Indian Contribution on Crystallography: A Bibliometric Study Using Scopus Database

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Abstract

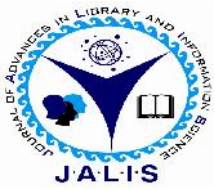
The research aims to study the growth of Indian research output on crystallography. The global multidiscipline citation database 'Scopus' was used for this study. A total of 227435 records contributed globally over a period of 1974 to 2016 of which Indian contribution works out 10023 (4.41%) and placed 7th position. Among the 10023 publications, 94.79% of the publications are in journal articles and 2.58% publications are from Conference proceedings. The techniques such year wise distribution, Language wise distribution, Bibliographic form, highly published institutions, highly contributed journal, highly contributed authors, source title, RGR and Doubling time, were identified. The study shows the linear growth in Tuberculosis research. Their exist collaborative research among the scientists throughout the globe.

Keywords

Bibliometric Study; Growth and Research Output; crystallography, RGR, doubling time
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INTRODUCTION

A number of quantitative methods have been adopted to evaluate the resources and services more objectively and effectively. These quantitative methods in Science includes metric studies which are known as Bibliometrics in 1960's, Scientometrics in 1970's and Informetrics in the midst of 1980's.The metric studies are used for measuring scholarly communication; identify research trends and growth of knowledge; identify users of different subjects; estimate comprehensiveness of secondary periodicals; forecast past, present and future publishing trends; identify authorship and its trends in documents on various subjects; predict productivity of publishers or individual authors etc. Therefore in this study an attempt has been made to identify the Indian contribution on Crystallography using bibliometric study.

The term 'bibliometrics' was coined by British Scientist Alan Pritchard in 1969. It can be defined as the application of mathematics and statistical methods to books and other media of communication (Pritchard, 1969). Bibliometric include studies of the growth of the literature in some subject, how much literature is contributed by various individuals, groups, or organisations or countries; how much exists in various languages; how the literature on some subject becomes out of date (studies of obsolescence). Another important bibliometric study includes what sources author cite, citation studies and geographical distribution of documents (Sangam, 2008; Rao, 2010). The bibliometric studies or research is conducted by applying three laws: Lotka's Law (Productivity of authors in terms of scientific papers), Bradford's Law (Scattering of articles over different journals), and Zipf's Law (Frequency of occurrence of words in text).

CRYSTALLOGRAPHY IN INDIA

India's scientific endeavour, as many other developments in the last century, matured with the freedom struggle as a backdrop. It may be claimed that the modern scientific era began in early 20th century. The starting of two centres of higher education, namely, Indian Institute of Science (IISc) at Bangalore and Indian Association for the Cultivation of Science (IACS) at Calcutta, coincided with these efforts. Work in crystallographic research towards the structure determination efforts began with the work of K. Banerjee at IACS with the structures of naphthalene and anthracene being

solved (Nature, 125, 456, 1930). Even though considerable interest in crystallographic research existed several years before, the discovery that X-ray diffraction can lead to structure determination catalyzed interest in many scientists including C.V. Raman, K. S. Krishnan, M. N. Saha and S. Bhagavantam to name a few. Crystallography was regarded as the science of condensed matter with emphasis on the atomic and molecular structure and its relation to physical and chemical properties. The analysis was thus primarily considered a job for the physicists initially, and this concept percolated deep in Indian science. Indeed, crystallography was considered a component of physical sciences for several decades until the importance of structure–property relationships was established, which brought in the idea of including chemists and biologists. Interestingly, crystallographers (physicists) were employed in chemistry and biology departments only in the late 1960s.

