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SCIENTOMETRIC DIMENSIONS OF CHEMICAL ENGINEERING RESEARCH IN INDIA WITH REFERENCE TO WEB OF SCIENCE CITATION DATABASE

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ABSTRACT:

This study adopts a scientometric approach to quantitatively assess current research trends in Indian research performance in chemical engineering,it analyses scientific papers published during 2011 to 2015.Its focuses on countries global publication share, growth rate,citation quality, international collaborative publications share, using 5 years data from the web of science database. The study suggests the need to increase the pace of Indian scientific research and also improve itsquality compared with other developed and developing countries. It also suggests the need for India tobuild up its scientific capacity, competence and knowledge base to help bridging the scientific andtechnological gap with leading countries.

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KEYWORDS: *Scientometrics, Chemical Engineering, Web of Science, Relative Growth Rate and Doubling Time.*

INTRODUCTION:

Chemical engineering is the study and practice of transforming substances at large scales for the tangible improvement of the human condition. Such transformations are executed to produce other useful substances or energy, and lie at the heart of vast segments of the chemical,

petroleum, pharmaceutical and electronic industries.

Chemical engineering differs from chemistry mainly in the focus on large scales. The definition of "large" is a bit arbitrary, of course, but is set mainly by the scale of useful commercial production. Typically, this scale ranges from barrels to tank cars, whereas the chemist tends to be concerned about sizes ranging from vials to beakers.

Chemical engineering has been practiced in rudimentary form since at least the great Roman road-building projects that began about 300 B.C. The cement used for pavement was based on the contemporary Hellenistic formula employing lime, a calcined (heated) form of calcium carbonate. However, academic programs in the U.S. formally called "chemical engineering" — or something similar — originated only near the start of the 20th Century.

Recognizing the importance of science and technology in economic and industrial development, the Government of India reemphasized the need to view them together in its “Science and Technology Policy –2003” following the “Science Policy Resolution of 1958” and the “Technology Policy Resolution of 1983”.The policy has recognized the central role of the S&T system in the economic and industrial development of the country, in raising the quality of life of its people, in creating national wealth, in utilizing natural resources, in protecting environment and in ensuring national security. Over the years, the country has invested heavily in developing infrastructure for R&D in different fields of S&T, including frontier areas, such as atomic energy, space sciences, electronics and telecommunications and more recently in biotechnology and information technology (Gupta & Gupta, 2011).

Today, there is an increasing interest in using scientometric information for assessing or monitoring research activities. The discipline devoted to the quantitative study and evaluation of the scientific literature is called scientometric or bibliometrics. Bibliometrics has been applied to the evaluation of scientific disciplines, national scientific production, and bibliographic databases, and it provides valuable tools to describe the scientific activity in the past and to orient future research (Schoepflin&Glänzel, 2001). The aim of scientometrics is to provide quantitative characterizations of scientific activity. Because of the particular importance of publication in scientific communities, it largely overlaps with bibliometrics, which is quantitative analysis of media in any written form.

Scientometrics indicators can be classified to the number of scientometrics sets they represent and the application of reference standards (Vinkler, 1988). Scientometrics indicators referring to the measure of a single Scientometrics aspect of Scientometrics system represented by a single Scientometrics set with a single hierarchical level are termed gross indicators. Those indicators which consist of several gross or complex indicators, preferably with weighting factors and each representing a special aspect of a Scientometrics system are composite or compound indexes.Scientometric approach to quantitative assess current research trends in India & South Korea research performance in chemical engineering, it analysis scientific papers published five years and its suggested the need to increase the improve its quality compared with other development and developed countries (Chaman Sab, M et al 2016). The Study identified with the help of Web of Science (WoS) the most of the research publications are published in English language and most of the publications published in the form of research articles; China is the highest contributor to the field of Crystallography (Neelamma and GavisidappaAnandhalli (2015). The study analysis the growth of literature published by the researches in India for 2006 – 2015. The study presented a summary of scientometric research in the crystallographic area.(Chaman Sab, M et al 2016)

NEED FOR THE STUDY

Research is a prolonged process, aiming at discovering the truth and is a means for acquiring knowledge about any natural or human phenomena. Research in all fields is growing at a faster rate and particularly the field like library and information science is advancing. This is due to the change in the trends of research followed but the change is gradual and not all of a sudden. In the process of identifying the research trends in a field it is essential to analyze the various patterns that evident in the literature of the field.

