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Research in Indian CSIR Laboratories: A Bibliometric Study

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Abstract

India is perhaps unique amongst developing countries in having established a distinct science identity since last few centuries. The Council of Scientific and Industrial Research (CSIR) is an autonomous body established in 1942 with the aim of providing strong S&T base for the industry, strategic sectors and advancement of fundamental knowledge. The present study is to understand the quality and quantity of research output and current state-of-the-art of CSIR laboratories using publications output data as reflected in Web of Science and Scopus. The study points out that during 2010 to 2015, although the yearly output has increased from 3940 papers to 5531 papers, the growth rate is neither linear nor exponential. The scientists of the laboratory attach more weight to foreign journals rather than Indian journals having SCI impact factor within the range of 2.0 to 4.0. The authorship trend is completely slanted towards co-authorship and CSIR is assisting considerable financial support for conducting research. The citation analysis of CSIR publications reveals that, a total of 30011 articles published during 2010-2015, received 251212 citations during 2010-2016 with an average rate of 7 citations per article. Almost 10% articles did not receive any citation and 62% articles received citation in the range of 1 to 10.

Keywords: CSIR, Indian Research Laboratories, Indian Research - Bibliometric Study, Research Output - Indian Laboratories

1. Introduction

Science is one of the most powerful instruments for growth and development of society, especially in the emerging scenario and competitive economy. India's first Prime Minister Jawaharlal Nehru once mentioned that "It is science alone that can solve the problems of hunger and poverty, of insanitation and illiteracy, of superstition …. of vast resources running to waste, or a rich country inhabited by starving poor". The present government has a vision to make India one among the top 3 countries in science and technology by 2030. Talking on the inauguration of the 104th session of Indian Science Congress, Tirupati, on 03 January 2017, the Prime Minister urged that "Our best science and technology institutions should further strengthen their basic research in line with leading global standards". Translating this basic knowledge into innovations, start-ups and industry will help us achieve inclusive and sustainable growth.

India is perhaps unique among developing countries in having established a distinct science identity. This identity is reflected in the quality and quantity of scientific research in chemistry, biology, mathematics, astronomy, and physics. The Indian Institute of Science (1909), Bose Research Institute (1917), Raman Research Institute (1938), Tata Institute of Fundamental Research (1945) and Calcutta College of Science (1918) are all institutes carrying out frontier research in S&T since early 20th century. Along with these, several research laboratories were established in the latter half of 20th century including laboratories under CSIR, DRDO, ISRO, ICAR, ICMR, DAE, etc. In terms of funding, much of the S&T efforts are supported by governments. India has a reasonably large research base but only a small proportion of GDP is spent on research (0.69% in 1995-96 to 0.81% in 1999-2000; to 0.88% in 2006 to 1% in 2008-10; fell to 0.85 in 2015). The GERD as a percentage of GDP has remained below 1% as compared to the developed and emerging economies despite increase in absolute terms. However, the Science, Technology and Innovation (STI) Policy, 2013 envisages increasing R&D expenditure to 2% of GDP with enhanced participation of private sector

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through policy and reform processes. However, there is less focus on basic research among Indians as less than four persons out of every 1,000 are choosing S&T or research, as compared to 110 in Japan, 76 in Germany and Israel, 55 in USA, 46 in Korea and eight in China.

2. CSIR at a Glance

CSIR is an autonomous body established in 1942. The first CSIR-Laboratory i.e. National Chemical Laboratory was established at Pune on 6 April 1947, four months before India became independent. Subsequently, National Physical Laboratory, Delhi, National Metallurgical Laboratory, Jamshedpur, Central Fuel Research Institute, Dhanbad, Central Glass and Ceramics Research Institute, Calcutta and Central Food Technological Research Institute, Mysore were established in 1950. Over time CSIR became one of the world's largest publicly funded R&D organisations having linkages to academia, R&D organisations and industry. At present, there are 38 laboratories, 39 outreach centres, 3 innovation complexes and 5 units spread across the nation working under the aegis of CSIR. The laboratories of the CSIR are grouped under five disciplines, namely, physical and earth sciences, chemical sciences, biological sciences, engineering sciences and information sciences. The total annual operating budget of the CSIR exceeds Rs.3200 crores. CSIR earns an income by way of extra budgetary resources, mainly out of R&D services. The annual industrial production in India based on the CSIR know-how is also quite high. CSIR files about 1000 patents per year with roughly half in countries outside India. CSIR has also played a major role in promoting scientific research in universities through award of junior and senior research fellowships to students and research grants to faculty (Sivaram, 2002. http://sap.csir.res.in/foundationday2012/files/Article_by_Dr_Sivaram.pdf.).