The technological developments percolated to India obviously due to the interactions with the scientists in Great Britain. Metallurgists and geologists eventually joined this area of research with Banaras Hindu University (BHU) spearheading such activities. It is of interest to note that an X-ray film manufacturing unit was started (INDU films) at Ootacamand (Ooty) and X-ray generators were manufactured at Calcutta (Kolkata) by Radon House Pvt. Ltd., inspired by Siddharth Ray and Gowri Ray in the late 1960s. C. V. Raman, after moving to Bangalore, provided a major boost with G. N. Ramachandran and S. Ramaseshan carrying out path breaking work in structural science with X-ray diffraction and crystallography as the main experimental modules. They developed strong groups with students like M. A. Viswamitra, K. Venkatesan, R. Chidambaram and H. Manohar. A parallel group developed under the leadership of A. R. Varma at BHU, Varanasi.

G. N. Ramachandran made seminal contributions to the development of X-ray diffraction techniques, and his discoveries were at that time in tandem with several significant strides made around the world including the work of Watson and Crick discovering the double helix in DNA. Indeed, Ramachandran's triple helix in collagen presented much more challenging work in terms of interpreting the fibre diffraction pattern. Other major contributions from him include the phi-psi plot depicting the conformational angles in a peptide unit, which constitutes the building block in large proteins and his suggested methods of Fourier synthesis, which provides a basis for structure evaluation.

NEED FOR THE STUDY

Many young crystallographers, chemists, biologists and physicists are trained abroad and have returned and are egging to pursue work in some of these areas. The areas pursued by the young scientists are modulated structures, disorder and reactivity, in situcryo crystallography, non-ambient crystallography and time resolved crystallography on one hand, and large proteins and enzymes (small crystals), complexes and structure based drug design, combining cognate techniques like NMR, electron diffraction (microscopy) and discerning time resolved biological processes on the other hand. In order to identify the level of reach of the research of these young scientists, an attempt has been made in this study to identify the growth of literature in Crystallography with specific emphasis with Indian authors.

REVIEW OF RELATED LITERATURE

Bibliometric method, a common research tool, has already been widely applied in scientific production and research-trend studies in many disciplines of Science and Engineering (Almind&Ingwersen, 1997; Cronin, 2001; Moed, Debruin, &Vanleeuwen, 1995). The popularity in the adaptation of bibliometric techniques in various disciplines stimulated stupendous growth of literature on bibliometrics and its related areas. Research output of individual scientists, universities, research institutes, and research areas have been conducted based on Bibliometic study. The Conventional bibliometricmethods is generally evaluate the research trend. Some of the studies that investigating the publication outputs of different countries (Rahman, Haque, & Fukui, 2005), research institutes (Rajendram, Lewison, &Preedy, 2006 , Nagarajan and others, 2014), journals (Javed M (2008),subjects (Rajendran , Ramesh Babu , &Gopalakrishnan , 2005) and research fields (, Krishnamoorthy, Ramakrishnan, & Devi, 2009).

OBJECTIVE

The objectives of the study are:

- To examine the Indian research output on Crystallography during the period 1974 - 2016.
- To analyse the bibliographic form/document type of the publications on Crystallography.

- To identify the organisations conducting the research on Crystallography
- To identify the top global authors conducting research on Crystallography
- To identify the top source titles those carry the research productions on Crystallography.
- To identify the language where more research outputs are published

HYPOTHESES

The following hypotheses will be formulated for this study based on the objectives.

- There are more literatures published worldwide on Crystallography.
- Growth of literature Crystallography is comparatively in increasing trends.
- Journals are major source of publications on Crystallography.
- There exists no steady growth in research output Crystallography research.
- Major developing countries were collaborating in crystallography research with India.

SAMPLE

The literature on Crystallography covered in SCOPUS bibliographic database has been considered for the purpose of quantitative analysis. The data retrieved on crystallography for the period 1974 to 2016 by the Indian scientists were taken up for the study and a total of 10023 records were found. The search term adopted for retrieving the data from Scopus data base were as shown below:

Your query : (TITLE-ABS-KEY(crystallography) AND PUBYEAR > 1969 AND PUBYEAR < 2017 AND (LIMIT-TO (AFFILCOUNTRY,"India")))
Number of results : 10023

DATA ANALYSIS

The global research output on Crystallography has been analysed using various scientometric / bibliometric tools such as Rate of Growth (RoG), Relative Growth Rate (RGR) and Doubling Time (Dt) apart from the percentage and cumulative percentage. The literature on Crystalography covered in SCOPUS bibliographic database has been considered for the purpose of quantitative analysis. The data retrieved on Crystallography were for the period 1970 to 2016 and a total of 227435 records were found. Out of which Indian contribution is 10043 (4.41%) taken up for this study (Table 1).
The Indian contribution n Crystallography were further analyzed based on the following criteria.

