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Scientometric Visualisation of Fifteen Years of Indian Engineering Research Output

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Abstract

Engineering is the most preferred research area among Indian research and development for quite some time in terms of the total number of publications, global share, and visibility and citation impact are concerned. The present study deals with the assessment of Indian engineering research output as reflected in the Web of Science (WOS) database for the period 2003 to 2017 for identifying the research output in the field of engineering literature. We measure India's contribution to engineering research from a global perspective. In the fifteen years, 2003-2017 Indian researchers have published 1,589,361 papers in 1,266 journals. In terms of % share, India (with 6.9% of the world's publications) is behind only the USA (5.28%) and South Korea (2.12%). But only 0.86% of papers from India are among the top 1% of the most highly cited papers of the world, compared to 4,984 papers from the USA, 2,006 papers from South Korea, 1,436 papers from Germany, 1,246 papers from England, 1,005 from Canada of papers. The 25 core journals are identified which contains 26.83% of the total articles. Among 25 journals 20 journals are published outside India. The topmost productive journals publishing India's research papers in Engineering research contributed 25,285 papers, which accounts for a 29.83% share in the cumulative publications output of India from 2003 to 2017.

Keywords: Scientometrics; Engineering Research,; Research Growth; Collaborative research; Web of Science; India.

1. Introduction

Engineering is the design and development of structures and constructions for influencing the world around us and improving our journey inside it. Engineers use the quintessential ideas of mathematics, physics, and chemistry to create machines that allow us to travel faster, furnish increased scientific care, and process greater tricky information. India's most impactful area in terms of research output is engineering whilst it is most prolific in phrases of citations are chemistry, physics, and computer science in accordance with the Web of Science citation database. Although India is nonetheless an incredibly small participant on the world scientific stage, its wide-ranging collaboration community and growing share of the world's main research performance indicators mirror its usual increase in output, impact, and information transfer," our study identified. In terms of knowledge transfer, India indicates a greater emphasis in areas of computer science, material science, chemistry and pharmacology, toxicology, and pharmaceuticals. Knowledge transmission consists of studies of patent citation patterns and collaborations between academic and corporate research institutions as a whole, there is a promising trend as greater Indian research is covered in international journals and more institutes are generally making appearances in such databases. It has also been viewed that collaboration is increasing to not just include OECD (Organization for Economic Cooperation and Development) partners, however others such as Brazil, China, and Iran," stated Sujit Bhattacharya, senior foremost scientist, Council of Scientific and Industrial Research-National Institute of Science, Technology and Development Studies. Bhattacharya (2003).

2. Review of literature

The bibliometric studies in engineering including its broader areas are limited to a few publications (Jaya Kumar & Pandit, 2018) discussed scientometric measures such as the numbers of publications, citations, and the h-index for the period 1985-2016. (Raghavan & Rao, 2015) an attempt has been made to examine Indian re- search output in Engineering. The papers with at least one among the authors having an Indian affiliation and published in any of the IEEE journals are considered for this study. (Singh & Gupta, 2010) presents an analysis of India's emerging research during 1999–2008 on several parameters. (Tahira et al., 2013) examined scientometric study addresses the usefulness of the most noted metric h-index alongside other selected indicators within the field of Engineering in Malaysian universities. (Naqvi, 2018)

analyzed quantitative investigation of research papers published in Genetic Engineering from 2006 to 2015. (Hosamani et al., 2014) discussed with the scientometric analysis of Indian engineering research output as reflected in Web of Science (WOS) database for the period 1999 to 2013. (Santisteban-Espejo et al., 2018) analyzed tissue engineering (TE) is defined as a multidisciplinary science with the most objective to develop artificial bioengineered living tissues to regenerate damaged or lost tissues. (Elango, 2019) evaluated quantitative analysis and compare the scientific productivity within the area of engineering among the BRIC (Brazil, Russia, India, and China) countries. (Jaya Kumar & Pandit, 2018) measures such as the numbers of publications, citations, and the h-index for the period 1985-2016. (Kumar et al., 2009) evaluated the growth and development of Bibliometric and scientometric research in the physics and engineering field as per the INSPEC database (1999-2008). Scientometric parameters for chemical engineering publications. (Modak & Madras, 2008) compared the number of journal publications and citations by various countries and institutions. (Hossain & Ahmed, 2020) analyzed use of scholarly communication and citation data to rank the universities in a developing country perspective in Bangladesh. (Husain & Mushtaq, 2010) the number of parameters to evaluate an academic institution and one of them being the publication output of the institutions. (Alma et al., 2016) identified there have been several efforts to develop ranking systems for universities.

3. Methods and Materials

For this study, the literature on Indian engineering was downloaded from “Web of Science”. The term ‘Indian engineering’ was used for retrieving literature, the collected data has been classified using Microsoft Excel for analysis. Statistical tools such as frequency distribution, percentage analysis were used for the study. Analysis of year-wise distribution, subject coverage and organisations which contributed papers were covered.

4. Objectives of the study

1. To examine the growth of Indian engineering during the period 2003 – 2017.
2. To identify the document type of publications in Indian engineering.
3. To examine the Language-wise distribution of records in Indian engineering.
4. To identify the organisations researching Indian engineering.
5. To identify the top 25 productive sources in Indian Engineering research.

