# Scientometric Analysis of Indian Engineering Literature during 1999-2013

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**ABSTRACT-** The present study deals with the scientometric analysis of Indian engineering research output as reflected in Web of Science (WOS) database for the period 1999 to 2013 for identifying the research output in the field of engineering literature. It also provides a comparative evaluation and performance of different types of scientometric indicators, such as number of publications, number of citations, relative growth, doubling time, activity index and collaboration from India. The Indian engineering research has increased exponentially over the last decade.

**KEYWORDS-** Scientometrics, Scientometric Analysis, Engineering, Web of Science, Relative Growth Rate, Doubling Time and Activity Index.

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# 1 INTRODUCTION

The term Engineering derived from Latin word 'ingenium', meaning 'cleverness' and 'ingeniare', meaning 'to contrive, devise'. Engineering is the application of scientific, economic, social, and practical knowledge in order to design, build, maintain, and improve structures, machines, devices, systems, materials and processes using the engineering design process. Engineering is the broad discipline, encompasses the range of more specialized fields with a more specific emphasis on particular areas of technology and types of application.

Scientometrics is a discipline which analyses scientific publications to explore the structure and growth of science. The bibliometric / scientometric / informetric techniques used to analyze various quantitative or qualitative aspects of a publication. It is a scientific field that studies the evolution of science through some quantitative measures of scientific information, as the number of scientific articles published in a given period of time, their citation impact, etc. The history of science and technology, philosophy of science and sociology of scientific knowledge are the related fields of Scientometrics.

The assessment of research performance using scientometric technique is a valuable method for the identification and evaluation of the strength and weakness in scientific achievements. The generation of new scientific and technical knowledge/information has been accelerating over the past several years. The growth in literature has become a major concern for the scientists, scholars, and library professional as they try to keep themselves abreast with new advances in their subject, and information professionals try to organize this knowledge. How the growth, origin and language of literature reflect in various national level activities in R & D is a matter of great concern to the managers of the scientific activities in government industry and in academic community.

The study analyses India's performance in the field of engineering, using publications data and different quantitative and qualitative measures. Its focuses on India's publication share in world, growth rate, quality of citation, international collaborative publications, its publication share and distribution in sub-fields using 15 years data from the Web of Science database.

# 2 METHODS AND MATERIALS

Data for the world and India since 1999-2013 has been collected, by using **Web of Science** database. For analyzing the data, Excel and SPSS- statistical software has been used. The Relative Growth Rate (RGR), Doubling Time (Dt) and Activity Index (AI) has been calculated.

**2.1 Relative Growth Rate:** is the growth rate relative to the size of population. It is also called as the exponential growth rate or continuous growth rate with reference to scientific literature publication time, **Relative Growth Rate (GR)** is the increase in the number of publications per unit time. The formula for calculating the mean R

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

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

**2.2 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

**2.3 Activity Index (AI):** Activity index characterizes the relative research efforts of a country in a given subject field and takes into consideration the effect of the size of the country as well as the size of the field. Activity Index (AI) for India has been calculated for different years to see how India's performance gradually changed during different years. For this the author has used the Activity Index for fifteen years period.

The Activity Index (AI) characterizes the relative research effort of a country in given subjects. It is defined as:

$$AI = \frac{\text{given field's share in the country's publication output}}{\text{given field's share in the world's publication output}}$$

Mathematically

$$AI = \frac{nij/nio}{noj/noo} * 100$$

Where:

nij -Indian output of papers in particular field

nio -Total Indian output on all subjects

noj -World output of papers in particular field

noo -Total World output on all subjects

# 3 RESULTS AND DISCUSSION

## 3.1 Growth of Publications of World and India in Engineering

Table 1 depicts the engineering research output of World and India, Average Citations per publications and global publications share of India. India has produced 48,570 publications, and received 4,44,223

citations during the period 1999-2013, Average Citations per Publication is 9.15. As per the web of science data, cumulative publications growth, the cumulative engineering publications output of India had increased from 8,999 publications during 1999-2003 to 15,096 publications during 2004-2007, and 24,475 publications during 2008-2013. India's publications are gradually increased year by year. The global publications share of India during 1999-2013 was 3.72 %, which has increased from 2.52 in 1999 to 5.08 in 2013. This analysis proves that there is an increasing trend in the Indian engineering research.

The global research output in engineering research has increased from 3,29,412 in 1999 to 5,38,447 in 2013. The trend shows a steady and significant increase in the publications. In the same manner, the Indian research output in engineering too has increased from 8,999 in 1997 to 24,475 by 2011. The trend shows a higher steepness, indicating a faster increase in research output vis-à-vis global research output (Table 1).

**Table 1 Growth of Publications of World and India in Engineering**

| Year | World (TP) | India (TP) | % TP Share | ACPP |
|---|---|---|---|---|
| 1999 | 62083 | 1566 | 2.52 | 14.90 |
| 2000 | 63118 | 1658 | 2.63 | 16.68 |
| 2001 | 66617 | 1920 | 2.88 | 14.59 |
| 2002 | 66393 | 1750 | 2.64 | 1.33 |
| 2003 | 71201 | 2105 | 2.96 | 16.32 |
| 2004 | 77568 | 2360 | 3.04 | 16.34 |
| 2005 | 85014 | 2560 | 3.01 | 15.69 |
| 2006 | 88442 | 2770 | 3.13 | 16.50 |
| 2007 | 90240 | 3396 | 3.76 | 13.80 |
| 2008 | 96558 | 4010 | 4.15 | 11.10 |
| 2009 | 105662 | 4608 | 4.36 | 9.39 |
| 2010 | 103183 | 4688 | 4.54 | 6.51 |
| 2011 | 107099 | 4676 | 4.37 | 4.94 |
| 2012 | 107643 | 4672 | 4.34 | 2.62 |
| 2013 | 114860 | 5831 | 5.08 | 0.62 |
| 1999-2003 | 329412 | 8999 | 2.73 | 12.85 |
| 2004-2008 | 437822 | 15096 | 3.45 | 14.29 |
| 2009-2013 | 538447 | 24475 | 4.55 | 4.61 |
| **1999-2013** | **1305681** | **48570** | **3.72** | **9.15** |