- Countrywise contribution
- Yearwise contribution
- RGR and DT
- Document Type
- Language
- Highly published organization
- Highly published journals
- Collaborated countries
- Highly contributed Authors

Country wise Contribution

The growth of literature of any research globally is gauged through the region or the country where more no of publications are published. The researcher also studied the countrywise publication on Crystallography for the period 1970 to 2016 which helps to find out the total no. of publications published in the subject. The top 10 countries publications were shown in table 1. The details of total no. of publications along with the percentage of contribution globally is shown in table 1.

Table 1: Country wise distribution

S.No.	Country	No. of publications	%
1	United States	68016	29.91
2	China	27543	12.11
3	United Kingdom	22921	10.08
4	Germany	22850	10.05
5	Japan	21628	9.51
6	France	15262	6.71
7	India	10023	4.41
8	Canada	8376	3.68
9	Italy	7607	3.34
10	Spain	6632	2.92
11	Others	16577	7.28
	Total	227435	100.00

Table 1 reveals that amaximum of publications i.e 29.91% were from the United States followed by China (12.11%) and United Kingdom(10.08%). It is also to note that India occupies 7th position with total production of 4.41%.

Quantum of India Contribution on Crystallography

The year wise distribution of Indian research output on Crystallography with its total publications (TP), percentage, cumulative, cumulative percentage and RoG and CAGR were calculated and the same is shown in Table 2 and Figure 1.

Table 2: Year Wise Distribution

S. No	Year	Publications	%	Cumulative Publications	Cum %	RoG	CAGR
1	1970	2	0.02	2	0.02	1.00	0.89
2	1972	2	0.02	4	0.04	1.00	0.89
3	1973	6	0.06	10	0.10	3.00	0.91
4	1974	4	0.04	14	0.14	0.67	0.90
5	1975	8	0.08	22	0.22	2.00	0.91
6	1976	2	0.02	24	0.24	0.25	0.88
7	1977	6	0.06	30	0.30	3.00	0.90
8	1978	2	0.02	32	0.32	0.33	0.87
9	1979	10	0.10	42	0.42	5.00	0.91
10	1980	7	0.07	49	0.49	0.70	0.90
11	1981	9	0.09	58	0.58	1.29	0.90
12	1982	6	0.06	64	0.64	0.67	0.89
13	1983	13	0.13	77	0.77	2.17	0.90
14	1984	16	0.16	93	0.93	1.23	0.91
15	1985	10	0.10	103	1.03	0.63	0.89
16	1986	8	0.08	111	1.11	0.80	0.88
17	1987	18	0.18	129	1.29	2.25	0.90
18	1988	14	0.14	143	1.43	0.78	0.89
19	1989	21	0.21	164	1.64	1.50	0.90
20	1990	28	0.28	192	1.92	1.33	0.91
21	1991	42	0.42	234	2.33	1.50	0.92
22	1992	26	0.26	260	2.59	0.62	0.90
23	1993	44	0.44	304	3.03	1.69	0.91
24	1994	61	0.61	365	3.64	1.39	0.92
25	1995	75	0.75	440	4.39	1.23	0.93
26	1996	126	1.26	566	5.65	1.68	0.95
27	1997	99	0.99	665	6.63	0.79	0.93
28	1998	139	1.39	804	8.02	1.40	0.95
29	1999	222	2.21	1026	10.24	1.60	0.97
30	2000	231	2.30	1257	12.54	1.04	0.97
31	2001	241	2.40	1498	14.95	1.04	0.97
32	2002	246	2.45	1744	17.40	1.02	0.97
33	2003	484	4.83	2228	22.23	1.97	1.01
34	2004	452	4.51	2680	26.74	0.93	1.01
35	2005	568	5.67	3248	32.41	1.26	1.03
36	2006	645	6.43	3893	38.84	1.14	1.04
37	2007	962	9.60	4855	48.44	1.49	1.09
38	2008	669	6.67	5524	55.11	0.70	1.06
39	2009	423	4.22	5947	59.33	0.63	1.01
40	2010	452	4.51	6399	63.84	1.07	1.02
41	2011	550	5.49	6949	69.33	1.22	1.05
42	2012	633	6.32	7582	75.65	1.15	1.10
43	2013	623	6.21	8205	81.86	0.98	1.12
44	2014	723	7.22	8928	89.08	1.16	1.22
45	2015	694	6.92	9622	96.00	0.96	1.32
46	2016	401	4.00	10023	100.00	0.58	1.00
	Total	**10023**	**100**				