3. Review of Literature

Much of the scientometric literature is devoted to scientific enterprises in the advanced countries and not much is written about science done in the rest of the world. Garg and Rao (1988)[2] analyzed the publication output of an Indian laboratory in the field of physics published in *SCI* and non-SCI covered Indian and foreign journals, processes developed and Indian patents filed during the period 1965-82 to find out the pattern of productivity. They found that Indian scientists prefer to publish in foreign journals. Similarly, Kademani et.al. (2005)[3] attempted to analyze quantitatively 475 papers published by the Bio-Organic Division of Bhabha Atomic Research Centre during 1972-2002 in various domains Kademani et.al. (2007)[4] analyzed the growth and development of science and technology (S&T) activities in India, in terms of growth characteristics, language, format and media of communication, research quality, institutional productivity, patterns of research collaboration, and broad and narrow subject areas of interest as reflected in publication output covered by Science Citation Index (SCI) during 1990-2004.

Choudhary and Khanna (2009) found that 42 Indian state-owned laboratories over 1993-2006 significantly improved performance and were granted more patents than all domestic private firms. Furthermore, patent licensing revenue increased from 3 per cent to 15 percent of government budget, without significantly affecting publication quality and quantity following incentives policy change and leadership change at labs. Pathak and Bharati (2014)[6] reported on the research performance of the Botanical Survey of India (BSI) between 1971 and 2010, based on number of parameters, including publications, citations, impact in terms of average citations per paper, international and national collaboration output, share of publication by different circles of BSI, type of communication, most preferred journals, highly cited papers, authorship pattern and most productive authors. The study analyzed 40 years (1971-2010) of publication data drawn from Web of Science (SCI-Expanded). They found that *Current Science* is the most preferred journal, Council of Scientific and Industrial Research (CSIR) is major domestic collaborator (21 papers), University of Rhode Island, Kingston is the major foreign collaborator (11 papers), USA is the major collaborator country (16 papers) and BSI, Kolkata has contributed maximum number of publications (41%).

Dwivedi, Kumar and Garg (2015)[1] analyzed 17,344 papers published by Indian scientists and indexed in Web of Science in the discipline of organic chemistry and its sub-disciplines during 2004-2013. It was found that the Indian output has increased significantly. Academic institutions contributed about 46% of the total output followed by the CSIR with 26% of the total output. The average citation per paper for most of the prolific institutions was higher than the Indian average.

4. Objectives

The main objectives of this study are to:

- Measure the quantity of research output of all CSIR laboratories in general and individual laboratories;

- Study the pattern of research in CSIR laboratories; and
- Measure the quality of research output in terms of citations.

5. Methodology

This study uses Web of Science and Scopus databases for publications data of CSIR laboratories. Six years publications data from 2010 to 2015 were selected and all the searched results were first saved as tab-delimited text and imported to Excel for analysis. The study does not include forms classified as Conference paper, book chapter, editorial materials, meetings abstracts etc. for detailed analysis. In addition, it used citations data for measuring quality and visibility of Indian research output. Complete citations window has been used for computing average citations per paper for all S&T papers published by the CSIR scientists from 2010 to 2015. But for papers published in 2015 we had two years citation window, 2015 and 2016. The study used the absolute number of publications, and citations.

6. Results

Using the methodology described above, we retrieved 32725 items contributed by CSIR authors during the six-year period (Table 1). CSIR scientists mostly (91.7%) prefer to publish their work in the form of articles than in other forms. It is interesting to observe that although the number of scientific publications has raised sharply the growth rate cannot be explained using either linear or logistic models. The two peak years are 2014 followed by 2015 and two low output years are 2012 followed by 2010.

As articles are the major forms of CSIR research publications, in the remaining part of this analysis we analyze the pattern and characteristics of research by CSIR scientists by considering articles only.