6. To identify the top prolific authors in Indian Engineering Research.
7. To identify the top 25 collaborative countries.

5. Results and Discussion

Sample Data Details During 2003 To 2017

The bibliographic records for this analysis were searched in the web of science database from 2003 to 2017 on 10th November 2020. The below table describes the brief details of the total sample bibliographical details.

Table 1: Sample data details from 2003 to 2017

Sl. No	Details About Sample	Observed Values	
1	Duration	2013 to 2017	
2	Period	15 years	
3	Total records	World	India
		2,356,658	94,225
4	Total Number of observed Authors	65,536	
5	Total calculating authors	65,536	
6	Total Number of Journals	1,265	
7	Document types	16	
8	Languages	12	
9	Contributing countries	124	
10	Contributing Institutions	14,298	
11	All Cited References	India	1,589,362
12	Total Local Citation Scores (TLCS)	1,265	
13	Total Cited References (CR)	522,608	
14	Total funded institutions	15,165	

Table 1 represented sample data details from the web of science database. The study from 2003 to 2017 period is a total of 15 years of research output in the field of engineering research. The data was downloaded 94,225 records, the total number of contributing authors 65536, total number of calculating authors is 65,536 total number of journals 1,265, 12 types of languages, 102 countries from various continents, 6039

institutions from different countries, 14,117 subdivisions are contributed various institutions, 268,625 times cited by local and global references, 5,906 Total Local citation scores, 127,307 total Global citation score, and 373,917 were cited referenced of the whole sample records, total funded institutions 15165 and only top 25 institutions are calculated. Table 1: Sample data details from 2013 to 2017.

6. Status of World engineering Literature

It could be observed from table 2 the research output of India and Average Citations per Papers of India. India has produced 94,225 papers and received 15, 89361 citations during the period 2003-2017, Average Citations per Paper is 24.96.

India has produced the highest publication i.e. 12,948 papers in 2017. The lowest publication is 2,687 in 2003. Engineering publications are gradually increased year by year, the publications share of engineering which has increased from 2.852% in 2003 to 13.742% in 2017. According to the research, the trend line shows that there is a steady and significant increase in the publications in Engineering (Fig. 1). India's publications are gradually increased year by year. The global publications share of India during 2003-2017 was 5.46%, which has increased from 4.649% in 2003 to 9.68% in 2017.

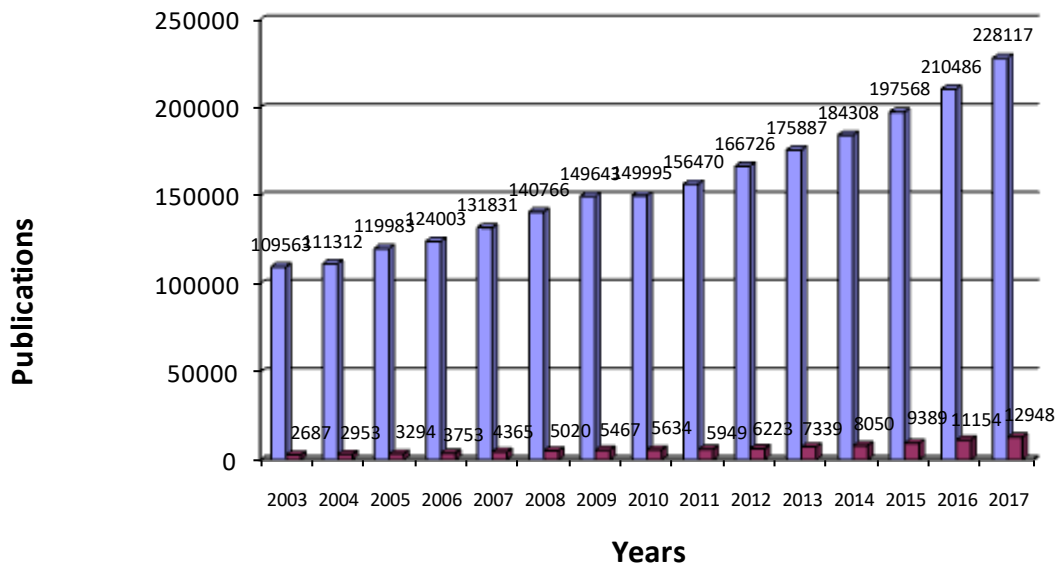
Table -2: Status of World and Indian Engineering Literature

World			India				
Year	TP	%	TP	TC	ACPP	H-index	%
2003	109563	4.649	2687	70044	26.07	108	2.852
2004	111312	4.723	2953	81955	27.75	113	3.134
2005	119983	5.091	3294	90038	27.33	119	3.496
2006	124003	5.262	3753	112430	29.96	130	3.983
2007	131831	5.594	4365	123700	28.34	132	4.633
2008	140766	5.973	5020	134910	26.87	139	5.328
2009	149643	6.35	5467	148834	27.22	135	5.802