It is seen from the Table 2 and Figures 1 that the total number of publications are more than 100 from the period 1996 to 2016. The highest no. of publications (723) could be seen in the year 2014. This study reveals that a periodical growth could be seen from the period 1996 till the end of the study period i.e 2016. The cumulative total of the publication is 10023. The Ratio of Growth (RoG) varies from 0.25 to 5.00 between the study period 1970 and 2016. It is also to note that there was no publication in the year 1972 and till 1986, the publications are less than 20 in a year. The RoG value 5.00 is seen in the year 1979. From the year 1996 onwards, the RoG shows that there is a steady growth on the research output of Indian contribution on Crystallography. This confirms that the Indian researchers are interested to publish papers on Crystallography. It is seen from the table that CAGR values are between 0.87 and 1.32 during the years of study period. It is also to note that the CAGR values are more or less same during the whole study period.

RELATIVE GROWTH RATE (RGR) AND DOUBLING TIME (DT) OF RESEARCH PRODUCTIVITY ON CRYSTALLOGRAPHY

The research productivity on Crystallography have been calculated based on RGR and the Dt () which is shown in table 3 and figure 2. The Relative Growth Rate (RGR) is the increase in number of articles/pages per unit of time. This definition is derived from the definition of relative growth rates in the study of growth analysis of individual plants and effectively applied in the field of botany (Hunt, R 1978), which in turn, had its origin from the study of the rate of interest in the financial investment (Blackman, V.H. 1919). The mean Relative Growth Rate (RGR) over the specific period of interval can be calculated from the following equation:

$$RGR\ 1\text{-}2 = \frac{Log_e\ W_2 - log_e\ W_1}{T_2 - T_1}$$

whereas

1-2 = mean relative growth rate over the specific period of interval

$log_{e1}W$ = log of initial number of articles/pages

$log_{e2}W$ = log of final number of articles/pages after a specific period of interval

$_2T - _1T$ = the unit difference between the initial time and the final time

The year can be taken here as the unit of time. The RGR for both articles and pages can be calculated separately. Therefore

- 1- 2 ^{R}(aaZ1 year Z1) can represent the mean relative growth rate per unit of articles per unit of year over a specific period of interval and
- 1 - 2 ^{R} (ppZ1 year Z1) can represent the mean relative growth rate per unit of pages per unit of year over a specific period of interval.

Doubling Time (Dt (P))

There exists a direct equivalence between the relative growth rate and the doubling time. If the number of articles/pages of a subject doubles during a given period then the difference between the logarithms of numbers at the beginning and end of this period must be the logarithms of number 2. If natural logarithm is used this difference has a value of 0.693. Thus the corresponding doubling time for each specific period of interval and for both articles and pages can be calculated by the following formula:

Doubling time (Dt) = Log $_e$ 2 / ∈R

Therefore

$$\text{Doubling time for articles Dt (a)} = \frac{\text{Log}_e 2}{1\text{-}2\ \in R\ (\text{aa-1 year-1})}$$