Table 2 shows the research output by individual laboratories. Indian Institute Chemical Technology, Hyderabad has contributed highest percentage (12.7%) of articles followed by National Chemical Laboratory, Pune (8.5%) and National Physical Laboratory, New Delhi (6.5%). Institutes involving research in the domain of materials processing, building, instrumentation,

Table 1. Pattern of CSIR research output though various years under various forms

Documentary Form	2010	2011	2012	2013	2014	2015	Total Output
Article	3940	4651	4802	5130	5957	5531	30011
Review	156	144	118	167	269	209	1063
Meeting Abstract	156	86	30	101	74	66	513
Proceedings Paper	125	89	23	50	75	69	431
Editorial Material	46	65	25	44	74	64	318
Letter	31	33	21	29	28	21	163
Correction	16	21	11	29	39	28	144
Book Chapter (Article & Book)	4	3	8	0	13	6	34
News Items	1	3	1	2	6	10	23
Biographical-Item	1	3	1	2	2	2	11
Retracted Publication	1	4	1	2	0	1	9
Book Review	1	0	0	1	2	0	4
Software Review	0	0	0	0	1	0	1
Total	**6488**	**7113**	**7053**	**7570**	**8554**	**8022**	**32725**

Table 2. Research in various laboratories of CSIR

Name of CSIR Laboratory	2010	2011	2012	2013	2014	2015	Total	% of Total
Indian Institute Chemical Technology, Hyderabad	520	583	620	581	785	732	3821	12.73
National Chemical Laboratory, Pune	307	355	423	436	520	535	2576	8.58
National Physical Laboratory, New Delhi	262	312	299	328	424	344	1969	6.56
Central Drug Research Institute, Lucknow	174	198	233	256	348	335	1544	5.14
Central Leather Research Institute, Chennai	156	174	217	222	238	236	1243	4.14
Central Salt Marine Chemicals Research Institute, Bhavnagar	193	207	167	173	199	200	1139	3.80
Indian Institute of Chemical Biology, Kolkata	144	169	192	212	226	195	1138	3.79

National Institute For Inter-disciplinary Science and Technology, Thiruvanantha-puram	165	187	131	176	224	198	1081	3.60
Central Electrochemical Research Institute, Karaikudi	139	174	133	166	230	197	1039	3.46
Centre for Cellular Molecular Biology, Hyderabad	135	162	157	182	169	162	967	3.22
Central Food Technological Research Institute, Mysore	130	150	144	142	202	189	957	3.19
National Institute of Oceanography, Goa	164	177	158	132	134	138	903	3.01
National Botanical Research Institute, Lucknow	130	129	159	138	126	133	815	2.72
National Geophysical Research Institute, Hyderabad	97	139	146	143	155	119	799	2.66
Indian Institute of Toxicology Research, Lucknow	109	175	128	121	144	114	791	2.64
Institute of Genomics and Integrative Biology, Delhi	81	110	129	135	141	153	749	2.50
Central Institute of Medicinal Aromatic Plants, Lucknow	96	73	113	146	189	121	738	2.46
Institute of Minerals and Materials Technology (IMMT), Bhubaneswar	95	113	122	142	150	114	736	2.45
Central Glass Ceramic Research Institute, Kolkata	91	89	113	135	144	124	696	2.32
Indian Institute of Integrative Medicine (IIIM), Jammu	65	94	109	156	135	133	692	2.31
National Environmental Engineering Research Institute, Nagpur	127	134	121	89	111	95	677	2.26
Institute of Microbial Technology, Chandigarh	70	79	103	142	137	111	642	2.14
National Metallurgical Laboratory, Jamshedpur	103	91	85	118	99	90	586	1.95
National Aerospace Laboratories, Bangalore	60	84	104	120	118	88	574	1.91
Institute of Himalayan Bioresource Technology, Palampur	55	80	91	100	82	99	507	1.69
Central Mechanical Engineering Research Institute, Durgapur	31	53	65	76	93	106	424	1.41
Indian Institute of Petroleum, Dehradun	28	40	52	52	88	117	377	1.26
Central Electronics Engineering Research Institute, Pilani	26	60	52	48	64	72	322	1.07
Structural Engineering Research Centre, Chennai	40	46	54	55	47	67	309	1.03
Central Institute of Mining and Fuel Research, Dhanbad	33	45	37	44	51	59	269	0.90
North - East Institute of Science and Technology, Jorhat	17	40	41	49	42	50	239	0.80
Central Scientific Instruments Organisation, Chandigarh	16	34	36	40	54	43	223	0.74
Central Building Research Institute, Roorkee	15	19	14	19	18	13	98	0.33
Advanced Materials and Processes Research Institute (AMPRI), Bhopal	29	27	15	9	8	7	95	0.32
CSIR Fourth Paradigm Institute, Bengaluru	11	17	10	7	22	15	82	0.27
National Institute of Science, Technology And Development Studies, New Delhi	9	9	12	18	16	8	72	0.24
Central Road Research Institute, New Delhi	9	13	5	10	15	18	70	0.23
National Institute of Science Communication and Information Resources, New Delhi	8	10	12	12	9	1	52	0.17
Total	**3940**	**4651**	**4802**	**5130**	**5957**	**5531**	**30011**	