2010	149995	6.365	5634	134154	23.81	120	5.979
2011	156470	6.639	5949	136095	22.88	123	6.314
2012	166726	7.075	6223	130551	20.98	116	6.604
2013	175887	7.463	7339	141950	19.34	110	7.789
2014	184308	7.821	8050	142544	17.17	109	8.543
2015	197568	8.383	9389	142156	15.14	103	9.964
2016	210486	8.932	11154	NA	NA	NA	11.838
2017	228117	9.68	12948	NA	NA	NA	13.742
2003 - 2007	596692	25.319%	17052	478167	139.45	602	18.098
2008 - 2012	763600	32.402%	28293	684544	121.76	633	30.027
2013 - 2017	996366	42.279%	48880	NA	NA	NA	51.876
2003 - 2017	2,35,6,658	100%	94,225	1589361	312.86	1557	100%

TP= Total Papers; TC= Total Citations; ACPP=Average Citations per Paper

Fig. 1. Status of World & India's Engineering Literature



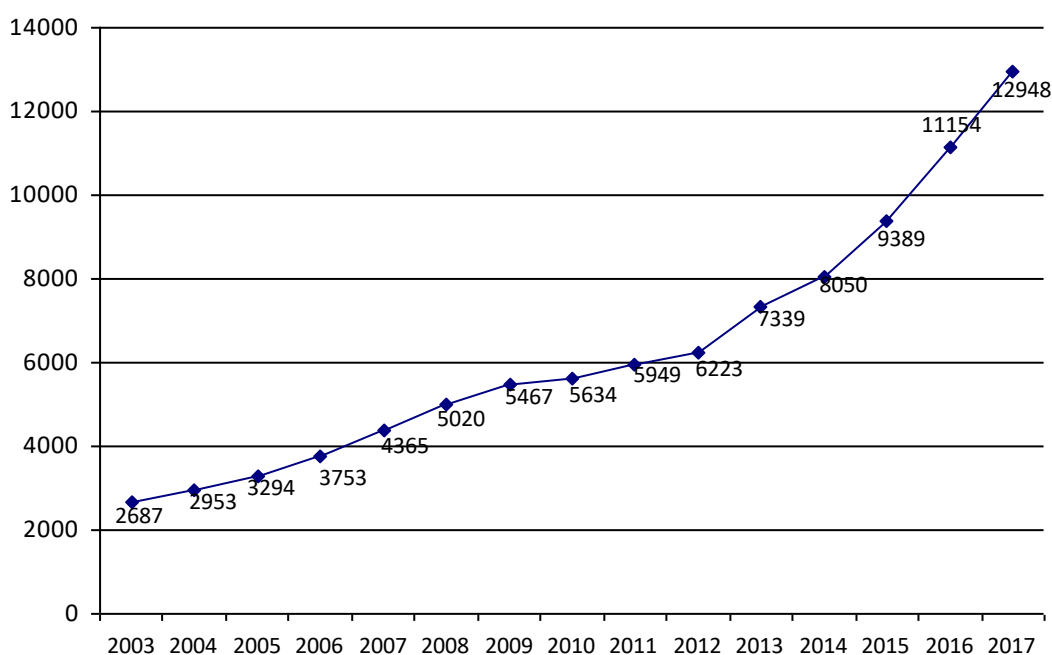
The global research output in Engineering has increased from 10,9563 in 2003 to 22,8117 in 2017. World's publications had increased from 59,6692 publications during **2008-2012** to 763600 publications during **2013-2017**, and 996366 publications

during **2012-2016**. In the same manner, the Indian research output in engineering has increased from 2687 in 2003 to 12,948 by 2017.(Table 3).

Table: 3 Indian Research output in engineering research

Year	TP	% of TP Share
2003	2687	2.852
2004	2953	3.134
2005	3294	3.496
2006	3753	3.983
2007	4365	4.633
2008	5020	5.328
2009	5467	5.802
2010	5634	5.979
2011	5949	6.314
2012	6223	6.604
2013	7339	7.789
2014	8050	8.543
2015	9389	9.964
2016	11154	11.838
2017	12948	13.742
2003 - 2007	17052	18.098
2008 - 2012	28293	30.027
2013 - 2017	48880	51.876
2003 - 2017	94,225	100%

Fig. 2 Indian Research output in engineering research



It is observed from the study that the above point gets clarified when we analyses the percentage of India's papers compared to that of the world's papers. India's share of science and technology research output increased from 3.94% in 2003 to 13.74% in 2017. It is observed from the study that the above point gets clarified when we analyses the percentage of India's papers compared to that of the world's papers. India's share of science and technology research output increased from 3.94% in 2002 to 6.99% in 2016. The plot shows a significant increase and the trend suggests a 5.30% average growth in the share per annum in the study period.

7. Channels used for communicating Engineering research

The channels used for communicating engineering research include articles published in journals, reviews, conference and seminar proceedings, editorial materials, corrections and book chapters. This study has observed a total of 94,225 publications in engineering from India. It has been observed from the table there are many communicating channels are used by scientists to publish their research articles in the Indian engineering literature. The majority of publications are published in Journals i.e. 90756 (96.318%), followed by Proceedings paper 3249 (3.448%) publications, Reviews 1614 (1.713%) are papers published, Editorial Material 1201 (1.275%) papers are

published. and less than 1% of articles are published in other communication channels (table 6).