The analysis of the research output of any discipline will provide great effects on the subject and its research. Therefore an attempt is made in the present study to investigate the research output of India during the year 2011 to 2015 using scientometric indicators. This study certainly helps to ascertain the trends of research in developing countries in the field of chemical engineering.

SCOPE OF THE STUDY

The present study includes the chemical engineering research output of India. However the data covered in the study includes only the data retrieved from the web of science during the period 2011-2015.

OBJECTIVES OF THE STUDY

The purpose of this study is to explore the main scientific output in order to measure the extent of scientific research in chemical engineering. The specific objectives of this study are as follows:

- To identify the year wise distribution of research articles of India
- To find out the relative growth rate and doubling time ofchemical engineering during the five year (2011 to 2015);
- To identify the distribution of articles in different document formats;
- To know the highly productive research institutions in the field;
- To know the subject-wise (sub fields) distribution of the research publications;
- To know the international collaborations.

METHODOLOGY

The data for this study were collected by searchingthe Science Citation Index- Expanded (SCI-E) ofWeb of Science Database which is a verycomprehensive and exhaustive database envelopingalmost all subjects of Science and Technology, viathe subject of concerned countries for the period from 2011 to 2015. The Web of ScienceAffiliation search was used to gather the raw datarequired to study the scientific productivity of eachuniversity (for example, SU=Chemistry,Refined by: Web of Science Categories: (engineering chemical) ANDCU=India,Timespan: 2011-2015. Indexes: SCI-Expanded) search aid is used to retrieve the most comprehensiveand accurate results.

Relative Growth Rate (RGR)The Relative Growth Rate (RGR) is the increase in number of articles 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 (1978and 1982); Poorter and Garnier, 1996; Hoffmann andPoorter, 2002). There exists a direct equivalence between Relative Growth Rate and Doubling Time (Bradford, 1934). If the number of articles of a subject get doubled during a given period then the difference between the logarithms of numbers at the beginning and end of the period must be logarithms of number 2. If natural logarithm is used this difference has a value of 0.693. The mean RGR of articles over the specific period of interval is represented as

$$R = W_2 - W_1/T_2 - T_1$$

Where

R = mean relative growth rate over the specific period of intervals;

W_1 = Log W_1 (natural log of initial number of publication);

W_2 = Log W_2 (natural log of final number of publication);

$T_2 - T_1$ = the unit difference between the initial and final time

This formula even holds good for the calculation of RGR Subject wise

Doubling Time (D_t) Doubling Time (Dt): The doubling time is the given period required for quantity to double in size or value. This can be calculated by using the formula.

Doubling time $D_t = 0.693/R$

Here, Dt (P) = average doubling time of publications

RESULTS AND DISCUSSION

Growth of Publications of India in Chemical Engineering

Table 1 depicts the chemical engineering research output of India has produced 2,324publications, and received 11,299 citations during the period 2011 to 2015, average citations per publicationis 4.86. The publications are gradually increased year by year. Maximum publication (539) observed in the year 2015 and minimum publication observed in 2011 (387). In terms of citation impact per paper higher impact 36 was registered in the year of 2011.

Table 1: Growth of Publications and Citations

Years	TP	%	TC	ACP	H-Index
2011	387	16.65	3353	8.66	26
2012	419	18.03	2809	6.7	22
2013	494	21.26	2826	5.72	19
2014	485	20.87	1933	3.99	17
2015	539	23.19	378	0.7	7
	2324	**100**			

Note: TP=Total publications, TC= Total Citations, ACP=Average Citations per Paper

Relative Growth Rate (RGR) and Doubling Time (Dt.)

The year-wise total output of India shown in Table 2 (five years) along with the growth rate and doubling time. The table shows that the relative growth rate of Indian output decreases gradually from 0.73 to 0.26 in five year's period (2011-2015). The doubling time (Dt) correspondingly increases from 0.94 to 2.63 in this period. But the year-wise analysis of growth rate and doubling time. The average growth rate of Indiais 26.07.

Table 2: Relative Growth Rate (RGR) and Doubling Time (Dt.)