structural engineering, mining and fuel do not have significant presence. There is a need to strengthen these areas of research for overall scientific excellence of the country.

7. Statistics Involving Publications by Authors

Only 1.27% of all publications were of single authorship; Over 98% of papers involved two or more authors. Koehler et.al. (2000)[5] in their study mentioned that "multiple-authorship is a sign of a mature discipline, publishing complex articles addressing complex issues". Subramanyam (1983)[8] has also mentioned about increasing collaboration. According to Qiu (1992)[7] there is also a strong trend towards borrowing from and interpenetration across disciplines. Table 3 shows the distribution of publications by number of authors and leading authors of each individual CSIR units.

Interestingly, 10% of all papers involved the "top" author of the 38 organization. Jhillu Singh Yadav of Indian Institute Chemical Technology, Hyderabad, Ram Anuj Vishwakarma of Indian Institute of Integrative Medicine (IIIM), Jammu, and Anil Kumar Singh of Institute of Himalayan Bioresource Technology, Palampur are three leading authors who have contributed more than 200 articles during the last six years. Table 3 also shows the distribution of contributions made by other leading authors.

Table 3. Publication by authors

Name of CSIR Laboratory	TP	TA	A/A	Leading Author	TP
Indian Institute Chemical Technology, Hyderabad	3821	1758	2.2	Yadav, Jhillu Singh	397
National Chemical Laboratory, Pune	2576	752	3.4	Choudhary, Vasant R.	82
National Physics Laboratory, New Delhi	1969	409	4.8	Srivastava, Sanjay Kumar	127
Central Drug Research Institute, Lucknow	1544	786	2.0	Saxena, Anil Kumar	123
Central Leather Research Institute, Chennai	1243	531	2.3	Perumal, Paramasivan Thirumalai	134
Central Salt Marine Chemicals Research Institute, Bhavnagar	1139	313	3.6	Suresh, Eringathodi S M	110
Indian Institute of Chemical Biology, Kolkata	1138	192	5.9	Bhattacharyya, Debnath	28
National Institute For Interdisciplinary Science and Technology, Thiruvananthapuram	1081	323	3.3	Pandey, Ashok	109
Central Electrochemical Research Institute, Karaikudi	1039	294	3.5	Murali, Kollegal Ramakrishna	46
Centre for Cellular Molecular Biology, Hyderabad	967	265	3.6	Shivaji, Sisinthy S.	62
Central Food Technological Research Institute, Mysore	957	557	1.7	Ravishankar, Gokare Aswathanarayana	65
National Institute of Oceanography, Goa	903	298	3.0	Ingole, Baban S.	21
National Botanical Research Institute, Lucknow	815	173	4.7	Singh, Nandita Kumar Sharat	51
National Geophysical Research Institute, Hyderabad	799	190	4.2	Gupta, Harsh K.	27
Indian Institute of Toxicology Research, Lucknow	791	148	5.3	Singh, Mahendra Pratap	54
Institute of Genomics and Integrative Biology, Delhi	749	39	19.2	Kumar, Ashok N.	38
Central Institute of Medicinal Aromatic Plants, Lucknow	738	343	2.2	Gupta, Atul Kumar	103
Institute of Minerals and Materials Technology (IMMT), Bhubaneswar	736	137	5.4	Das, Trupti P.	81
Central Glass Ceramic Research Institute, Kolkata	696	245	2.8	Bhadra, Shyamal Kumar	67
Indian Institute of Integrative Medicine (IIIM), Jammu	692	557	1.2	Vishwakarma, Ram Anuj	221
National Environmental Engineering Research Institute, Nagpur	677	206	3.3	Purohit, Hemant J.	40
Institute of Microbial Technology, Chandigarh	642	178	3.6	Kumar, Ashwani Senthil	100
National Metallurgical Laboratory, Jamshedpur	586	148	4.0	Das, Swapan Kumar	41
National Aerospace Laboratories, Bangalore	574	192	3.0	Chakradhar, R. P Sreekanth	39
Institute of Himalayan Bioresource Technology, Palampur	507	110	4.6	Singh, Anil Kumar	206
Central Mechanical Engineering Research Institute, Durgapur	424	122	3.5	Shukla, Ashish Kumar	74
Indian Institute of Petroleum, Dehradun	377	122	3.1	Singh, Rajesh Kumar P	81
Central Electronics Engineering Research Institute, Pilani	322	96	3.4	Srivastava, Vishnu	19
Structural Engineering Research Centre, Chennai	309	55	5.6	Lakshmanan, Nachammai	22
Central Institute of Mining and Fuel Research, Dhanbad	269	81	3.3	Singh, Rajendra Kumar Brojen	105
North - East Institute of Science and Technology, Jorhat	239	140	1.7	Prajãpati, Dipak	103
Central Scientific Instruments Organisation, Chandigarh	223	82	2.7	Deep, Akash	21
Central Building Research Institute, Roorkee	98	21	4.7	Jain, Arvind Kumar	9
Advanced Materials and Processes Research Institute (AMPRI), Bhopal	95	39	2.4	Chand, Navin Ramakrishna K	60
CSIR Fourth Paradigm Institute, Bengaluru	82	8	10.3	Gaur, Vinod K.	12
National Institute of Science, Technology And Development Studies, New Delhi	72	10	7.2	Garg, Kailash C.	8
Central Road Research Institute, New Delhi	70	NA	-	NA	NA
National Institute of Science Communication And Information Resources, New Delhi	52	13	4.0	Mahesh, G.	10