Table: 6 - Channels used for communicating Engineering research

Sl. No	Document Types	Records	% of 94225
1	Article	90756	96.318
2	Proceedings Paper	3249	3.448
3	Review	1614	1.713
4	Editorial Material	1201	1.275
5	Correction	326	0.346
6	Letter	188	0.2
7	Meeting Abstract	95	0.101
8	Retracted Publication	38	0.04
9	Biographical Item	17	0.018
10	Book Review	13	0.014
11	Book Chapter	8	0.008
12	News Item	6	0.006
13	Retraction	6	0.006
14	Bibliography	2	0.002
15	Data Paper	1	0.001
16	Reprint	1	0.001

8. Language-wise distribution of publications of Indian Engineering research

Table 7 reveals the language-wise distribution of publications, the scientist's researchers from Indian Engineering are published in different languages; English, Chinese, Japanese, German, Welsh, French, Estonian and Danish. It is observed that the majority 94193 (99.9666%) of articles published in the English language, 0.014 % of articles published in Croatian language and very less number of articles are published in remaining languages.

Table: 7- Language-wise distribution of publications of Indian Engineering research

Sl No	Languages	Records	% of 94225
1	English	94193	99.966
2	Croatian	13	0.014
3	German	5	0.005
4	Japanese	4	0.004
5	Spanish	3	0.003
6	Korean	2	0.002
7	Chinese	1	0.001
8	Estonian	1	0.001
9	French	1	0.001
10	Polish	1	0.001
11	Portuguese	1	0.001
12	Unspecified	1	0.001

9. Organizational / Institution productivity in the field of engineering literature

Table 8 reveals the ranking list of the top 25 highly productive Research Institutions in India based on their highest publications, citations, average citations per publication and h-index. According to the web of science database, the Indian Institute Of Technology System IIT System contributed the highest publications to the field of engineering, i.e. 30355 publications, followed by Council Of Scientific Industrial Research CSIR India published 10.16 % i.e. 9575 articles and received 232392 citations with an average (average citations per paper) 24.27 and h-index is 154. Indian Institute Of Technology IIT Kharagpur produced 5688 papers and received 120362 citations next to this Indian Institute Of Technology IIT Madras published 5.239% of papers (4,936 papers and received 98561 citations), Indian Institute Of Science IISc Bangalore published 4544 papers and received 100428 citations and h index is 111, Indian Institute Of Technology IIT Delhi produced 4285 articles and received 108042 citations and average citations per paper are 25.21, Indian Institute Of Technology IIT Bombay produced 3820 articles and received 80163 citations and Indian Institute Of

Technology IIT Roorkee published 3534 papers with 24.45 average citations per paper. The study has identified the most active institutions engaged in chemical research and proves the hypothesis

Table: 8 - Organizational / Institution productivity in engineering research

Sl. No.	Organizations	TP	TC	ACP	H-index	%
1	Indian Institute of Technology System IIT System	30355	-	-		32.215
2	Council of Scientific Industrial Research CSIR India	9575	232392	24.27	154	10.162
3	Indian Institute of Technology IIT Kharagpur	5688	120362	21.16	113	6.037
4	Indian Institute of Technology IIT Madras	4936	98561	19.97	107	5.239
5	Indian Institute of Science IISC Bangalore	4544	100428	22.1	111	4.822
6	Indian Institute of Technology IIT Delhi	4285	108042	25.21	120	4.548
7	Indian Institute of Technology IIT Bombay	3820	80163	20.99	98	4.054
8	Indian Institute of Technology IIT Roorkee	3534	86392	24.45	112	3.751
9	Indian Institute of Technology IIT Kanpur	3201	69187	21.61	94	3.397
10	Anna University	2743	56044	20.43	98	2.911
11	Anna University Chennai	2389	50157	20.99	94	2.535
12	Defense Research Development Organization DRDO	2333	40859	17.51	73	2.476
13	Anna University of Technology Chennai	2295	48961	21.33	94	2.436
14	Jadavpur University	2258	44987	19.92	80	2.396
15	Bhabha Atomic Research Center BARC	2204	37763	17.13	70	2.339
16	Indian Institute of Technology IIT Guwahati	1841	38492	20.91	77	1.954
17	National Institute of Technology Tiruchirappalli	1472	30214	20.53	72	1.562
18	Department of Space Dos Government Of India	1389	16242	11.69	52	1.474
19	Banaras Hindu University	1370	31558	23.04	76	1.454
20	Indira Gandhi Centre For Atomic Research IGCAR	1245	19326	15.52	58	1.321
21	National Institute of Technology Rourkela	1240	23760	19.16	61	1.316
22	Indian Space Research Organization	1190	12825	10.78	45	1.263
23	Institute of Chemical Technology Mumbai	1183	30984	26.19	72	1.256
24	Indian Institute of Technology IIT Bhu Varanasi	1177	26072	22.15	73	1.249
25	Indian Institute of Technology Indian School Of Mines Dhanbad	1153	18172	15.76	53	1.224