*Note: TP= Total Publications, ACPP= Average Citations per Publications*

### 3.2 Relative Growth Rate and Doubling time

The total output of world and India has been shown in Table 2 (fifteen year) along with the growth rate and doubling time. The table shows that the relative growth rate of world output decreases gradually from 0.701 to 0.092 in fifteen year's period (1999-2013). The doubling time (Dt) correspondingly increases from 0.988 to 7.526 in this period. The mean growth rate & doubling time for the world is 0.203 and 4.129 respectively.

Indian output, as shown in Table 3, also decreases gradually from 0.722 to 0.128 during fifteen years period (1999-2013). This growth may be due to the establishment of major scientific institutions which resulted into more scientific research. Correspondingly, the doubling time increases from 0.960 to 5.419 in the same period. The mean growth rate and doubling time for Indian output is 0.229 and 3.360.

But the year-wise analysis of growth rate and doubling time for world and India indicates a different finding. The average growth rate of world and India is 0.218 and 0.245 respectively. Correspondingly, the doubling time of world is 4.424 and India is 3.600 respectively (Fig.1 & 2).

**Table 2 World v/s India Relative Growth Rate (RGR) and Doubling Time (Dt.)**

| Year | World TP | RGR | Dt. (P) | India TP | RGR | Dt.(P) |
|---|---|---|---|---|---|---|
| 1999 | 62083 | | | 1566 | | |
| 2000 | 63118 | 0.701 | 0.988 | 1658 | 0.722 | 0.960 |
| 2001 | 66617 | 0.427 | 1.624 | 1920 | 0.467 | 1.483 |
| 2002 | 66393 | 0.297 | 2.332 | 1750 | 0.293 | 2.367 |
| 2003 | 71201 | 0.244 | 2.846 | 2105 | 0.266 | 2.601 |
| 2004 | 77568 | 0.211 | 3.277 | 2360 | 0.233 | 2.976 |
| 2005 | 85014 | 0.190 | 3.653 | 2560 | 0.203 | 3.410 |
| 2006 | 88442 | 0.165 | 4.192 | 2770 | 0.181 | 3.818 |
| 2007 | 90240 | 0.145 | 4.796 | 3396 | 0.185 | 3.741 |
| 2008 | 96558 | 0.135 | 5.152 | 4010 | 0.182 | 3.807 |
| 2009 | 105662 | 0.129 | 5.371 | 4608 | 0.175 | 3.960 |
| 2010 | 103183 | 0.112 | 6.203 | 4688 | 0.151 | 4.581 |
| 2011 | 107099 | 0.104 | 6.656 | 4676 | 0.131 | 5.288 |
| 2012 | 107643 | 0.095 | 7.314 | 4672 | 0.116 | 5.986 |
| 2013 | 114860 | 0.092 | 7.526 | 5831 | 0.128 | 5.419 |
| **Mean Value** | | **0.203** | **4.129** | | **0.229** | **3.360** |

