kumar C. Ganesh	Indian Institute of Chemical Technology (IICT)	175	2551	27	37	2.250
Sreedhar B.	Indian Institute of Chemical Technology (IICT)	174	5641	38	68	3.167
Suresh Eringathodi	Central Salt & Marine Chemical Research Institute (CSMCRI)	174	4782	35	60	2.917
Pal Sayan	National Chemical Laboratory (NCL)	170	2900	26	43	2.167
Jha Bhavanath	Central Salt & Marine Chemical Research Institute (CSMCRI)	168	5852	45	66	3.750
Kumar Rahul	Central Salt & Marine Chemical Research Institute (CSMCRI)	163	8477	39	89	3.250
Amitava Das	Central Salt & Marine Chemical Research Institute (CSMCRI)	162	5174	38	62	3.167
Rajesh G.Gonnade	National Chemical Laboratory (NCL)	161	2555	28	39	2.333
Swarbhanu Ghosh	Kalyani University	157	3687	35	52	2.917
Surya Prakash Singh	Indian Institute of Chemical Technology (IICT)	154	3456	35	48	2.917

belong to IICT, Hyderabad and contributed 2092 papers. The most productive author was Jhillu Singh Yadav who contributed 406 papers with 51799 TC and h index value of 32, followed by Sridhar Balasubramanian (NP;345, TC=5068, h index=36) and Subba Reddy BV (NP;344, TC=5144, h index=33) contributed. The papers published by Banerjee Rahul were most often cited and the 205 papers have a TC of 15626 (ACPP 76.22). Figure 2 shows the Authors – Coauthorship collaboration network.