Year	TP	Cumulative Publications	RGR	Dt.
2011	387	387		
2012	419	806	0.73	0.94
2013	494	1300	0.48	1.45
2014	485	1785	0.32	2.19
2015	539	2324	0.26	2.63

Source wise Distribution of Research output of in the field of Chemical Engineering

The sources of Chemical Engineering research include articles published in the journals,reviews, conference and seminars proceedings, editorial materials, corrections and book chapters. This study has observed a totalof 4931 publications in chemical engineering from India of six years from 2011 to 2015. Out of them,articles appeared in the journals have shown a predominant contribution (94.77%) from India. The analysis indicates that the total output of articles in the years (96.60).However the whole study period 4673publications are appeared injournals articles from India The chemical engineering research output appeared with reviews rankas second in order (2.68%) in an overall output. The output from the conference and seminars proceedings publicationsrecords a third place in an overall chemical engineeringliterature output.

Table 3:Publication patterns ofIndiain the field of Chemical Engineering

Sl. No.	Document Types	Publications	%
1	Article	2245	96.60
2	Review	53	2.28
3	Proceedings Paper	9	0.39
4	Editorial Material	8	0.34
5	Correction	5	0.22
6	Book Chapter	4	0.17
	Total	**2324**	

National collaboration links of India

The Table 3 displays results of top selected institutions in India based on their highest publications according to the web of science database.Indian Institute of Technology (IIT), Delhi contributed the highestpublications to the field of chemical engineering, i.e. 183 publications with 8.61%, followed by Institute Chemical Technology (ICT), Mumbai with 99 publications (4.26%), Council of Scientific Industrial Research (CSIR), Delhi, with 98 publications (4.22%), Bhabha Atomic Research Centre (BARC), Mumbai with 98 publications (4.22%),National Institute of Technology, Goawith 82publications (3.53%), Aligarh Muslim University, Aligarh, with 69 publications (2.97%), and Institute Chemical Technology (ICT), Hyderabad with 54publications (2.32%).

Table 4: National collaboration links of India

S.N	Research Institution	TP	%
1	Indian Institute of Technology (IIT), Delhi	183	7.87
2	Institute Chemical Technology (ICT),Mumbai	99	4.26
3	Council of Scientific and Industrial Research (CSIR), New Delhi	98	4.22
4	Bhabha Atomic Research Centre (BARC), Mumbai	98	4.22
5	National Institute of Technology, Goa	82	3.53
6	Aligarh Muslim University, Aligarh, Uttar Pradesh	69	2.97
7	Institute Chemical Technology (ICT), Hyderabad	54	2.32
8	Anna University, Chennai	49	2.11
9	Indian Institute of Science, Bangalore	41	1.76
10	National Chemical Laboratory, Pune	37	1.59
11	High Energy Materials Research Laboratory, Pune	33	1.42
12	Guru Nanak Dev University, Punjab	33	1.42
13	Indian Institute of Technology (IIT), Guwahati	32	1.38
14	Jadavapur University, Kolkata	29	1.25
15	University of Delhi, Delhi	28	1.21
16	Banaras Hindu University, Varanasi	28	1.21
17	University of Calcutta, Kolkata	27	1.16
18	Indira Gandhi Centre for Atomic Research, Tamil Nadu	27	1.16
19	Tezpur University, Assam	25	1.08
20	Indian Institute of Technology Roorkee , Uttarakhand	24	1.03

Top sub-fields research priority in Chemical Engineering of India

Table 6 indicates that the sub-fields research priorityin chemical engineering research of India Thermodynamics, Materials Science, Energy Fuels, Biotechnology Applied Microbiology, Pharmacology

Pharmacy, Environmental Sciences Ecology, Polymer Science, were considered on the basis of the highest number of publications. In India during the period 2011 to 2015Thermodynamicshas got the first position with 301(12.95%) publications, followed byMaterials Sciencewith 177(7.62%)publications, Energy Fuels with 120 (5.16%) publications, Biotechnology Applied Microbiology with 91 (3.92%) publications, Pharmacology Pharmacy with 61 (2.63%) publications, Environmental Sciences Ecology with 30 (1.29%) publications, and Polymer Science with 28 (1.21%) publications.