*Note: RGR= Relative Growth Rate, Dt. (P) = Doubling Time*

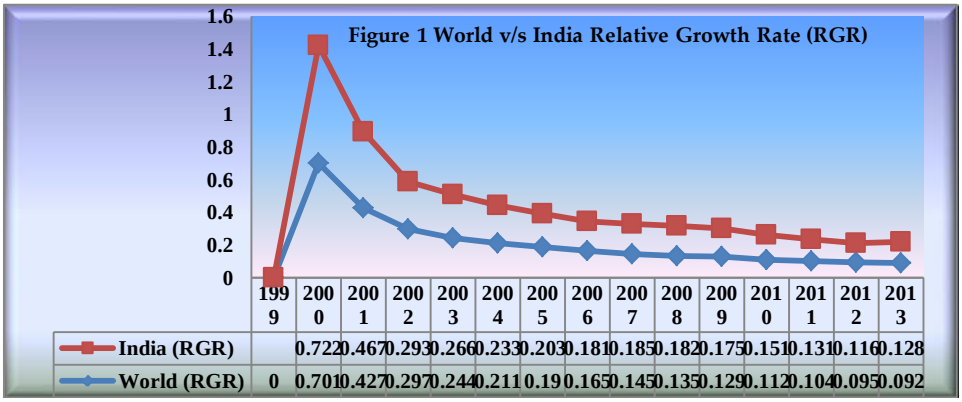



**Figure 1 World v/s India Relative Growth Rate (RGR)**

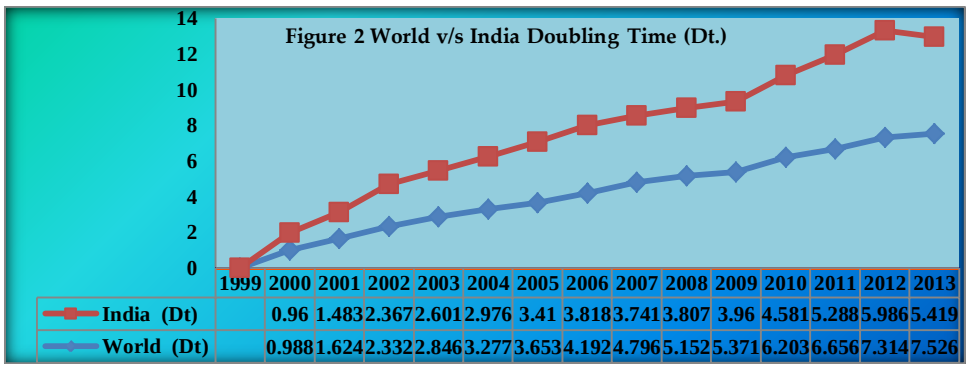



**Figure 2 World v/s India Doubling Time (Dt.)**

### 3.3 Organizational / Institution productivity in the field of engineering literature

Table 3 reveals the ranking list of top 20 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 Indian Institute of Technology (IIT), Delhi contributed the highest publications to the field of engineering, i.e. 18824 publications with 38.61%, followed by Council of Scientific Industrial Research (CSIR), Delhi, with 7407 publications (15.19%), Indian Institute of Technology (IIT), Kharagpur with 4256 publications (8.73%), and Indian Institute of Science (IISC), Bangalore with 3565 publications. In terms of citations received the Council of Scientific Industrial Research (CSIR), Delhi has received the highest citations i.e. 73920 with 9.98 average citations per paper (ACP), followed by Indian Institute of Technology (IIT), Kharagpur with 34488 and it's average citations per publication is 8.1, and Indian Institute of Science (IISC), Bangalore with 34308 citations with 9.62 average citations per publication.

**Table 3 Organizational / Institution productivity in the field of Engineering literature**

| Rank by TP | Rank by ACP | Rank by TC | Research / Academic Institution | TP | Citations | ACP | H-Index |
|---|---|---|---|---|---|---|---|
| 1 | NA | NA | Indian Institute of Technology (IIT), Delhi | 18824 | NA | NA | NA |
| 2 | 2 | 1 | Council of Scientific Industrial Research (CSIR), Delhi | 7407 | 73920 | 9.98 | 82 |
| 3 | 11 | 2 | Indian Institute of Technology (IIT), Kharagpur | 4256 | 34488 | 8.1 | 57 |
| 4 | 3 | 3 | Indian Institute of Science (IISC), Bangalore | 3565 | 34308 | 9.62 | 64 |
| 5 | 12 | 5 | Indian Institute of Technology (IIT), Madras | 3533 | 27348 | 7.74 | 52 |
| 6 | 4 | 4 | Indian Institute of Technology (IIT), Chennai | 2896 | 27612 | 9.53 | 59 |
| 7 | 9 | 6 | Indian Institute of Technology (IIT), Bombay | 2743 | 23888 | 8.71 | 51 |
| 8 | 5 | 7 | Indian Institute of Technology (IIT), Kanpur | 2541 | 23786 | 9.36 | 51 |
| 9 | 19 | 12 | National Institute of Technology, Rourkela | 2139 | 11167 | 5.22 | 35 |
| 10 | 7 | 8 | Indian Institute of Technology (IIT), Roorkee | 1830 | 16399 | 8.96 | 52 |
| 11 | 16 | 11 | Bhabha Atomic Research Center (BARC), Mumbai | 1632 | 12029 | 7.37 | 40 |
| 12 | 8 | 9 | Annamalai University, Chidambaram | 1570 | 13900 | 8.85 | 50 |
| 13 | 6 | 10 | Anna University, Chennai | 1477 | 13325 | 9.02 | 48 |
| 14 | 17 | 13 | Jadavpur University, Jadavpur | 1472 | 10697 | 7.27 | 39 |
| 15 | 13 | 15 | Banaras Hindu University, Varanasi | 1151 | 8789 | 7.64 | 39 |
| 16 | 18 | 16 | Indira Gandhi Centre for Atomic Research, Kalpakkam, Tamil Nadu | 931 | 6224 | 6.69 | 33 |
| 17 | 15 | 19 | National Metallurgical Laboratory India, Jamshedpur Jharkhand | 697 | 5256 | 7.54 | 31 |
| 18 | 14 | 18 | Defence Metallurgical Research Laboratory (DMRL), Hyderabad | 690 | 5264 | 7.63 | 30 |
| 19 | 10 | 17 | Aligarh Muslim University, Aligarh, Uttar Pradesh | 663 | 5407 | 8.16 | 33 |
| 20 | 1 | 14 | National Chemistry Laboratory, PUNE | 636 | 9864 | 15.51 | 45 |

*Note: NA- Not Available (since Indian Institute of Technology TC, ACP, H-Index data was not available, ranking by TC, ACP was done excluding IIT*

### 3.4 Highly Productive Scientists in India

The table 4 shows the top highly productive scientists based on their highest publications, irrespective of their disciplines during 1999-2013 appeared in Web of Science. These authors have together published 6774 publications with 13.95% and received 49034 citations with an average citation per publication of 7.28. Kumar, A. is the highly productive author, he contributed 747 publications and received 4863 citations, and average citation per publication is 6.51 Kumar, S. contributed 701 publications and received 4836 citations with 6.9 average citations per publication, Kumar, R. contributed 510 publications and received 3823 citations with 7.5 average citations per publication. Das, S. contributed 408 publications and received 2568 citations.

