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Publication Analysis of Nanotechnology in Global Perspective: a Scientometric Approach

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ABSTRACT

The purpose of this paper is to identify the global scientific publications of Nanotechnology research, and a significant emerging thrust area that has huge potential to improve information understanding, organization, decision making and administration. This study retrieved scholarly communications published during 2001-2015 from various versions such as Science Citation Index (SCI), Social Science Citation Index (SSCI), and Arts & Humanities Citation Index (ACHI) which are available on Web of Science. The scientometric analysis was performed from characteristics of global output, institutional, core journals, continental, countries/territories and topical aspects. Basic statistical methods, activity index, relative growth rate and doubling time and CAGR were applied to the selected data. The characteristics of global publications identified that Nanotechnology research has improved stage, along with huge participation and collaboration. The huge papers were found in 2015. The Activity Index was high (140.41) in 2015 whereas the least (31.81) in 2003. Majority of records was from China (24.34 %) and ranked first and followed by United States with 22.83%. India has got sixth position with a total output of 54, 190 (5.41%) contributing a share of total output. The relative growth rate of Nanotechnology (global level) has been progressed from 0.6 in 2001 to 2.05 in 2015 and its average relative growth rate was 1.518 and the doubling time showed the decline trend. The highest exponential growth rate was 1.27 with 33, 472 research output in 2004 and it is noticed that except the period 2002 to 2005. This study focused that there was a fluctuation trend after 2006. This is the first study to evaluate global literature output trends in Nanotechnology, which might provide a potential guide for the future research. These indicators lead Nanotechnology to formulate policy, setting priorities, and undertake strategic planning, monitoring, and evaluation.

Keywords: *Nanotechnology, Scientometrics, WoS, Nano Science, Scientific publications, Scholarly communication*

INTRODUCTION

Nanotechnology is being an interdisciplinary science that constitutes all Sciences and Engineering disciplines. It transcends the subjects such as Physics, Chemistry, Biology, Mathematics, Information Technology and Engineering. Nanotechnology exists for the last 2000 years (India) and this is revealed in, 'The Hindu, January 6, 2008' stated that Indian craftsmen, artisans used nanotech 2000 years ago for designing Sword of Tipu Sultan. In India, there was a leading exporter of wootz steel for years.

There are examples of nanotechnology based applications in use over centuries. This study focuses on research in terms of scholarly publications using scientometric analysis.

Scientometrics is one of the most important measures for assessing scientific output. Scientometrics is related to Bibliometrics and Informetrics. The terms Bibliometrics, Scientometrics, and Informetrics refer to component the fields related to the study of the dynamics of disciplines as reflected in the production of their literature (Hood & Wilson, 2001). Van Raan (1997) believed that scientometric research is devoted to quantitative studies of science and technology which aimed at the advancement of knowledge and the growth of science and technology. Scientometrics is referred to as a science about science and is a distinctive, unique, recognized and well established intellectual field of knowledge. There are several well-known academicians such as Robert King, Merton,

Derek J.de Solla Price and Eugene Garfield who formed the foundation of scientometrics (Price, 1965, Garfield, 1979). Scientometric studies are often discussed about the meta-analysis of topics and methodologies, and identify the prolific individual authors, institutions and countries, examine the collaboration processes, investigate the citation and co-citation analysis, analyze research anomalies, and conduct opinion surveys. The value of scientometrics has received recognition in different disciplines (Straub, 2006).