10. Most productive authors in Indian Engineering Research

The table shows the most productive authors from Indian engineering research output during the study period. The top 25 authors have been identified as the most productive authors in Indian engineering research, the publications profile of these 25 authors along with their research output, citations received and h-index values are presented in Table 4. These 25 authors contributed 13,797 papers with an average of 474.5 papers per author and account for a 14.64% share in the cumulative Indian publications output during 2003-2017. According to table 5 highest publications Kumar, Arvind, occupies the first rank with 1,391 papers (26,329 citations) with 18.93 average citations per paper and his h-index is 71, followed by Kumar, Sandeep. published 1,338 papers and received 25,200 citations with an average of 18.83 and his h-index is 66, Kumar, Ratnesh published 971 papers with 18,012 citations and his h-index is 56, Das, Sankar produced 724 papers and received 13,766 citations (h-index 54), Kumar, Prashant. published 671 articles and received 11,078 citations. Singh, Sunpreet has published 629 papers and received 11,287 citations with an average of 17.94 and his h-index is 47 and Singh, Bhupinder published 613 articles.

Table: 8 - Most productive authors in Indian engineering research

Name	Affiliation	TP	TC	ACCP	h-index
Kumar, Arvind	Central Salt & Marine Chemical Research Institute (CSMCRI)	1,391	26,329	18.93	71
Kumar, Sandeep	Council of Scientific & Industrial Research (CSIR) - India	1338	25200	18.83	66
Kumar, Ratnesh	Visvesvaraya National Institute of Technology, Nagpur	971	18012	18.55	56
Das, Sankar	SN Bose Natl Ctr Basic Sci, Dept Chem Biol & Macromol Sci, Sect 3, Block JD, Kolkata	724	13766	19.01	54
Kumar, Prashant	Univ Delhi, Dept Chem, Bioorgan Lab, Delhi	671	11078	16.51	46
Singh, Sunpreet	GNDEC, Dept Prod Engn, Ludhiana	629	11287	17.94	47
Singh, Bhupinder	Cochin University Science & Technology Cochin Univ Sci & Technol, Sch Engn, Kochi,	613	16035	26.16	58

Kumar, Vijay	Indian Sch Mines, Dept Appl Phys, Dhanbad	569	11044	19.49	49
Ghosh, Subrata	Indian Inst Technol Mandi, Sch Basic Sci, Mandi	553	9898	17.9	44
Singh, Rupinder	GNDEC, Dept Prod Engn, Ludhiana	543	10057	18.52	47
Singh, Anil K	Univ Delhi, Dept Chem, Bioorgan Lab, Delhi	538	8912	16.57	44
Chakraborty, Sudip	Natl Inst Technol Durgapur, Dept Chem Engn, Durgapur	447	8937	19.99	46
Kumar, Manoj	Motilal Nehru Natl Inst Technol, Dept Math, Allahabad	429	8768	20.44	46
Sharma, Abhimanyu	Indian Inst Technol, Dept Civil Engn, Delhi	423	7207	17.04	38
Sharma, Shyamalima	Tezpur Univ, Dept Chem Sci, Sonitpur	413	6523	15.79	35
Kumar, Nitesh	Natl Inst Technol, Dept Energy & Environm, Tiruchirappalli	408	7730	18.95	43
Roy, Sudip	Indian Inst Technol, Dept Comp Sci & Engn, Kharagpur	398	7666	19.26	42
Singh, Anupriya	Malaviya Natl Inst Technol Jaipur, Dept Chem, Jaipur	398	7791	19.58	43
Gupta, Ajay	North Eastern Hill Univ, Ctr Adv Studies, Dept Chem, Shillong	366	7725	21.11	42
Ghosh, Arindam	Indian Inst Sci, Dept Phys, Bangalore	341	7597	22.28	47
Singh, S. K	CSIR, Acad Sci & Innovat Res AcSIR, Anusandhan Bhawan	338	5259	15.56	36
Banerjee, S	Bhabha Atom Res Ctr, Bombay, Maharashtra	331	6800	20.54	42
Sarkar, Subhadeep	Indian Inst Technol Kharagpur, Dept Comp Sci & Engn, Kharagpur	323	5755	17.82	39
Gupta, Shruti	Indian Inst Technol Roorkee, Dept Elect & Commun Engn, Roorkee	321	6929	21.59	37
Singh, Virendra	Indian Inst Technol, Dept Elect Engn, Mumbai,	321	5180	16.14	34
		13,797	2,61,485	474.5	

11. Source wise distribution of Indian contributions in engineering literature

The 25 core journals are identified which contains 26.83% of the total articles. Among 25 journals 20 journals are published outside India. The topmost productive journals publishing India's research papers in engineering research contributed 25,285 papers, which accounts for a 29.83% share in the cumulative publications output of India from 2003 to 2017. In these topmost productive journals, 8 journals are published from the USA, 5 journals each are published from India & England, 4 journals are published from Switzerland and 3 journals are published from the Netherlands.