**Table 4 Highly Productive Scientists in India**

| Rank by TP | Rank by TC | Rank by ACP | Author | TP | TC | ACP | H-Index |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 14 | Kumar, A. | 747 | 4863 | 6.51 | 29 |
| 2 | 2 | 10 | Kumar, S. | 701 | 4836 | 6.9 | 29 |
| 3 | 3 | 9 | Kumar, R. | 510 | 3823 | 7.5 | 28 |
| 4 | 6 | 16 | Das, S. | 408 | 2568 | 6.29 | 23 |
| 5 | 4 | 2 | Singh, B. | 354 | 3786 | 10.69 | 26 |
| 6 | 10 | 17 | Kumar, P. | 330 | 1990 | 6.03 | 20 |
| 7 | 15 | 18 | Kumar, V. | 301 | 1770 | 5.88 | 20 |
| 8 | 18 | 20 | Ghosh, S. | 300 | 1528 | 5.09 | 16 |
| 9 | 13 | 15 | Singh, R. | 294 | 1886 | 6.41 | 19 |
| 10 | 11 | 12 | Singh, A. K. | 292 | 1986 | 6.8 | 20 |
| 11 | 12 | 11 | Singh, S. | 284 | 1933 | 6.81 | 22 |
| 12 | 7 | 6 | Chakraborty, S. | 258 | 2123 | 8.23 | 22 |
| 13 | 5 | 1 | Das, S.K. | 251 | 3090 | 12.31 | 22 |
| 14 | 14 | 8 | Roy, S. | 234 | 1806 | 7.72 | 21 |
| 15 | 8 | 4 | Ghosh, A. | 227 | 2097 | 9.24 | 23 |
| 16 | 20 | 21 | Singh, S.K. | 223 | 1128 | 5.06 | 15 |
| 17 | 9 | 3 | Banerjee, S. | 220 | 2051 | 9.32 | 23 |
| 17 | 19 | 13 | Gupta, A. | 220 | 1476 | 6.71 | 19 |
| 18 | 17 | 7 | Sharma, A. | 210 | 1703 | 8.11 | 19 |
| 19 | 16 | 5 | Kumar, M. | 208 | 1766 | 8.49 | 21 |
| 20 | 21 | 19 | Gupta, M. | 202 | 1095 | 5.42 | 13 |

*Note: TP=Total Publications, TC= Total Citations, ACP=Average Citations per Publication*

### 3.5 International collaboration

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.

Table 5 depicts the international collaborative papers of India with top with 20 countries during 1999-2013. The share of International collaborative publications in the Indian Engineering research output was 23.84% during 1999-2013. The largest number of collaborative publications (3356) of India in engineering research was with United States with 6.98% share, followed by Germany 2.23% share, South Korea 2.03% share, England 1.55% share, Japan 1.52% share, Canada 1.30% share, Australia 1.09% share, France 1.07% share, Singapore 1.01% share. Many countries are contributed with below 1% share with India in engineering research during 1999-2013 (Table-4).

**Table 5 International collaboration**

| Rank by collaborative papers | Country | Total Publications (TP) | Total Citations (TC) | Average Citations per Publication (ACP) | H-Index |
|---|---|---|---|---|---|
| 1 | USA | 3356 | 37582 | 11.2 | 73 |
| 2 | Germany | 1073 | 12005 | 11.19 | 44 |
| 3 | South Korea | 976 | 7305 | 7.48 | 33 |
| 4 | England | 746 | 5820 | 7.8 | 32 |
| 5 | Japan | 729 | 7700 | 10.56 | 39 |
| 6 | Canada | 625 | 6252 | 10 | 34 |
| 7 | Australia | 523 | 4848 | 9.27 | 29 |
| 8 | France | 516 | 5927 | 11.49 | 40 |
| 9 | Singapore | 486 | 4592 | 9.45 | 34 |
| 10 | Malaysia | 427 | 2949 | 6.91 | 25 |
| 11 | Peoples r china | 426 | 3797 | 8.91 | 30 |
| 12 | Taiwan | 246 | 2411 | 9.8 | 25 |
| 13 | Italy | 242 | 2409 | 9.95 | 21 |
| 14 | Netherlands | 196 | 2412 | 12.31 | 25 |
| 15 | Sweden | 186 | 1506 | 8.1 | 20 |

| | | | | | |
|---|---|---|---|---|---|
| 16 | Saudi Arabia | 179 | 1107 | 6.18 | 17 |
| 17 | South Africa | 145 | 897 | 6.19 | 14 |
| 18 | Switzerland | 131 | 1363 | 10.4 | 19 |
| 19 | Iran | 126 | 961 | 7.63 | 16 |
| 19 | Spain | 126 | 1135 | 9.01 | 15 |
| 20 | Portugal | 119 | 1365 | 11.47 | 22 |

### 3.6 Major Journals Preferred by scientists of Indian Engineering literature

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. Table 6 reveals that the list of top twenty productive journals preferred the scientists of India in the field of engineering research. These ranked journals are accounting for 34.085 % of total output. Out of the 20 journals, 07 are basically from India, 09 from Netherlands, 02 from USA, 01 from England and Germany.

Journal of Alloys and Compounds ranked first in terms of publications i.e. 1816 publications and followed by Journal of Scientific Industrial Research which has contributed 1415 publications, Industrial Engineering Chemistry Research ranked third with 1303 publications, Materials Science and Engineering A Structural Materials Properties Microstructure and Processing ranked fourth in terms of publications. Similarly, Journal of Hazardous Materials fifteenth with 1074 publications.

With regard to average citations per papers (ACP), Journal of Hazardous Materials has got top position with 25.32 ACP and received 27199 citations, followed by Process Biochemistry 22.57 ACP and received 10857 citations, Chemical Engineering Journal 14.12 ACP and received 7935 citations, Journal of Materials Processing Technology 13.59 ACP and received 7285 citations and International Journal of Heat and Mass Transfer 11.76 ACP and received 7011 citations.