Log $_e$2 = 0.693

Table 3: Relative Growth Rate (RGR) And Doubling Time (DT)

S.No	Year	Publi cations	%	Cumulative Publications	Cum %	W1	w2	RGR	Dt
1	1970	2	0.02	2	0.02		0.693147	0.69	1.00
2	1972	2	0.02	4	0.04	0.693147	1.386294	0.69	1.00
3	1973	6	0.06	10	0.10	1.386294	2.302585	0.92	0.76
4	1974	4	0.04	14	0.14	2.302585	2.639057	0.34	2.06
5	1975	8	0.08	22	0.22	2.639057	3.091042	0.45	1.53
6	1976	2	0.02	24	0.24	3.091042	3.178054	0.09	7.96
7	1977	6	0.06	30	0.30	3.178054	3.401197	0.22	3.11
8	1978	2	0.02	32	0.32	3.401197	3.465736	0.06	10.74
9	1979	10	0.10	42	0.42	3.465736	3.73767	0.27	2.55
10	1980	7	0.07	49	0.49	3.73767	3.89182	0.15	4.50
11	1981	9	0.09	58	0.58	3.89182	4.060443	0.17	4.11
12	1982	6	0.06	64	0.64	4.060443	4.158883	0.10	7.04
13	1983	13	0.13	77	0.77	4.158883	4.343805	0.18	3.75
14	1984	16	0.16	93	0.93	4.343805	4.532599	0.19	3.67
15	1985	10	0.10	103	1.03	4.532599	4.634729	0.10	6.79
16	1986	8	0.08	111	1.11	4.634729	4.70953	0.07	9.26
17	1987	18	0.18	129	1.29	4.70953	4.859812	0.15	4.61
18	1988	14	0.14	143	1.43	4.859812	4.962845	0.10	6.73
19	1989	21	0.21	164	1.64	4.962845	5.099866	0.14	5.06
20	1990	28	0.28	192	1.92	5.099866	5.257495	0.16	4.40
21	1991	42	0.42	234	2.33	5.257495	5.455321	0.20	3.50
22	1992	26	0.26	260	2.59	5.455321	5.560682	0.11	6.58
23	1993	44	0.44	304	3.03	5.560682	5.717028	0.16	4.43
24	1994	61	0.61	365	3.64	5.717028	5.899897	0.18	3.79
25	1995	75	0.75	440	4.39	5.899897	6.086775	0.19	3.71
26	1996	126	1.26	566	5.65	6.086775	6.338594	0.25	2.75
27	1997	99	0.99	665	6.63	6.338594	6.499787	0.16	4.30

28	1998	139	1.39	804	8.02	6.499787	6.689599	0.19	3.65
29	1999	222	2.21	1026	10.24	6.689599	6.933423	0.24	2.84
30	2000	231	2.30	1257	12.54	6.933423	7.136483	0.20	3.41
31	2001	241	2.40	1498	14.95	7.136483	7.311886	0.18	3.95
32	2002	246	2.45	1744	17.40	7.311886	7.463937	0.15	4.56
33	2003	484	4.83	2228	22.23	7.463937	7.70886	0.24	2.83
34	2004	452	4.51	2680	26.74	7.70886	7.893572	0.18	3.75
35	2005	568	5.67	3248	32.41	7.893572	8.085795	0.19	3.61
36	2006	645	6.44	3893	38.84	8.085795	8.266935	0.18	3.83
37	2007	962	9.60	4855	48.44	8.266935	8.487764	0.22	3.14
38	2008	669	6.67	5524	55.11	8.487764	8.616858	0.13	5.37
39	2009	423	4.22	5947	59.33	8.616858	8.690642	0.07	9.39
40	2010	452	4.51	6399	63.84	8.690642	8.763897	0.07	9.46
41	2011	550	5.49	6949	69.33	8.763897	8.846353	0.08	8.40
42	2012	633	6.32	7582	75.65	8.846353	8.933532	0.09	7.95
43	2013	623	6.22	8205	81.86	8.933532	9.012499	0.08	8.78
44	2014	723	7.21	8928	89.08	9.012499	9.096948	0.08	8.21
45	2015	694	6.92	9622	96.00	9.096948	9.171807	0.07	9.26
46	2016	401	4.00	10023	100.00	9.171807	9.212638	0.04	16.97
	Total	**10023**							