RELATED WORK

Hasan and Singh (2015) discussed the scientific research collaboration between India and Turkey in terms of research papers published with authors during 2009-2013 which were indexed in the Web of Science. A total of 330,071 records of both countries and 966 records were found to be in joint collaborative authorship from the researchers. The results indicates that the Istanbul University occupied top (6.18%), followed by Ege University with 5.21%, Hacettepe University with 5.19%, Gazi University with 5387 (4.90%) and Ankara University with 5339 (4.85%). Kumar and Garg (2005) carried out a comparative analysis of the status of computer science research effort in India and China by computing various scientometric parameters during 1971-2000. It was observed that the maximum amount of research output was published in journals. Chinese researchers have preferred to publish their research papers in native journals while Indian scientists preferred to publish their papers in the West. Wiysonge et al (2013) have taken a survey on childhood immunization literature output from Africa using PubMed citation software during 1974-2010. They retrieved 1,641 research output and used zero-truncated negative binomial regression models to examine the factors in connection with research papers. The maximum output of (48%) was produced by five countries such as South Africa, Nigeria, The Gambia, Egypt and Kenya. Borsi and Schubert (2010) carried out the research in the field of agrifood in Europe for the period from 1996 to 2005 and the data was extracted from the Web of Science database. The publications were analyzed on a fractional count basis. The results revealed that the EU-33 countries together were predominant in agrifood research across the world and these countries have produced more number of publications rather than the United States in 27 sub-fields. It was found that the agrifood articles from the USA were high impact and the average citation per paper was 30% higher than EU-33 countries.

He (2009) reported the international collaborative research in China with the G7 countries for the period 1996-2005 through the Science Citation Index Expanded (SCIE) with 69,367 records were found from China and from G7 countries were also downloaded. The study revealed that the international collaboration research between China and G7 countries which has indicated exponential growth produced in China. The United States was the highest proportion and most dominate collaborative country between China and G7 countries in terms of research. Guan and Ma (2007) compared the literature output in the field of semiconductor research in China with a few of the major nations in Asia. The time span was 1995 -2004 and the relevant data was collected through SCI- Expanded citation database using the Web of Science database. The findings showed that based on the output, China has been the second productive country in Asia. Velmurugan and Radhakrishnan (2016) highlighted the publication analysis on Nanotechnology in global level through Web of Science (WoS) database. It was observed that a total output of global publications in the field of Nanotechnology is 20,825 during the period 1989-2014. The results reflected that the maximum number of output (34.91 %) was published by USA which got placed in first rank. China with 2121 research papers (10.19%) got next and followed by Germany which was in third rank. It was noticed that the world growth rate showed increasing trend as well as the Indian growth rate was found upward trend.

Garg (2002) compared the scientific publications on laser science and technology between India and China as reflected in the INSPEC database. This was the first study based on the scientometrics which had been reported in India and China. It was observed that Indian researchers have preferred to publish their publications in foreign journals whereas the Chinese scientists to publish in national journals. Collaborative research trends were identified in China rather than India. Velmurugan and Radhakrishnan (2015) tried to identify the records of Amylase in Microbiology which was produced by Indian Scientists during 2010 - 2014. The bibliographic research work was performed with 412 publications in which only 107 publications were contributed by Indian authors. 26.17% was the highest proportion of literature output in 2012 and the

lowest amount was 14.97% in 2011. It was observed that there was a slight decrease in the growth of literature in 2014 (17.75%) compared with the year 2010. The majority of (92.53%) scientific papers were journal articles and almost 96.40% of articles were published by Indian authors and the remaining 4 (3.60%) papers were contributed by England and South Korea. Zhao and Ma (2012) reported their study on bibliometric research of China's R&D Activities on Nano-Science and Nanotechnology.

The findings suggested that the strong occurrence of research output in Materials Science, Physical Chemistry, and Applied Physics and also focused on the pharmaceutical products which have recently applied in Chinese Traditional Medicine and finally the collaborative research links were not good between organizations during the period of study. Tang and Shapira (2012) observed that China is a leading one in terms of quantity of research output in the emerging field of nanotechnology. This research investigated the impact of Chinese research articles and identified the effects of international collaboration and the Chinese researchers who collaborate in both national and international cooperation. It reveals that a positive impact on the quality of Chinese research by direct collaboration as well as indirect collaboration through knowledge moderators, by language, subject, research capacity and other factors.