**Table 6 Major Journals Preferred by scientists of Indian Engineering literature**

| Rank by TP | Rank by ACP | Source /Journal | Country | TP | TC | ACP |
|---|---|---|---|---|---|---|
| 1 | 9 | Journal of Alloys and Compounds | Netherlands | 1816 | 14988 | 8.25 |
| 2 | 14 | Journal of Scientific Industrial Research | India | 1415 | 3767 | 2.66 |
| 3 | 8 | Industrial Engineering Chemistry Research | Netherlands | 1303 | 12785 | 9.81 |
| 4 | 6 | Materials Science and Engineering A Structural Materials Properties Microstructure and Processing | Netherlands | 1178 | 13543 | 11.5 |
| 5 | 1 | Journal of Hazardous Materials | Netherlands | 1074 | 27199 | 25.32 |
| 6 | 15 | Indian Journal of Chemical Technology | India | 1040 | 2616 | 2.52 |
| 7 | 18 | Transactions of The Indian Institute Of Metals | India | 995 | 913 | 0.92 |
| 8 | 10 | International Journal of Advanced Manufacturing Technology | England | 792 | 5214 | 6.58 |
| 9 | 17 | Indian Journal of Engineering and Materials Sciences | India | 726 | 1190 | 1.64 |
| 10 | 20 | IETE Journal of Research | India | 655 | 344 | 0.53 |
| 11 | 16 | Microwave and Optical Technology Letters | USA | 647 | 1511 | 2.34 |
| 12 | 5 | International Journal of Heat and Mass Transfer | Netherlands | 596 | 7011 | 11.76 |
| 13 | 12 | Journal of Materials Science Materials in Electronics | Germany | 592 | 2392 | 4.04 |
| 14 | 11 | Materials and Manufacturing Processes | Netherlands | 564 | 2663 | 4.72 |
| 15 | 3 | Chemical Engineering Journal | Netherlands | 562 | 7935 | 14.12 |
| 16 | 19 | IETE Technical Review | India | 561 | 351 | 0.63 |
| 17 | 4 | Journal of Materials Processing Technology | Netherlands | 536 | 7285 | 13.59 |
| 18 | 13 | Sadhana Academy Proceedings in Engineering Sciences | India | 521 | 1877 | 3.6 |
| 19 | 7 | Journal of Chemical And Engineering Data | USA | 501 | 4973 | 9.93 |
| 20 | 2 | Process Biochemistry | Netherlands | 481 | 10857 | 22.57 |

### 3.7 Subject-wise productivity in India

Table 6 and figure 3 indicate the subject-wise productivity of India in engineering research. General Internal Medicine, Materials Science, Metallurgy Metallurgical Engineering, Chemistry, Physics, Mechanics, Environmental Sciences Ecology, Computer Science, Telecommunications, Water Resources, Thermodynamics, were considered on the basis of the total number of publications. During 1999-2013 Materials Science has got the first position with 12329 (4.50%) publications, followed by Metallurgy Metallurgical Engineering with 8715 (4.14%) publications, Chemistry with 6668 (4.31%) publications, Physics with 3619 (2.64%) publications, Mechanics with 3363 (4.30%) publications, Environmental Sciences Ecology with 3202 (3.31%) publications, Computer Science with 3188 (2.36%) publications and Telecommunications with 2812 (2.63%) publications. Similarly the table 8 and figure 4 shows the subject wise productivity of world engineering literature.

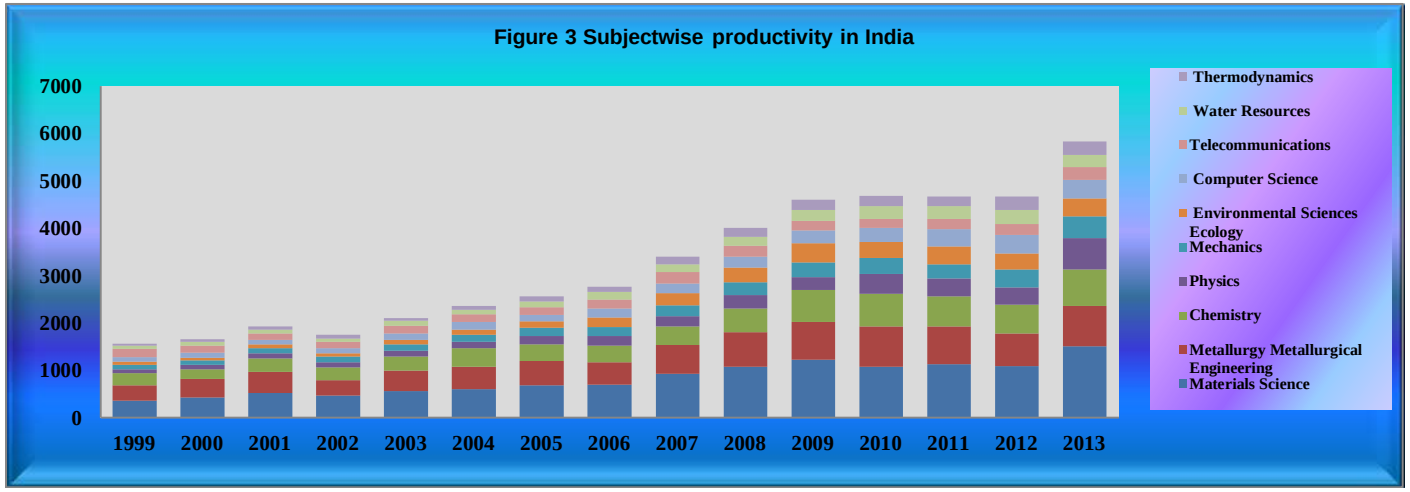
**Table 7 Subject wise productivity in India**