It is observed from the table 3 that the relative growth rate (RGR) lies between 0.04 and 0.92 except the year 1972 where there is no publications. It is also to note that some of the RGR values are same in few years over the study period. This shows that the Indian contribution on Crystallography is increasing and the range of publications are on many folds.

LANGUAGE AND BIBLIOGRAPHIC FORM OF PUBLICATIONS BY INDIAN AUTHORS

The language as well as the bibliographic form of publications in respect of Indian research output on Crystallography were analysed and the same is presented in table 4.

Table 4: Indian Research Output on Crystallography Vs Language and Bibliographic Form

S. No	Description	No. of publications	Percentage
Language			
1	English	10020	99.97
2	German	3	0.03
Bibliographic Form			
1	Article	9501	94.79
2	Conference Paper	259	2.58
3	Review	190	1.90
4	Note	23	0.23
5	Short Survey	15	0.15
6	Editorial	14	0.14
7	Letter	10	0.10
8	Book Chapter	7	0.07
9	Erratum	2	0.02

It is observed from table 4 that the research output largely published in English language (99.97%). The Indian contribution other than English can also be seen in German. 94.79% (9501) of the total Indian contribution in the form of articles followed by conference papaer (2.58%) and reviews (1.90%). The contributions can also be seen in other bibliographic forms such as note, short survey, editorial, letter, book chapters and erratum. By and large it is found that the scholarly communication is mostly through journals.

SOURCE TITLES ON LASER IN MEDICAL SCIENCES

The core journals which publishes more than 100 researches work on Crystallography has been presented in table 5.

Table 5: Highly Published Journals

S. No.	Journal Title	Papers	%
1	ActaCrystallographica Section E Structure Reports Online	1403	14.00
2	Inorganic Chemistry	329	3.28
3	ActaCrystallographica Section C Crystal Structure Communications	291	2.90
4	SpectrochimicaActa Part A Molecular And Biomolecular Spectroscopy	289	2.88
5	Polyhedron	277	2.76
6	Dalton Transactions	248	2.47
7	ActaCrystallographica Section F Structural Biology And Crystallization Communications	183	1.83
8	ActaCrystallographica Section D Biological Crystallography	182	1.82
9	Journal Of Molecular Structure	164	1.64
10	InorganicaChimicaActa	152	1.52
11	Tetrahedron Letters	144	1.44
12	Journal Of Organometallic Chemistry	139	1.39
13	Journal Of Organic Chemistry	123	1.23
14	Chemical Communications	120	1.20
15	European Journal Of Medicinal Chemistry	101	1.01
16	Journal Of Applied Crystallography	101	1.01
17	Tetrahedron	101	1.01
18	Journal Of Molecular Biology	100	1.00

A total 10023 Indian contribution on crystallography literature were published in various sources out of which 94.79% were published in the form of journal articles. The highly productive articles in journals are ranked and the first five ranked journals are:

i. ActaCrystallographica Section E Structure Reports Online, 1403 (14.00%)
ii. Inorganic Chemistry, 329 (3.28%)
iii. ActaCrystallographica Section C Crystal Structure Communications, 291 (2.90%)
iv. SpectrochimicaActa Part A Molecular AndBiomolecular Spectroscopy, 289 (2.88%)
v. Polyhedron, 277 (2.76%)

HIGHLY PUBLISHED INSTITUTIONS FROM INDIA

The publications on Crystallography published by the Indian authors with various institutes in India and the authors affiliation with the institutes are taken for the study. The top institutes which has more than 100publications are shown in Table 6.