Based on the publications the *Journal Of Alloys And Compounds* from Switzerland published the highest publications i.e. 3,094 articles and received 69,795 citations, followed by *Journal Of Materials Science Materials In Electronics* (Netherlands) published 1,982 articles and received 19,087 citations, *Industrial Engineering Chemistry Research* (USA) published 1,694 articles and received 42,813 citations, *Journal Of Scientific Industrial Research* (India) contributed 1,428 papers and received 11,600 citations, *Materials Science And Engineering A Structural Materials Properties Microstructure And Processing* from Switzerland published 1,373 papers and received 37,761 citations, *Transactions Of The Indian Institute Of Metals* (India) published 1,332 articles and received 5,267 citations, *Journal Of Hazardous Materials* (Netherlands) published 1,192 articles and received 85,585 citations, *International Journal Of Advanced Manufacturing Technology* published 1,070 articles and received 24,382 citations, *Desalination And Water Treatment* published 995 articles and received 8,634 citations and *Indian Journal Of Chemical Technology* published 944 articles and received 5,874 citations.

Table: 14 - Source wise distribution of Indian Engineering literature

SN	Source Titles	TP	TC	ACP	H Index	% of 94225	Country
1	Journal of Alloys and Compounds	3094	69795	22.56	85	3.284	Switzerland
2	Journal of Materials Science Materials in Electronics	1982	19087	9.63	39	2.103	Netherlands
3	Industrial Engineering Chemistry Research	1694	42813	25.27	79	1.798	USA
4	Journal of Scientific Industrial Research	1428	11600	8.12	40	1.516	India
5	Materials Science and Engineering A Structural Materials Properties Microstructure and Processing	1373	37761	27.5	77	1.457	Switzerland
6	Transactions of The Indian Institute Of Metals	1332	5267	3.95	21	1.414	India
7	Journal of Hazardous Materials	1192	85585	71.8	134	1.265	Netherlands
8	International Journal of Advanced Manufacturing Technology	1070	24382	22.79	61	1.136	England
9	Desalination and Water Treatment	995	8634	8.68	32	1.056	USA
10	Indian Journal of Chemical Technology	944	5874	6.22	28	1.002	India
11	Microwave and Optical Technology Letters	900	5263	5.85	24	0.955	USA
12	International Journal of Heat And Mass Transfer	858	26661	31.01	70	0.911	England
13	Materials and Manufacturing Processes	840	14114	16.8	48	0.891	USA
14	Chemical Engineering Journal	817	40360	49.4	94	0.867	Switzerland
15	Sadhana Academy Proceedings in Engineering Sciences	809	6417	7.93	30	0.859	India
16	International Journal of Electrical Power Energy Systems	782	25563	32.69	76	0.83	England
17	Metallurgical and Materials Transactions A Physical Metallurgy and Materials Science	659	9022	13.69	39	0.699	USA
18	IETE Journal of Research	613	1938	3.16	18	0.651	England
19	Indian Journal of Engineering and Materials Sciences	599	3114	5.2	22	0.636	India
20	Separation Science and Technology	575	6638	11.54	32	0.61	USA
21	Journal of Chemical and Engineering Data	569	11824	20.78	50	0.604	USA
22	Materials Science in Semiconductor Processing	557	8645	15.52	37	0.591	England
23	IEEE Transactions on Electron Devices	543	11016	20.22	51	0.576	USA
24	Desalination	542	22324	41.19	73	0.575	Netherlands
25	Journal of Materials Processing Technology	518	18911	36.51	69	0.55	Switzerland

12. International Collaboration

Due to the interdisciplinary growth of the subject, the universe of knowledge is ever dynamic and is ever-growing. More and more specialization in the subjects is achieved by the scientists, which is a result of increased participation of a group of researchers of different expertise. It has been found from earlier studies that collaboration in research varies from discipline to discipline and for the same discipline from time to time and from one country to another.

Collaborative research has become a well-established feature in the field of Engineering. It is observed that there is a consistently increasing trend towards collaboration among various branches of engineering which leads to collaborative authorship in literature.

The table depicts the international collaborative papers of India with top with 25 countries during 2003-2017. The share of international collaborative publications in the Indian engineering research output was 21.69% during 2003-2017. The largest number of collaborative publications 4984 of India in engineering research was with the United States with 5.289% share, followed by South Korea contributed 2006 papers with 2.129 of the total share, Germany published 1436 papers, England produced 1246 papers, Canada published 1005 articles, Peoples R China contributes 997 papers, Japan published 990 papers and Australia has contributed with India in engineering research i.e. 989 papers. Many countries are contributed below 1% share with India in engineering research from 2003 to 2017 (Table-).