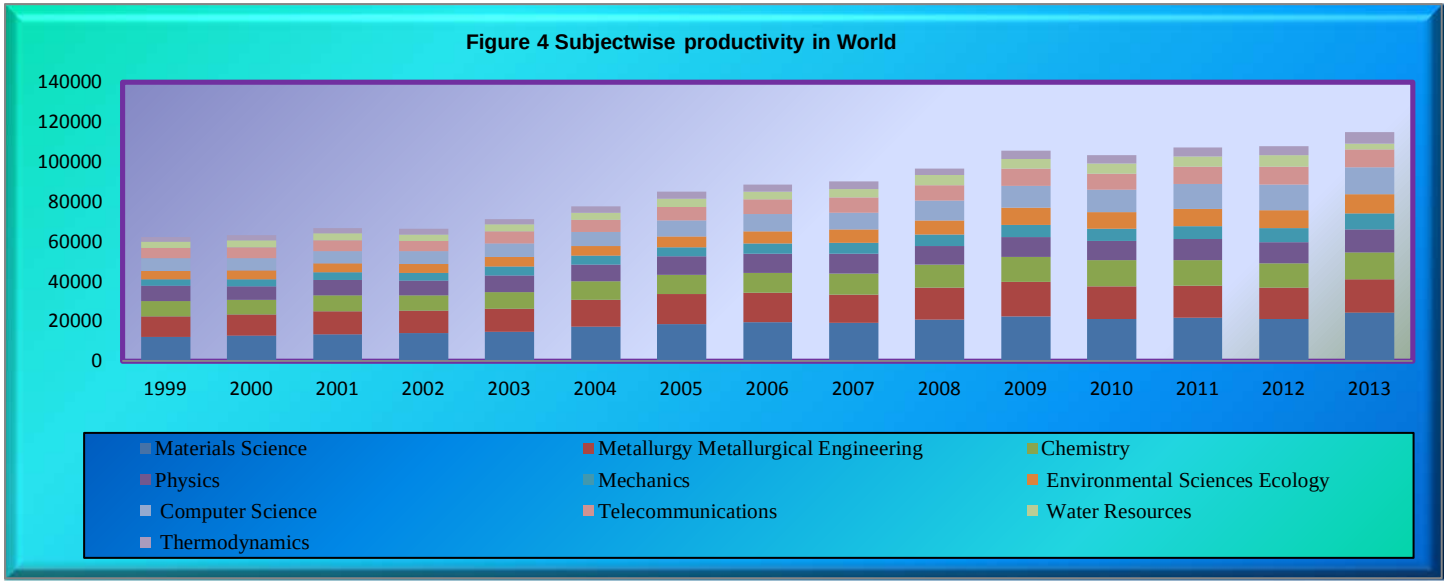
| Year | Materials Science | Metallurgy Metallurgical Engineering | Chemistry | Physics | Mechanics | Environmental Sciences Ecology | Computer Science | Telecommunications | Water Resources | Thermodynamics | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1999 | 360 | 326 | 256 | 76 | 99 | 66 | 100 | 165 | 71 | 47 | **1566** |
| 2000 | 428 | 387 | 205 | 91 | 97 | 55 | 108 | 145 | 89 | 53 | **1658** |
| 2001 | 516 | 444 | 286 | 118 | 101 | 77 | 94 | 138 | 89 | 57 | **1920** |
| 2002 | 461 | 329 | 270 | 113 | 114 | 72 | 112 | 127 | 73 | 79 | **1750** |
| 2003 | 557 | 433 | 296 | 129 | 127 | 106 | 124 | 167 | 102 | 64 | **2105** |
| 2004 | 606 | 464 | 398 | 139 | 142 | 104 | 164 | 160 | 100 | 83 | **2360** |
| 2005 | 682 | 521 | 346 | 169 | 185 | 125 | 141 | 165 | 117 | 109 | **2560** |
| 2006 | 702 | 474 | 345 | 198 | 192 | 205 | 185 | 195 | 158 | 116 | **2770** |
| 2007 | 928 | 609 | 394 | 213 | 226 | 263 | 205 | 240 | 155 | 163 | **3396** |
| 2008 | 1072 | 731 | 501 | 280 | 278 | 306 | 230 | 226 | 197 | 189 | **4010** |
| 2009 | 1219 | 797 | 675 | 274 | 319 | 405 | 269 | 193 | 233 | 224 | **4608** |
| 2010 | 1074 | 856 | 691 | 411 | 336 | 340 | 306 | 181 | 270 | 223 | **4688** |
| 2011 | 1127 | 797 | 631 | 382 | 305 | 370 | 371 | 210 | 279 | 204 | **4676** |
| 2012 | 1089 | 692 | 603 | 369 | 376 | 340 | 386 | 231 | 302 | 284 | **4672** |
| 2013 | 1508 | 855 | 771 | 657 | 466 | 368 | 393 | 269 | 256 | 288 | **5831** |
| Total | **12329** | **8715** | **6668** | **3619** | **3363** | **3202** | **3188** | **2812** | **2491** | **2183** | **48570** |

**Table 8 Subject wise productivity in World**

| Year | Materials Science | Metallurgy Metallurgical Engineering | Chemistry | Physics | Mechanics | Environmental Sciences Ecology | Computer Science | Telecomm -unications | Water Resources | Thermodynamics | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1999 | 12239 | 10178 | 7529 | 7916 | 3162 | 4162 | 6242 | 5405 | 3037 | 2213 | **62083** |
| 2000 | 12606 | 10834 | 7244 | 6705 | 3568 | 4405 | 6216 | 5478 | 3495 | 2567 | **63118** |
| 2001 | 13515 | 11325 | 8110 | 7751 | 3831 | 4445 | 6190 | 5469 | 3532 | 2449 | **66617** |
| 2002 | 14154 | 11102 | 7836 | 7357 | 3809 | 4365 | 6515 | 5029 | 3249 | 2977 | **66393** |
| 2003 | 14695 | 11638 | 8331 | 8404 | 4228 | 4794 | 6987 | 6037 | 3 397 | 2690 | **71201** |
| 2004 | 17368 | 13305 | 9367 | 8222 | 4501 | 4892 | 7101 | 6157 | 3585 | 3070 | **77568** |
| 2005 | 18616 | 14874 | 9636 | 9340 | 4609 | 5493 | 7892 | 6727 | 4334 | 3493 | **85014** |
| 2006 | 19609 | 14702 | 9971 | 9402 | 5267 | 6111 | 8811 | 7194 | 4016 | 3359 | **88442** |
| 2007 | 19175 | 14211 | 10625 | 9701 | 5523 | 6663 | 8531 | 7764 | 4177 | 3870 | **90240** |
| 2008 | 20787 | 16027 | 11440 | 9382 | 5747 | 7174 | 9794 | 7902 | 4940 | 3365 | **96558** |
| 2009 | 22249 | 17387 | 12731 | 9801 | 5995 | 8854 | 10908 | 8512 | 5003 | 4222 | **105662** |
| 2010 | 21133 | 16400 | 12935 | 9674 | 6248 | 8369 | 11020 | 8238 | 5234 | 3932 | **103183** |
| 2011 | 21580 | 16232 | 12850 | 10598 | 6418 | 8730 | 12403 | 8734 | 5057 | 4497 | **107099** |
| 2012 | 21216 | 15479 | 12277 | 10674 | 7130 | 8752 | 12867 | 9143 | 5626 | 4479 | **107643** |
| 2013 | 24457 | 16408 | 13533 | 11716 | 8095 | 9407 | 13453 | 8995 | 3009 | 5787 | **114860** |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total** | **273399** | **210102** | **154415** | **136643** | **78131** | **96616** | **134930** | **106784** | **61691** | **52970** | **1305681** |