TP=Total publication, TA=Total author, A/A=Article/Author

8. Statistics Involving Publications by Journal

The 30011 articles are published in 2866 journals. Of these 2161 (7.2%) articles are published in Indian journals and the remaining 27850 (92.7%) articles in foreign journals. Table 4 shows the data related to number of journals and their share of the total number of articles.

Table 4. Publication pattern by journals

Journals where articles published	Quantity of article	% of articles	No. of Journals	% of journals
Once	905	3.02	905	31.58
Twice	814	2.71	407	14.20
Thrice	747	2.49	249	8.69
Four times	660	2.20	165	5.76
Five Times	675	2.25	135	4.71
6-10 times	2834	9.44	383	13.36
11-30 times	6463	21.54	374	13.05
31-50 times	3173	10.57	85	2.97
51-100 times	4498	14.99	65	2.27
More than 100 times	9242	30.80	47	1.64

It is seen from Table 4 that 905 journals (almost 32%, of journals) published only 3% of the total while major portion of articles (9242 article, approximately 31%) was published in just 2% of journals. From the shape of the curve (Figure 1), it may be seen that in science authors prefer to publish in a few preferred journals.

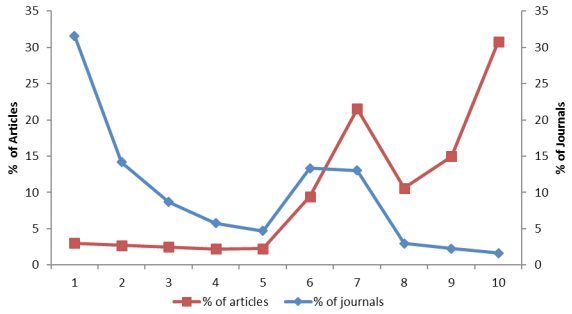

Figure 1. Distribution of articles in journals.

Table 5 lists the top 20 journals. Journals such as *RSC Advance, Tetrahedron Letters*, and *PLoS One* are the most utilized. The reason is clearly that DEA theory and many DEA applications fall within the fields of operations research and management science, exactly the arenas covered by these journals.