Table:15 - International Collaboration

S N	Countries/Regions	TP	% of 94225
1	USA	4984	5.289
2	South Korea	2006	2.129
3	Germany	1436	1.524
4	England	1246	1.322
5	Canada	1005	1.067
6	Peoples R China	997	1.058
7	Japan	990	1.051
8	Australia	989	1.05

9	France	801	0.85
10	Malaysia	791	0.839
11	Singapore	759	0.806
12	Saudi Arabia	691	0.733
13	Italy	489	0.519
14	Taiwan	441	0.468
15	South Africa	435	0.462
16	Sweden	316	0.335
17	Netherlands	280	0.297
18	Spain	276	0.293
19	Iran	259	0.275
20	Portugal	240	0.255
21	Switzerland	210	0.223
22	Russia	198	0.210
23	Brazil	194	0.206
24	Scotland	176	0.187
25	Turkey	171	0.181

13. Highly Cited Papers in the field of Indian Engineering

Table 19 shows characteristics of selected highly cited papers of India in Engineering were also evaluated in this section and the list of such high – cited papers is presented based on publication output of India in this area, 25 papers were identified as highly cited ones, who have received citations from 770 to 3,281 during 2003 to 2017 of these 25 papers, These 25 highly cited papers were published in 16 journals including 4 papers in *Journal of Hazardous Materials*, 3 each in *IEEE Transactions on Industrial Electronics* and *Progress in Energy and Combustion Science*, 2 each in *Acta Materialia* and *International Journal of Heat and Mass Transfer* and remaining papers are published 1 each. Citations received by these top 25 cited papers accumulated to 32,103 (2.019%) of all citations. Among 25 papers only 2 papers were written by a single author and the remaining 23 papers are having multiple authors, 9 papers are having two authors, 6 papers each having three and four authors, five authors and nine authors have published one paper each. The top-cited paper was ‘Pyrolysis of wood/biomass for bio-oil: A critical review’, authored by Mohan, D; Pittman, CU and Steele, PH. it is published in *Energy & Fuels* at *Washington* in the year 2006 and this paper has received

3,281 citations, followed by 'Overview No.144 - Mechanical behavior of amorphous alloys', authored by Schuh, CA; Hufnagel, TC and Ramamurty, U published in *Acta Materialia* in the year 2007, and this paper received 2217 citations, 'Arsenic removal from water/wastewater using adsorbents - A critical review' authored by Mohan, D and Pittman, CU. published in *Journal of Hazardous Materials* in the year 2007 and this paper received 2209 citations, 'Recent Advances and Industrial Applications of Multilevel Converters' authored by Kouro, S et al. published in *IEEE Transactions on Industrial Electronics* in the year 2010 this paper received 2133. 'Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines', authored Agarwal, AK published in *Progress in Energy and Combustion Science* and received 1737 citations. 'Temperature dependence of thermal conductivity enhancement for nanofluids', authored by Das, SK; Putra, N; Thiesen, P; Roetzel, W. published in *Journal of Heat Transfer-Transactions of the ASME* in the year 2003, and this paper received 1639 citations, 'Biodegradation aspects of Polycyclic Aromatic Hydrocarbons (PAHs): A review' authored by Haritash, AK; Kaushik, CP. published in *Journal of Hazardous Materials* in the year 2009 this paper received 1469. 'A review of imperative technologies for wastewater treatment I: oxidation technologies at ambient conditions' authored by Gogate, PR; Pandit, AB. published in *Advances in Environmental Research* in the year 2004 and this paper received 1317 citations, this shows that more research activities are being carried on in newly developing fields.

Table: 19 - Highly Cited Papers in the field of Indian Engineering

Citations Received	Title of the Article	Authors	Source	Country	Year of Publication
3281	Pyrolysis of wood/biomass for bio-oil: A critical review	Mohan, D; Pittman, CU; Steele, PH	Energy & Fuels	Washington	2006
2217	Overview No.144 - Mechanical behavior of amorphous alloys	Schuh, CA; Hufnagel, TC; Ramamurty, U	Acta Materialia	Oxford	2007
2209	Arsenic removal from water/wastewater using adsorbents - A critical review	Mohan, D; Pittman, CU	Journal of Hazardous Materials	Amsterdam	2007
2133	Recent Advances and Industrial Applications of Multilevel Converters	Kouro, S; Malinowski, M; Gopakumar, K; Pou, J; Franquelo, LG; Wu, B; Rodriguez, J; Perez, MA; Leon, JI	IEEE Transactions on Industrial Electronics	Piscataway	2010
1737	Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines	Agarwal, AK	Progress in Energy and Combustion Science	Oxford	2007

1639	Temperature dependence of thermal conductivity enhancement for nanofluids	Das, SK; Putra, N; Thiesen, P; Roetzel, W	Journal of Heat Transfer- Transactions of the ASME	New York	2003
1469	Biodegradation aspects of Polycyclic Aromatic Hydrocarbons (PAHs): A review	Haritash, AK; Kaushik, CP	Journal of Hazardous Materials	Amsterdam	2009
1317	A review of imperative technologies for wastewater treatment I: oxidation technologies at ambient conditions	Gogate, PR; Pandit, AB	Advances in Environmental Research	Oxford	2004
1215	A review on the utilization of fly ash	Ahmaruzzaman, M	Progress in Energy and Combustion Science	Oxford	2010
1202	A Survey on Cascaded Multilevel Inverters	Malinowski, M; Gopakumar, K; Rodriguez, J; Perez, MA	IEEE Transactions on Industrial Electronics	Piscataway	2010
1139	Activated carbons and low-cost adsorbents for remediation of tri- and hexavalent chromium from water	Mohan, D; Pittman, CU	Journal of Hazardous Materials	Amsterdam	2006
1110	Heat transfer augmentation in a two-sided lid-driven differentially heated square cavity utilizing nanofluids	Tiwari, RK; Das, MK	International Journal of Heat and Mass Transfer	Oxford	2007
1093	Heart rate variability: a review	Acharya, UR; Joseph, KP;	Medical & Biological Engineering & Computing	Heidelberg	2006