### 3.8 Activity Index

Activity index characterizes the relative research efforts of a country in a given subject field and takes into consideration the effect of the size of the country as well as the size of the field. Activity Index (AI) for India has been calculated for different years to see how India's performance gradually changed during different years. For this the author has used the Activity Index. The Activity Index is used for Indian engineering research output in Table 9. The table reveals the highest AI in various subject categories as follows: Materials Science (132.74) in 2001, Metallurgy Metallurgical Engineering (136.03) in 2001, Chemistry (139.65) in 2004, Physics (110.46) in 20013, Mechanics (133.30) in 2005, Environmental Sciences Ecology (104.90) in 2009, Computer Science (75.91) in 2004, Telecommunications (121.02) in 1999, Water Resources (167.59) in 1013, and Thermodynamics (135.24) in 2008. It is observed from the data that it indicates India's research efforts in these subjects correspond to the world's average.

**Table 9 Activity Index for sub-fields of Engineering**

| Year | Materials Science | Metallurgy Metallurgical Engineering | Chemistry | Physics | Mechanics | Environmental Sciences Ecology | Computer Science | Telecommunications | Water Resources | Thermodynamics |
|---|---|---|---|---|---|---|---|---|---|---|
| 1999 | 116.61 | 126.98 | 134.80 | 38.06 | 124.12 | 62.87 | 63.51 | 121.02 | 92.68 | 84.20 |
| 2000 | 129.25 | 135.98 | 107.73 | 51.67 | 103.49 | 47.53 | 66.14 | 100.77 | 96.94 | 78.60 |
| 2001 | 132.47 | 136.03 | 122.36 | 52.82 | 91.47 | 60.10 | 52.69 | 87.55 | 87.43 | 80.76 |
| 2002 | 123.57 | 112.43 | 130.72 | 58.27 | 113.55 | 62.58 | 65.22 | 95.81 | 85.24 | 100.68 |
| 2003 | 128.21 | 125.85 | 120.18 | 51.92 | 101.60 | 74.79 | 60.03 | 93.57 | 101.56 | 80.48 |
| 2004 | 114.68 | 114.62 | 139.65 | 55.57 | 103.69 | 69.87 | 75.91 | 85.41 | 91.68 | 88.86 |
| 2005 | 121.66 | 116.32 | 119.24 | 60.09 | 133.30 | 75.57 | 59.33 | 81.45 | 89.65 | 103.63 |
| 2006 | 114.30 | 102.94 | 110.47 | 67.24 | 116.39 | 107.11 | 67.04 | 86.55 | 125.62 | 110.26 |
| 2007 | 128.60 | 113.87 | 98.54 | 58.34 | 108.73 | 104.89 | 63.85 | 82.14 | 98.60 | 111.92 |
| 2008 | 124.18 | 109.83 | 105.45 | 71.86 | 116.48 | 102.71 | 56.55 | 68.87 | 96.02 | 135.24 |
| 2009 | 125.63 | 105.11 | 121.58 | 64.10 | 122.01 | 104.90 | 56.55 | 51.99 | 106.79 | 121.66 |
| 2010 | 111.86 | 114.88 | 117.58 | 93.51 | 118.36 | 89.42 | 61.12 | 48.36 | 113.54 | 124.83 |
| 2011 | 119.61 | 112.46 | 112.47 | 82.56 | 108.85 | 97.07 | 68.51 | 55.07 | 126.36 | 103.90 |
| 2012 | 118.26 | 103.00 | 113.16 | 79.65 | 121.50 | 89.51 | 69.12 | 58.21 | 123.68 | 146.09 |
| 2013 | 121.46 | 102.64 | 112.22 | 110.46 | 113.40 | 77.06 | 57.54 | 58.91 | 167.59 | 98.03 |
| **Average AI** | **122.02** | **115.53** | **117.74** | **66.41** | **113.13** | **81.73** | **62.87** | **78.38** | **106.89** | **104.61** |

### 3.9 Highly Cited Papers from India in Engineering

The table 10 shows the highly cited papers from India in engineering research during 1999 – 2013. Citations received by these top 20 cited papers accumulated to 11,409 (2.57%) of all citations. Most of the papers are having multiple authors (Three or more authors), only three papers are having single author. Six most cited papers are single country papers and originated from the United States, rest of the most cited papers are originated from the Canada. The most cited papers were published in two different journals.