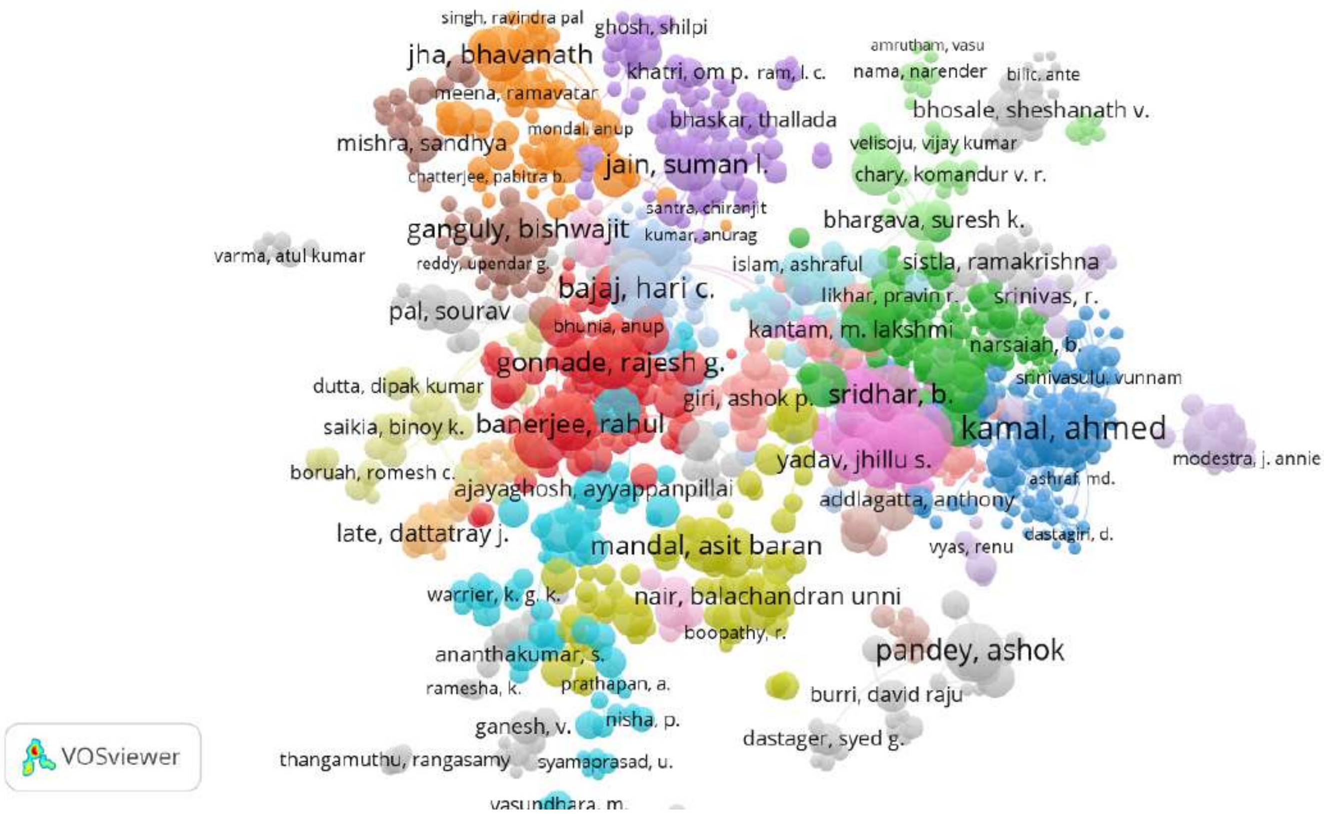

Figure 2: Authors – Coauthorship collaboration network

Preferred Sources and growth

The Table 6 shows the 20 most preferred journals and these journals accounted for (TP=5647; 27.41%) share of the total research output that appeared during the study period (figure 6). Therefore, the rate of highly cited articles varies from journal to journal. The topmost preferred journal was RSC Advances (TP=947; h index=50), followed by Tetrahedron Letters (TP=693; h index=41), Chemistryselect (TP=371; h index=17), Chemical Communications (TP=307; h index=50) and Bioresource Technology (TP=290; h index=61). The 5 journals were produced more than 58459 citations during the study period (Table 6). In that RSC Advances placed top in terms of total citations (16250), followed by Bioresource Technology (TC=14279), Tetrahedron Letters (TC=10504), Chemical Communications (TC=9696) and ACS applied materials & Interfaces (TC=7730). Figure 3 shows the sources growth.

Table 6: Most preferred journals and growth

Source	NP	TC	Cite Score	SNIP	JCR (2019)	Rank	h_index	g_index	m_index
RSC Advances	947	16250	6.5	0.827	0.736	58	50	66	5.000
Tetrahedron Letters	693	10504	4.5	0.64	0.582	188	41	57	3.417
ChemistrySelect	371	1981	2.6	0.466	0.445	176	17	24	2.833
Chemical Communications	307	9696	9.8	1.144	1.992	35	50	75	4.167
Bioresource Technology	290	14279	12.8	2.012	2.43	16	61	102	5.083
Organic and Biomolecular Chemistry	288	4614	6.1	0.804	0.969	99	31	48	2.583
New Journal of Chemistry	270	2908	4.7	0.775	0.712	93	25	32	2.083
Journal of Organic Chemistry	229	4931	7.8	0.987	1.349	16	36	48	3.000
European Journal of Organic Chemistry	226	3252	4.9	0.697	0.863	52	27	39	2.250
Organic Letters	222	7128	10.4	1.194	2.032	30	44	65	3.667
Synthesis-Stuttgart	220	2055	2.74	0.661	1.012	NA	19	28	1.583
Bioorganic and Medicinal Chemistry Letters	215	4886	5.1	0.837	0.64	159	37	51	3.083
Physical Chemistry Chemical Physics	213	3876	6.3	0.98	1.143	30	33	47	2.750
Journal of Physical Chemistry C	200	5346	7.3	1.063	1.477	34	37	61	3.083
ACS applied materials & Interfaces	173	7730	13.6	1.568	2.568	23	51	78	4.636
European Journal of Medicinal Chemistry	164	5560	8.3	1.54	1.144	29	43	60	3.583
Tetrahedron	164	2382	4.3	0.675	0.581	199	23	36	1.917
Industrial & Engineering Chemistry Research	159	3525	5.3	1.124	0.899	82	32	49	2.667
Synthetic Communications	151	965	2.6	0.58	0.367	111	15	20	1.250
Synlett	145	1813	4.4	0.507	0.7	67	22	31	1.833

NP= No. of Publications, TC=Total Citations, SNIP= Source Normalized Impact per Paper, SJR= SCImago Journal Rank

Highly Cited Papers

Highly cited papers are important to the reputation of the university (Ram & Nisha, 2020; Zhu et al., 2004). The top 5 highly cited papers were shown in table 7. Interestingly, all the highly cited papers are published in journals and these papers were received 828 or more citations. These five papers received a total of 7981 citations. All these citations were collected from the WoS Core Collection database. Although