9. Statistics Involving Keywords Used

There are 52,997 unique keywords falling within 730 broad subjects, with an average of 3.5 keywords per publication. The top ten basic subjects where most of the literature

Table 5. Preferential journals of CSIR Scientists

Top Journals according to quantity of article & IF 2016	QA	Top Journals according to IF 2016	QA
RSC Advance (3.289)	1344	Lancet (44.002)	02
Tetrahedron Letters (2.347)	661	Nature Biotechnology (43.0013)	01
PLoS One (3.057)	448	Nature Reviews Immunology (39.416)	01
Chemical Communication (6.567)	286	Nature Materials (38.891)	03
Organic & Biomolecular Chemistry (3.559)	276	Nature (38.138)	01
Current Science (0.967)	269	Science (34.661)	03
Bioorganic & Medicinal Chemistry Letters (2.486)	233	Chemical Reviews (37.369)	09
European Journal of Medical Chemistry (3.902)	229	Nature Genetics (31.616)	02
Physical Chemistry Chemical Physics (4.449)	222	Nature Photonics (31.167)	01
Journal of Food Science Technology, Mysore (NA)	210	Nature Medicine (30.357)	05
Journal of Alloys and Compounds (3.014)	201	Cell (28.710)	01
Synthesis-Stuttgart (2.652)	201	Energy & Environment (25.427)	01
Journal of Physical Chemistry C (4.509)	184	Nature Methods (25.328)	01
Dalton Transactions (4.177)	179	Nature Chemistry (27.893)	02
Tetrahedron (2.654)	178	Cell Stem Cell (22.387)	01
Journal of Physical Chemistry B (3.187)	176	Accounts Of Chemical Research (22.003)	06
The Journal of Organic Chemistry (4.785)	174	Journal Of Clinical Oncology (20.982)	02
Bio-resource Technology (4.917)	172	Cancer Discovery (19.783)	01
Journal of Applied Physics (2.101)	160	British Medical Journal (19.697)	01
Industrial & Engineering Chemistry Research (NA)	159	Advanced Materials (18.960)	14

NA=Not available, QA= Quantity of Articles

appeared are: Chemistry (6648), Materials Science (1206), Physics (946), Pharmacology and Pharmacy (794), Engineering (773), Biochemistry and Molecular Biology (558), Environmental Sciences and Ecology (511), Food Science and Technology (509), Polymer Science (400), and Plant Sciences (309). Table 6 lists the top 50 keywords that appeared frequently.

Table 6. Research trends as reflected in keywords

Keywords	Frequency	Keywords	Frequency
Cytotoxicity	245	ROS	61
Apoptosis	234	Toxicity	60
Oxidative stress	220	Polymorphism	59
X-ray diffraction	218	Pharmacokinetics	57
Microstructure	211	Stability	57
Nanoparticles	181	Crystal growth	56
Kinetics	177	Cyclic voltammetry	56
Photo-luminescence	170	Natural products	56
Antioxidant	128	Synthesis	56
XRD	128	Aldehydes	55
Oxidation	116	Characterization	55
SEM	111	GC-MS	55
Crystal structure	108	Mycobacterium tuberculosis	55
Magnetic properties	98	Reduction	55
Fluorescence	96	Cyclization	54
Essential oil	93	Heterogeneous catalysis	54
Nanostructures	91	Isotherms	54
XPS	90	Nanocomposite	54
Luminescence	88	Spectroscopy	54
Self-assembly	88	Apoptosis	54
Adsorption	88	Ring-closing metathesis	53
TEM	87	Biomass	52
Thermodynamics	84	Graphene	52
Dielectric properties	83	Crystal structure	52
Morphology	83	Gold nanoparticles	50
Antioxidant activity	82	Cytotoxic activity	49
Thin film	82	Sol-gel	49
Antibacterial activity	81	Nanostructures	49
Nanocomposites	81	Lipid peroxidation	46
Antimicrobial activity	80	Ceramics	46
Anticancer activity	79	Biodegradation	45
Rheology	79	EIS	45
Raman spectroscopy	78	Heterogeneous catalyst	45
Molecular docking	77	Nanoindentation	45
Corrosion	76	NMR	45
Heavy metals	76	Anticancer	44
HPLC	76	Esterification	44
Response surface methodology	76	Green chemistry	44
Thin films	76	Ionic liquid	44
Optimization	73	Sintering	44
FTIR	72	Cytokines	43
Chitosan	71	Density functional theory	43
Reactive oxygen species	68	Immobilization	43
DFT	67	Antifungal activity	42
Photocatalysis	67	Genetic diversity	42
Hardness	66	Genotoxicity	42
Palladium	64	HPTLC	41
Docking	63	Click chemistry	40
Gene expression	61	DNA damage	39
Microwave	61	Drug delivery	39

Going by frequency of occurrence of keywords, Cytotoxicity and Apoptosis are the two dominant areas of research in CSIR laboratories. As both are related to chemical biology, it seems that chemical biology is one of the major areas of research in CSIR laboratories.