		Kannathal, N; Lim, CM; Suri, JS			
1089	Strain specificity in antimicrobial activity of silver and copper nanoparticles	Ruparelia, JP; Chatterjee, AK; Duttagupta, SP; Mukherji, S	Acta Biomaterialia	Oxford	2008
1022	Modeling and Analysis of K-Tier Downlink Heterogeneous Cellular Networks	Dhillon, HS; Ganti, RK; Baccelli, F; Andrews, JG	IEEE Journal on Selected Areas in Communications	Piscataway	2012
951	Advanced Control Architectures for Intelligent Microgrids-Part I: Decentralized and Hierarchical Control	Guerrero, JM; Chandorkar, M; Lee, TL; Loh, PC	IEEE Transactions on Industrial Electronics	Piscataway	2013
868	Perspectives on Titanium Science and Technology	Banerjee, D; Williams, JC	Acta Materialia	Oxford	2013
831	A Survey of 5G Network: Architecture and Emerging Technologies	Gupta, A; Jha, RK	IEEE Access	Piscataway	2015
831	Solid polymer electrolyte membranes for fuel cell applications - a review	Smitha, B; Sridhar, S; Khan, AA	Journal of Membrane Science	Amsterdam	2005

831	Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India) - a case study	Singh, KP; Malik, A; Mohan, D; Sinha, S	Water Research	Oxford	2004
797	Pool boiling characteristics of nano-fluids	Das, SK; Putra, N; Roetzel, W	International Journal of Heat and Mass Transfer	Oxford	2003
795	Hierarchically porous carbon derived from polymers and biomass: effect of interconnected pores on energy applications	Dutta, S; Bhaumik, A; Wu, KCW	Energy & Environmental Science	Cambridge	2014
784	A Comparative Study on Maximum Power Point Tracking Techniques for Photovoltaic Power Systems	Subudhi, B; Pradhan, R	IEEE Transactions on Sustainable Energy	Piscataway	2013
773	Trends in bioconversion of lignocellulose: Biofuels, platform chemicals & biorefinery concept	Menon, V; Rao, M	Progress in Energy and Combustion Science	Oxford	2012
770	Synthesis and characterization of alumina-coated carbon nanotubes and their application for lead removal	Gupta, VK; Agarwal, S; Saleh, TA	Journal of Hazardous Materials	Amsterdam	2011

14. Top 25 funded agencies in the field of Indian Engineering research

Table 10 reveals the top 25 funding agencies for engineering research in India based on their highest publications. According to the web of science database Department Of Science Technology India funded for 5323 publications, followed by Council Of Scientific Industrial Research CSIR India funded for 3844 publications, University Grants Commission India funded for 3576 publications, Defence Research Development Organisation DRDO funded for 887 publications. Top 25 funding Instituitues were funded 17 % of publications

Table: 20 - To 25 funded agencies

SN	Funding Agencies	TP	%
1	Department of Science Technology India	5323	5.649
2	Council of Scientific Industrial Research CSIR India	3844	4.08
3	University Grants Commission India	3576	3.795
4	Defense Research Development Organisation DRDO	887	0.941
5	Department of Atomic Energy DAE	771	0.818
6	Department of Biotechnology DBT India	579	0.614
7	Board of Research in Nuclear Sciences BRNS	544	0.577
8	National Science Foundation NSF	483	0.513
9	Ministry of Human Resource Development MHRD Government of India	331	0.351
10	National Natural Science Foundation of China NSFC	236	0.25
11	Engineering Physical Sciences Research Council EPSRC	232	0.246
12	Ministry of Education Science and Technology Republic of Korea	184	0.195
13	Natural Sciences and Engineering Research Council of Canada	176	0.187
14	All India Council for Technical Education AICTE	155	0.164
15	European Union EU	144	0.153
16	Alexander Von Humboldt Foundation	143	0.152
17	United States Department of Energy DOE	133	0.141
18	German Research Foundation DFG	131	0.139
19	Government of India	128	0.136
20	Ministry of Education Culture Sports Science and Technology Japan MEXT	121	0.128
21	National Research Foundation of Korea	120	0.127
22	United States Department of Defense	110	0.117
23	Deutscher Akademischer Austausch Dienst DAAD	102	0.108
24	Korean Government	102	0.108
25	Department of Space Dos Government of India	98	0.104

Conclusion

The study looked at India's contribution in the field of science and technology in terms of volume of research papers, global share, and citation impact. The study identified India's scientific publications grew 13.742%, as against the global average of 9.68%, during 2009-13. Various indicators show India has a small but growing share of the world's total scholarly output. India's share of the world's science and technology scholarly output has grown from 2.852% in 2003 to 13.742% in 2003—from 2,687 papers in 2009 to 12,948 papers in 2017. Indian Institute of Technology System IIT System is the most prolific and in the greatest number of subjects, with the highest number of publications (30355) between 2003 and 2017.

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