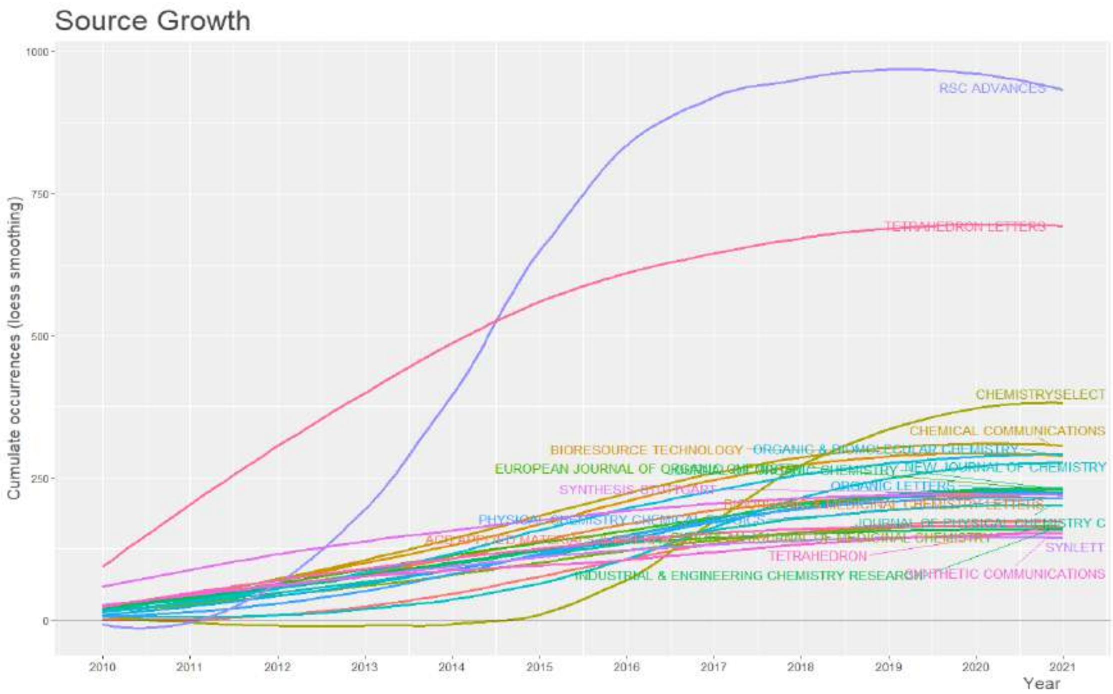

Figure 3: Source Growth

Table 7: Highly cited papers

Details of the Paper	TC	TCpY
Klionsky, D. J. et al., (2016). Guidelines for the use and interpretation of assays for monitoring autophagy (3rd edition). *Autophagy*, *12* (1), 1–222. doi:10.1080/15548627.2015.1100356	3624	604.000
K. Madhavan Nampoothiri et al., (2010). An overview of the recent developments in polylactide (PLA) research. *Bioresource Technology, 101* (22), 8493-8501. doi: 10.1016/j.biortech.2010.05.092	1375	114.583
Ajayaghosh, Ayyappanpillai (2014). Functional π-Gelators and Their Applications. *Chemical Reviews*, 114, 1973-2129. doi: 10.1021/cr400195e	1175	146.875
Kundu, Subrata (2016). Recent Trends and Perspectives in Electrochemical Water Splitting with an Emphasis on Sulfide, Selenide, and Phosphide Catalysts of Fe, Co, and Ni: A Review. *ACS Catalysis*, 6, 8069-8097. doi: 10.1021/acscatal.6b02479	979	163.167
Menon Vishnu, Rao Mala (2012). Trends in bioconversion of lignocellulose: Biofuels, platform chemicals & biorefinery concept. *Progress in Energy and Combustion Science*, *38*(4), 522-550. doi: 10.1016/j.pecs.2012.02.002	828	82.800

TC=Total Citations, TCpY=Total Citations per Year

many articles have been published, a relatively small number of individuals accounted for most of the citations during this period. "Guidelines for the use and interpretation… authored by D. J. Klionsky et al.," received (TC=3624; TCpY=604) citations till mid-April 2021, followed by "An overview of the… by K. Madhavan Nampoothiri, Nimisha Rajendran Nair" with TC of 1375 and TCpY of 114.583.

Most Prolific Keywords

Among 60,118 keywords, only 6,663 keywords (more than 5 times) meet the threshold of the map (Figure 4). The size of the circle indicates the number of articles that appear for each keyword, and the colour indicates the cluster of keywords based on the number of common appearances. Generally, the larger the size of the frame, the more frequently the keyword appears. If they co-occur in the publication more frequently, they are two words close to each other. The smaller the distance between two keywords, the more the keywords appear at the same time. These keywords were divided into 6 clusters with red, green, blue, yellow, purple, and light blue colours. The top 10 keywords with the highest frequency are derivatives (1298), nanoparticles (1273), performance (995), water (827), acid (823), oxidation (698), efficient (618), design (596), adsorption (564) and chemistry (554).