10. Funding Agencies

Funding necessarily requires evaluation of submitted project proposals and only the most promising receive financial assistance. As indicated in Table 7, CSIR itself is one of the major funding agencies for pursuing research in India. Mostly it allots funds to its 38 laboratories in few cases they also allot grants to academic institutions. Of the total articles, almost 52% of articles were reporting research that received funding from CSIR itself.

The foreign funders like Welcome Trust, National Research Foundation of Korea, Australian Research Council, Alexander von Humboldt-Foundation, Japan Society for the Promotion of Science etc. are associated with papers where one of the co-authors is from the respective country.

11. Pattern of Citation of Research Output

The citation analysis of CSIR publications reveals that the 30011 articles published during 2010-2015, received 251212 citations during 2010-2016 at an average 7 citations per article. Analysis of citation data also indicates that, out of the 30011 published articles, 3017 (10%) papers did not receive any citations and the remaining 18497 (62%) had between one and ten citations, 7892 (27%) received citations between ten and fifty, 464 articles (1.5%) received between fifty one and hundred citations and 141 (0.5%) articles received more than one hundred citations. The CSIR laboratory-wise citation pattern is shown in Table 8.

As indicated in Table 8, although Indian Institute Chemical Technology, Hyderabad has the highest (34197) number of articles, National Institute For Interdisciplinary Science and Technology, Thiruvananthapuram has the highest average citations per paper (12.02); Indian Institute of Chemical Biology, Kolkata has the least number of uncited articles (4.93%) and National Chemical Laboratory, Pune has the highest (22 articles) number of articles with more than 100 citations.

Table 7. Top 25 funding agencies

Sl.No.	Name of the Funding Agency	FT	% share
1.	Council of Scientific and Industrial Research	15821	52.72
2.	Department of Science and Technology	5069	16.89
3.	University Grants Commission	3307	11.02
4.	Indian Council of Medical Research	619	2.06
5.	Board of Research in Nuclear Science	576	1.92
6.	Board of Research in Nuclear Science	576	1.92
7.	National Science Foundation	353	1.18
8.	Ministry of Earth Sciences	348	1.16
9.	Jawaharlal Nehru Centre for Advanced Scientific Research	306	1.02
10.	Ministry of New and Renewable Energy	87	0.29
11.	National Institutes of Health	86	0.29
12.	Welcome Trust	82	0.27
13.	Ministry of Health and Family Welfare,	81	0.27
14.	Basic Science Research Program through the National Research Foundation of Korea	77	0.26
15.	Ministry of Environment and Forests	71	0.24
16.	Australian Research Council	69	0.23
17.	Indian Council of Agricultural Research	58	0.19
18.	Alexander von Humboldt-Foundation	53	0.18
19.	Japan Society for the Promotion of Science	52	0.17
20.	Indian National Science Academy	49	0.16
21.	All India Council for Technical Education	41	0.14
22.	Indian Space Research Organization	38	0.13
23.	Kerala State Council for Science, Technology and Environment	31	0.10
24.	Korea Institute of Energy Technology Evaluation and Planning	31	0.10
25.	Indian Academy of Science	27	0.09

FT=Total articles by financial support

Table 8. Statistics involving citation pattern (decreasing citation order)