Table 6: Highly published organistion

S.No	Organisation	Papers	%
1	Indian Institute of Science	1078	10.76
2	University of Madras	529	5.28
3	Molecular Biophysics Unit	422	4.21
4	Mangalore University India	409	4.08
5	Indian Institute of Chemical Technology	406	4.05
6	University of Mysore	367	3.66
7	Indian Association for the Cultivation of Science	329	3.28
8	University of Hyderabad	328	3.27
9	Bharathidasan University	316	3.15
10	Indian Institute of Technology, Kanpur	310	3.09
11	Indian Institute of Technology, Bombay	278	2.77
12	Bhabha Atomic Research Centre	275	2.74
13	Jadavpur University	273	2.72
14	UniversitiSains Malaysia	260	2.59
15	Howard University	235	2.34
16	National Chemical Laboratory India	229	2.28
17	Anna University	206	2.06
18	Indian Institute of Technology, Madras	200	2.00
19	Madurai Kamaraj University	194	1.94
20	Banaras Hindu University	193	1.93
21	University of Calcutta	189	1.89
22	Indian Institute of Technology, Kharagpur	165	1.65
23	Panjab University	162	1.62
24	University of Delhi	161	1.61
25	All India Institute of Medical Sciences	159	1.59
26	Jawaharlal Nehru Centre for Advanced Scientific Research	147	1.47
27	Guru Nanak Dev University India	137	1.37
28	University of Reading	130	1.30

29	Indian Institute of Technology Delhi	123	1.23
30	Central Drug Research Institute India	121	1.21
31	Annamalai University	111	1.11
32	Johann Wolfgang Goethe Universitat Frankfurt am Main	110	1.10
33	P. A. College of Engineering	109	1.09

The top 5 Indian contribution by the authors affiliation is show below alongwith the no. of publications.

i. Indian Institute of Science, 1078 (10.76%)
ii. University of Madras 529 (5.28%)
iii. Molecular Biophysics Unit, 422 (4.21%)
iv. Mangalore University India, 409 (4.08%)
v. Indian Institute of Chemical Technology , 406 (4.05%)

COLLABORATED COUNTRIES

The collaborated countries where the Indian authors are part of the publications are shown in table 7.

Table7: Collaborated countries

S.No	Country	Papers	%
1	United States	1066	10.64
2	Germany	662	6.60
3	United Kingdom	551	5.50
4	Malaysia	300	2.99
5	France	228	2.27
6	Italy	219	2.18
7	Japan	211	2.11
8	Spain	204	2.04
9	Taiwan	129	1.29
10	Switzerland	109	1.09
11	Canada	97	0.97
12	Australia	86	0.86
13	South Korea	78	0.78
14	Saudi Arabia	75	0.75
15	Poland	68	0.68
16	China	66	0.66
17	Portugal	54	0.54

It is seen from the table 7 that the Indian authors mostly collaborated with United States (1066, 10.64%) followed by Germany (662, 6.60%) and United Kingdom (551, 5.50%).

HIGHLY PUBLISHED AUTHORS

Among the 10023 publications, table 8 shows the authors with more than 50 publications. The name of the author, total no. of publications and the percentage are shown in table 8.