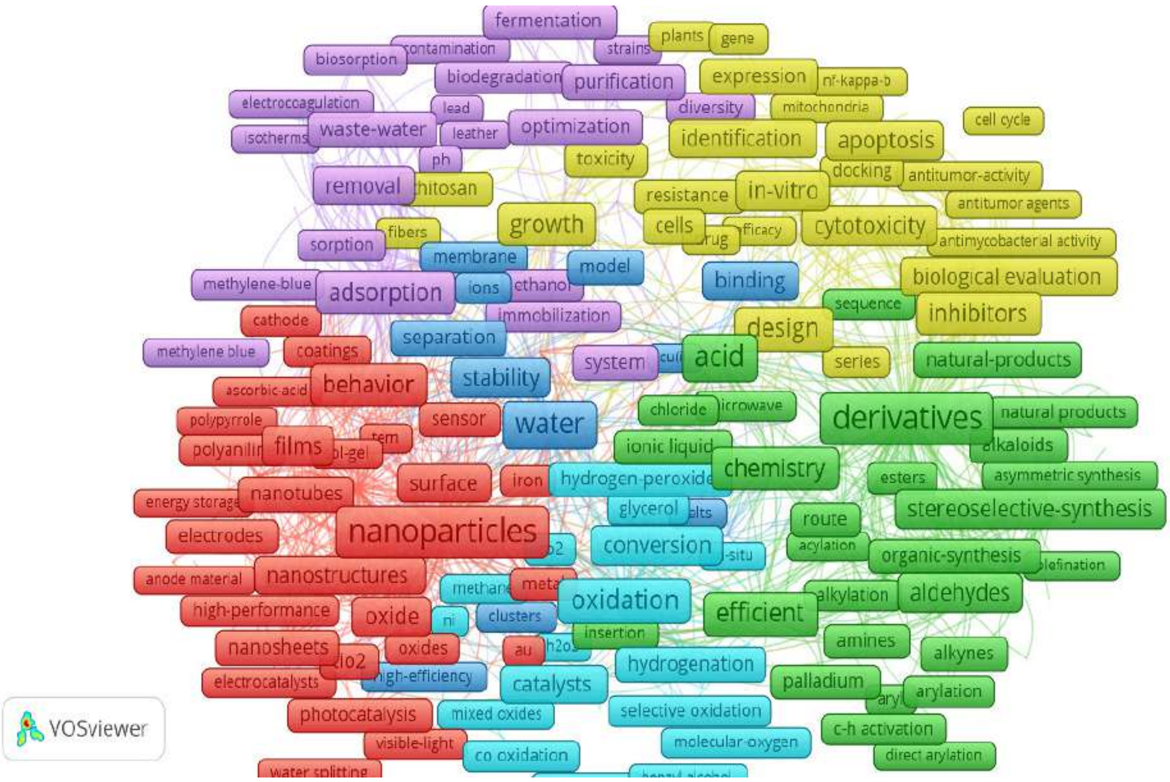

Figure 4: All Keywords VOSviewer Network

DISCUSSION AND CONCLUSION

The present study revels bibliometric analysis and mapping methods of research publications of Indian CSIR- Chemical Science laboratories. Studies consistently indicate that there exists enormous variation in scientist's levels of productivity. The analysis of publication productivity shows that there is an increasing trend of publication growth. A total of 19222 journal articles, 607 reviews, 300 proceedings paper, 172 meeting abstract, etc were published during the study period. Journals are the main sources of information and the fastest and most effective resource for disseminating research results (Kappi et al., 2020). The appearance of journals in the subject areas has measured the growth of knowledge. The acceptable fact is that in science, new journals are appearing faster to provide the rapid growth of information

Authors were highly preferred to publish their results in journals and it amounts to 93.31% of the total publications. The average citation impact per paper varied from 17.32 to 22.49, with an average citation per paper of 19.97 during 2010 – 2019. The 'degree of collaboration' shows the dominance of collaborative research (4.834), the h-index also varied from 43 to 116. Organic and Physical Chemistry research discipline contributed the highest publications (16.718% & 15.528%), followed by Chemical Engineering (7.674%), Energy Fuels (5.543%) and Biochemistry Molecular Biology (5.340%).

These findings will encourage Indian research institutions to work internationally to achieve greater research effectiveness and strengthen research infrastructure and capabilities. The CSIR- Chemical Science laboratories have implemented an institutional online repository system for archiving and distributing scientific and intellectual content in an open-access environment. However, it needs to be updated regularly for relevancy and more comprehensiveness.

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