CSIR Unit	Total Citations Received	Citation/ Article	% uncited articles	AC_{100}	AC_{50}	AC_{10}
Indian Institute Chemical Technology, Hyderabad	34197	8.95	6.23	10	64	1077
National Chemical Laboratory, Pune	30367	11.79	7.92	22	76	833
National Physics Laboratory, New Delhi	19054	9.68	8.68	17	39	575
National Institute For Inter-disciplinary Science and Technology, Thiruvanantha-puram	12993	12.02	7.49	17	21	337
Central Salt Marine Chemicals Research Institute, Bhavnagar	12011	10.55	4.65	6	24	439
Central Drug Research Institute, Lucknow	11722	7.59	7.64	3	16	523
Centre for Cellular Molecular Biology, Hyderabad	9564	9.89	11.79	5	20	265
Central Leather Research Institute, Chennai	8903	7.16	14.00	2	15	331
Central Food Technological Research Institute, Mysore	8607	8.99	16.30	2	16	263
Indian Institute of Toxicology Research, Lucknow	8566	10.83	10.87	12	20	222
Institute of Genomics and Integrative Biology, Delhi	7421	9.91	8.16	4	15	284
National Institute of Oceanography, Goa	7029	7.78	13.62	5	9	184
Institute of Minerals and Materials Technology (IMMT), Bhu-baneswar	6423	8.73	14.18	5	16	231
Central Electrochemical Research Institute, Karaikudi	6422	6.18	9.82	4	9	195
Indian Institute of Integrative Medicine (IIIM), Jammu	6127	8.85	12.70	3	12	241
Central Glass Ceramic Research Institute, Kolkata	6027	8.66	10.92	1	5	214
National Botanical Research Institute, Lucknow	5547	6.81	9.20	5	12	161
National Environmental Engineering Research Institute, Nagpur	5341	7.89	9.31	3	14	138
National Geophysical Research Institute, Hyderabad	5301	6.63	16.40	1	8	164
Indian Institute of Chemical Biology, Kolkata	4714	4.14	4.39	0	5	162
Institute of Microbial Technology, Chandigarh	4696	7.31	7.17	2	5	147
Institute of Himalayan Bioresource Technology, Palampur	4691	9.25	8.09	3	8	95
National Metallurgical Laboratory, Jamshedpur	4561	7.78	10.58	3	8	117
Central Institute of Medicinal Aromatic Plants, Lucknow	3936	5.33	12.60	1	5	125
Indian Institute of Petroleum, Dehradun	3200	8.49	7.96	2	6	87
Central Mechanical Engineering Research Institute, Durgapur	2954	6.97	15.56	0	5	121
National Aerospace Laboratories, Bangalore	2835	4.94	11.85	0	3	106
North - East Institute of Science and Technology, Jorhat	2038	8.53	11.30	1	2	52
Central Institute of Mining and Fuel Research, Dhanbad	1359	5.05	20.07	2	3	39
Central Scientific Instruments Organisation, Chandigarh	1029	4.61	17.04	0	1	43
Central Electronics Engineering Research Institute, Pilani	951	2.95	17.39	0	1	31
Central Building Research Institute, Roorkee	668	6.82	26.53	2	1	17
Advanced Materials and Processes Research Institute (AMPRI), Bhopal	554	5.83	22.10	0	0	28
CSIR Fourth Paradigm Institute, Bengaluru	418	5.10	9.75	0	0	18
Structural Engineering Research Centre, Chennai	353	1.14	19.27	0	0	7
Central Road Research Institute, New Delhi	262	3.74	28.57	0	0	8
National Institute of Science, Technology And Development Studies, New Delhi	192	2.67	29.16	0	0	7
National Institute of Science Communication And Information Resources, New Delhi	179	3.44	12.96	0	0	5

AC100= Number of articles with more than 100 citations; AC50 = Number of articles in between 50-99 citations; AC10 = Number of article in between 10-49 citations.

12. Conclusion

It is true that technological innovations and economic assistance of any nation helps considerably for qualitative research. After independence, CSIR laboratories in India have been equipped well and the Indian government is providing support for improving the quality of research in science. Therefore, it is quite pertinent to investigate the status of research in various CSIR laboratories. In this study, using *Web of Science and Scopus* data, an overview of research has been presented by analyzing the quality and quantity of research output in various CSIR laboratories. This analysis also helps to gather an idea about which laboratories are the most active in terms of scientific publications in science and technology.

The study points out that during 2010 to 2015, although the yearly output has increased from 3940 articles to 5531 articles, the growth rate is neither not linear nor exponential. The scientists give more weight to foreign journals rather than Indian journals for publishing their papers, and they have some preferential journals to which they submit their papers for publication. Although, a large proportion of their papers in Indian and foreign journals is covered by *SCI,* these journals have an impact factor in the range of 2.0 to 4.0. Only a few papers have been published in high impact factor journals.

Maximum number of the papers is in the area of Chemistry (6648), followed by Materials Science (1206) and Physics (946). These three constitute almost 30% of the laboratories' output of papers.

It is generally accepted that number of citations to a paper is an indication of its impact among scientific community. A small percentage of papers published by CSIR scientists are not cited at all. Ranking laboratories and individuals is a complex task and various factors and methods need to be considered. Such an analysis for the field of science can provide an additional perspective on the nature and extent of all CSIR scientists' contributions. While the analysis in this paper does not paint a complete picture, it has identified some of the most productive authors and institutions.

13. References

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