The top cited paper was 'Pyrolysis of wood/biomass for bio-oil: A critical review' authored by Mohan, Dinesh; Pittman, Charles U., Jr.; Steele, Philip H. and published in *Energy & Fuels* (United States) in 2006 and this paper received 1076 citations, followed by 'A review of chitin and chitosan applications' published by Kumar, MNVR and published in *Reactive & Functional Polymers* (Netherlands) in 2000 and this paper received 1008 citations, 860 the paper 'An efficient constraint handling method for genetic algorithms' got the third rank and it is published by Deb, K and published in *Computer Methods in Applied Mechanics and Engineering* (Netherlands) in 2000, next to these papers the paper 'Overview No.144 - Mechanical behavior of amorphous alloys' has received 841 citations published by Schuh, Christopher A.; Hufnagel, Todd C.; Ramamurty, Upadrasta published in *Acta Materialia* (United Kingdom) in 2007 and 'Arsenic removal from water/wastewater using adsorbents - A critical review' paper received 681 citations published by Mohan, Dinesh; Pittman, Charles U., Jr. published in *Journal of Hazardous Materials* (Netherlands) in 2007. This shows that more research activities are being carried on in newly developing fields.

**Table - 10: Twenty highly cited papers from India**

| Sl. No. | No. of Citations received | Tittle of the paper | Authors | Source | Year of publication |
|---|---|---|---|---|---|
| 1 | 1076 | Pyrolysis of wood/biomass for bio-oil: A critical review | Mohan, Dinesh; Pittman, Charles U., Jr.; Steele, Philip H. | Energy & Fuels | 2006 |
| 2 | 1008 | A review of chitin and chitosan applications | Kumar, MNVR | Reactive & Functional Polymers | 2000 |
| 3 | 860 | An efficient constraint handling method for genetic algorithms | Deb, K | Computer Methods in Applied Mechanics and Engineering | 2000 |
| 4 | 841 | Overview No.144 - Mechanical behavior of amorphous alloys | Schuh, Christopher A.; Hufnagel, Todd C.; Ramamurty, Upadrasta | Acta Materialia | 2007 |
| 5 | 681 | Arsenic removal from water/wastewater using adsorbents - A critical review | Mohan, Dinesh; Pittman, Charles U., Jr. | Journal of Hazardous Materials | 2007 |
| 6 | 577 | Biofuels applications as fuels for internal combustion engines | Agarwal, Avinash Kumar | Progress in Energy and Combustion Science | 2007 |
| 7 | 568 | Energy-aware wireless microsensor networks | Raghunathan, V; Schurgers, C; Park, S; et al. | IEEE Signal Processing Magazine | 2002 |
| 8 | 567 | A review of imperative technologies for wastewater treatment I: oxidation technologies at ambient conditions | Gogate, PR; Pandit, AB | Advances in Environmental Research | 2004 |
| 9 | 559 | Kinetics and mechanism of removal of Methylene blue by adsorption on various carbons - a comparative study | Kannan, N; Sundaram, MM | Dyes and Pigments | 2001 |
| 10 | 555 | A review of active filters for power quality improvement | Singh, B; Al-Haddad, K; Chandra, A | IEEE Transactions on Industrial Electronics | 1999 |
| 11 | 526 | Temperature dependence of thermal conductivity enhancement for nanofluids | Das, SK; Putra, N; Thiesen, P; et al. | Journal of Heat Transfer-Transactions of the Asme | 2003 |
| 12 | 476 | Natural fiber polymer composites: A review | Saheb, DN; Jog, JP | Advances in Polymer Technology | 1999 |
| 13 | 451 | Solid polymer electrolyte membranes for fuel cell applications - a review | Smitha, B; Sridhar, S; Khan, AA | Journal of Membrane Science | 2005 |
| 14 | 440 | Removal of Congo Red from water by adsorption onto activated carbon prepared from coir pith, an agricultural solid waste | Namasivayam, C; Kavitha, D | Dyes and Pigments | 2002 |
| 15 | 386 | Pool boiling characteristics of Nano-fluids | Das, SK; Putra, N; Roetzel, W | International Journal of Heat and Mass Transfer | 2003 |
| 16 | 382 | Single- and multi-component adsorption of cadmium and zinc using activated carbon derived from bagasse - an agricultural waste | Mohan, D; Singh, KP | Water Research | 2002 |
| 17 | 374 | New developments in solid state fermentation: I-bioprocesses and products | Pandey, A; Soccol, CR; Mitchell, D | Process Biochemistry | 2000 |
| 18 | 373 | Activated carbons and low cost adsorbents for remediation of tri- and hexavalent chromium from water | Mohan, Dinesh; Pittman, Charles U., Jr. | Journal of Hazardous Materials | 2006 |
| 19 | 370 | A review of imperative technologies for wastewater treatment II: hybrid methods | Gogate, PR; Pandit, AB | Advances in Environmental Research | 2004 |
| 20 | 339 | Use of activated carbons prepared from sawdust and rice-husk for adsorption of acid dyes: a case study of Acid Yellow 36 | Malik, PK | Dyes and Pigments | 2003 |

## 4 CONCLUSION

The study analyses India's performance in the field of engineering, using publications data and different quantitative and qualitative measures. Its focuses on India's global publication share, growth rate, citation quality, international collaborative publications, its publication share and distribution in sub-fields using 15 years data from the Web of Science database. The study suggests the need to increase the pace of Indian engineering research and also improve its quality. Scientometric analysis is also extremely essential to plan appropriate measures to be taken to upgrade the research activities.

A detail scientometric analysis of engineering research of India and its comparison with other countries is very important to obtain a clear picture and to take necessary measures to upgrade the research performance. It is important to evaluate the research performance of major engineering research institutes of the country and to compare their performance among themselves and similar institutes of other countries.

The growth in literature has become a major concern for the scientists, scholars, and library professional as they try to keep themselves abreast with new advances in their subject, and information professionals try to organize this knowledge.

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