Table 5: Top Sub-fields research priority in Chemical Engineering of India

Sl. No.	Subject	Publications	% of 2324
	Thermodynamics	301	12.95
	Materials Science	177	7.62
	Energy Fuels	120	5.16
	Biotechnology Applied Microbiology	91	3.92
	Pharmacology Pharmacy	61	2.63
	Environmental Sciences Ecology	30	1.29
	Polymer Science	28	1.21

Most preferred Indian Journals in the field of Chemical Engineering

Periodicals play a very vital role in scientific communication and serve as a repository of information, knowledge and media for communication from mind to mind.The list of top 15 source journals shown in Table 6. The share of the top 20 most productive journals in Indian output 86.53% share of the total countries output, Out of the 40 journals from countries, 15 are basically from Netherlands, 07 from USA,05 from England (U. K.), 02 from Chinaand South Korea, 1 from India, and Serbia.

Most preferred journals of Indian authors are Separation Science and Technologyhas published 283 articles, followed by Journal of Chemical and Engineering Data with 206 articles, Journal of Industrial and Engineering Chemistrywith 201 articles, Indian Journal of Chemical Technologywith 196 articles, Acs Sustainable Chemistry Engineering with 118 articles and Korean Journal of Chemical Engineering with 117 articles.

Table 6: Most preferred IndianJournals in the field of Chemical Engineering

Sl. No.	Source /Journal	TP
1	Separation Science And Technology United Kingdom	283
2	Journal Of Chemical And Engineering Data, USA	206
3	Journal Of Industrial And Engineering Chemistry, Netherlands	201
4	Indian Journal of Chemical Technology, India	196
5	Acs Sustainable Chemistry Engineering, USA	118
6	Korean Journal of Chemical Engineering, South Korea	117
7	Dyes And Pigments, Netherlands	101
8	Fluid Phase Equilibria, Netherlands	95
9	Journal Of Chemical Technology And Biotechnology, USA	91
10	Journal Of Surfactants And Detergents, USA	87
11	Catalysis Today, Netherlands	75
12	Fuel Processing Technology, Netherlands	73
13	Journal Of Microencapsulation, United Kingdom	61
14	Applied Catalysis B Environmental, Netherlands	56
15	Tenside Surfactants Detergents, Germany	53
16	Chemical Industry Chemical Engineering Quarterly,Serbia	46
17	Chinese Journal Of Catalysis, China	42
18	Polish Journal Of Chemical Technology, Germany	38
19	Propellants Explosives Pyrotechnics, USA	36
20	Pigment Resin Technology, United Kingdom	36

INTERNATIONAL COLLABORATING PARTNERS OF INDIA

Table 8 depicts the international collaborative papers of India with top with 20 countries during 2011-

2015. The share of International collaborative publications in the chemical engineering research output of India in this research was with South Korea with 3.70% share, followed by United Stateswith 1.98%share, Saudi Arabiawith 1.94%share and South Africa with090%share. Followed by Malaysia with 0.86%, Australia with 0.86%, Japan with 0.82 % and Germany with 0.78%. Many countries are contributed with below 1% share with India in chemical engineering research during 2011 to 2015 (Table-7).

Table 7: International collaborating partners of India

Sl. No	Country	TP	% of 2324
1	South Korea	86	3.70
2	USA	46	1.98
3	Saudi Arabia	45	1.94
4	South Africa	21	0.90
5	Malaysia	20	0.86
6	Australia	20	0.86
7	Japan	19	0.82
8	Germany	18	0.78
9	Canada	18	0.78
10	France	16	0.69
11	Italy	15	0.65
12	Singapore	13	0.56
13	Iran	13	0.56
14	Turkey	12	0.52
15	Taiwan	12	0.52
16	Spain	10	0.43
17	Peoples R China	9	0.39
18	England	8	0.34
19	Sweden	7	0.30
20	Portugal	7	0.30

CONCLUSION

The present study gives a scientometric description of the research performance of countries status in world. The assessment of countries productivity can be measured by the counting of research publications in the journals and proceedings, and the number of citations received in those publications. Scientometric indicators have been used as valuable indicators to quantitatively measure the output of scientific research. They merely show part of scientific enterprise, which is activity with diverse aspects. However, there is nothing on par with these indicators in terms of the abundance of information contained.

This study reveals that India has produced 2,324 publications, and received 11,299 citations during the period 2011 to 2015, the average citations per publication is 4.86.Publications are gradually increased year by year. The average growth rate of India is 26.07.

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