Table 8: Highly published Authors

S.No.	Author	Papers	%
1	Yathirajan, H.S.	250	2.49
2	Ravikumar, K.	236	2.35
3	Butcher, R.J.	235	2.34
4	Velmurugan, D.	194	1.94
5	Narayana, B.	191	1.91
6	Fun, H.K.	151	1.51
7	Singh, T.P.	132	1.32
8	Drew, M.G.B.	127	1.27
9	Vijayan, M.	121	1.21
10	Sarojini, B.K.	117	1.17
11	Nethaji, M.	109	1.09
12	Raghunathan, R.	109	1.09
13	Bolte, M.	103	1.03
14	Fun, H.K.	95	0.95
15	Gowda, B.T.	91	0.91
16	Sharma, R.P.	88	0.88
17	Sridhar, B.	88	0.88
18	Fuess, H.	86	0.86
19	Balaram, P.	83	0.83
20	Sekar, K.	79	0.79
21	Dharmaprakash, S.M.	78	0.78
22	Varghese, B.	78	0.78
23	Razak, I.A.	75	0.75
24	Chinnakali, K.	74	0.74
25	Venugopalan, P.	71	0.71
26	Patil, P.S.	69	0.69
27	Selvanayagam, S.	69	0.69
28	Sridhar, B.	66	0.66
29	Jasinski, J.P.	65	0.65
30	Foro, S.	64	0.64
31	Puranik, V.G.	64	0.64
32	Desiraju, G.R.	63	0.63
33	Sharma, S.	63	0.63
34	Chopra, D.	62	0.62
35	Murthy, M.R.N.	62	0.62
36	Muthiah, P.T.	60	0.60
37	Lobana, T.S.	59	0.59
38	Ghosh, A.	58	0.58
39	Ponnuswamy, M.N.	58	0.58
40	Guru Row, T.N.	57	0.57
41	Parthasarathi, V.	57	0.57
42	Suresh, E.	56	0.56
43	Athimoolam, S.	55	0.55

44	Chakravarty, A.R.	55	0.55
45	Surolia, A.	55	0.55
46	Gayathri, D.	54	0.54
47	Natarajan, S.	54	0.54
48	Srinivasan, A.	53	0.53
49	Natarajan, S.	52	0.52
50	Row, T.N.G.	52	0.52
51	Bhagavannarayana, G.	50	0.50
52	Bhattacharya, S.	50	0.50

It is seen from table 8 that Yathirajan, H.S. with 250 (2.498%) has the maximum no. of publications followed by Ravikumar, K. (236, 2.35%) and Butcher, R.J. (235, 2.34%) publications.

KEYWORDS RELATED TO CRYSTALLOGRAPHY

Among the 10023 publications, table 9 shows the keywords related with Crystallography with more than 500 publications. The type of keywords, total no. of publications and the percentage are shown in table 9.

Table 9: Keywords

S.No	Key word	Papers
1	X Ray Crystallography	4535
2	Crystallography, X-Ray	2916
3	Crystal Structure	2736
4	Chemistry	2109
5	Crystallography	1991
6	Chemical Structure	1810
7	Models, Molecular	1750
8	Unclassified Drug	1674
9	Synthesis	1333
10	Priority Journal	1273
11	Molecular Structure	1188
12	Crystallization	983
13	Nonhuman	974
14	Hydrogen Bond	971
15	X Ray Diffraction	946
16	Hydrogen Bonds	812
17	Protein Conformation	775
18	Single Crystals	771
19	Controlled Study	744
20	Humans	715
21	Synthesis (chemical)	710
22	Structure Analysis	683
23	Hydrogen Bonding	659
24	Human	654
25	Animals	651
26	Ligands	625
27	Molecular Conformation	614
28	Metabolism	608
29	Conformation	604
30	Amino Acid Sequence	587
31	Nuclear Magnetic Resonance Spectroscopy	575
32	Infrared Spectroscopy	570
33	Protein Binding	514
34	Binding Sites	511
35	Proton Nuclear Magnetic Resonance	508

It is seen from table 9 that the keyword X Ray Crystallography has more no. of publications (4535) followed with Crystallography, X-Ray (2916) and Crystal Structure (2736).

CONCLUSION

The Indian contribution in Crystallography has been studied in the light of the global research has been taken for the study with the use of global database SCOPUS. The data which were analysed is for the period 1970 to 2016. A total of 10023 records were retrieved in the database for analysis purpose. This study reported the findings to determine the publication trend with respect to growth of literature on yearwise, languagewise and countrywise with the bibliographic form where the publications are published. This study also enumerated the affiliation of the authors, source titles and the top Indian authors. The objectives and the hypotheses set for this study were thoroughly investigated. The results computed were quite encouraging particularly on the use of laser in medical sciences. This study also found that there is a steady growth on the research publications on laser in medical from India.

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