Thavamani and Velmurugan (2013) examined the bibliometric study on Webology journal research contributions for a period of ten years between 2004 and 2013. A total of 114 research papers have been published in ten years which consists of full articles. The findings depicts that the highest number of contributions (12.280%) was published in 2006 and 2007. The maximum number of the research articles was written by a single author.

The majority of (17.543%) articles have been contributed by authors from India, followed by USA 17 (14.912%). Majority (15.751%) of citations were published in 2008. The degree of author collaboration in the Webology research is 0.491, which clearly indicates its dominance upon single authored contributions.

Related Questions

- Which is the most productive period in the discipline of Nanotechnology?
- Which is the most preferred source document during the period of study?
- What are the languages and which is the predominant in Nanotechnology?
- Which institution produced productive papers in Nanotechnology?
- What are the top most countries which publish articles in the field of Nanotechnology?
- What are the research area are predominant during the research period?

Objectives

The study has been designed with the following objectives of the study:

- To identify the growth rate of most productive period for the scientific papers on Nanotechnology research.
- To examine the most preferred sources of documents such as journal articles, article review, and conference proceedings.
- To find out the dominating language in publishing articles on Nanotechnology.
- To know the published articles from top most countries in the field.
- To investigate the productive papers published by different institutions.
- To list out the eminent authors in the field of Nanotechnology.

Need for the Study

Publications are essential part of scientific work, a measure of the development and dynamics of different topics within the subject areas. It is understood that innovation indicators need to observe and explain technological changes within a specified field of interest so as to recognize new research avenues as a whole. The successful innovation in Nanotechnology depends on the provision of new and improved technologies. Demands, investments in Nanotechnology in many developing countries have stagnated over a period of time, despite numerous studies which repeatedly link the improvements in Nanotechnology productivity with drastic needs. Quantitative information provides the foundation of understanding of the new contributions to Nanotechnology in promoting growth and development. Indicators based on such information assist in measuring, monitoring, and benchmarking the performance, inputs, and outcomes of Nanotechnology systems. These indicators lead Nanotechnology to formulate policy, setting priorities, and undertake strategic planning, monitoring, and

evaluation. They also provide information to governments, research institutes, universities, and private-sectors which are involved in Nanotechnology at national and international levels. As such an attempt has been made so far. Hence, the present topic is chosen for the study.

METHODOLOGY

The Web of Science (WoS) bibliographic database is one of the online databases which have been subscribed by Periyar University, Salem, India. This facility has enabled the researcher to collect the required data on Nanotechnology literature from the bibliographic database of various versions such as Science Citation Index (SCI), Social Science Citation Index (SSCI), and Arts & Humanities Citation Index (ACHI) which are available on Web of Science. The study period (2001-2015) has been chosen for retrieving the source data. The selected keywords were used on Nanotechnology to limit the search options through online. A total of 10, 01, 761 at global level and a total number of 54, 190 Indian Literature output were found but only 54,187 unique records were alone retrieved through the HistCite software. The total number of authors was 2, 31, 036 and 2, 304 were core journals. The cited references were 21, 46, 452 during the period of study. These records have provided with full bibliographical details such as title, authors, year, affiliations, language, and document type.

(NANO*) *NOT* **:** (NANO2 OR NANO3 OR NANO4 OR NANO5 OR NANO-SECON* OR NANOSECON* OR NANO-GRAM* OR NANOGRAM* OR NANOMOL* OR NANOPHTALM* OR NANOMELI* OR NANOGETEROTROPH* OR NANOPLANKTON* OR NANOKELVIN* OR NANO-CURIE OR NANOCURIE OR NANOS OR NANOS1 OR NANOPRTO* OR NANOPHYTO* OR NANOFLAGELLATE*) *OR* (QUANTUM DOT*) *OR* (QUANTUM-WIRE*) *OR* (MOLECULAR-BEAM-EPITAXY OR MBE OR CARBONTUB*) *OR* (CARBONTUB*) *OR* (BUCKYTUB*) *OR* (BUCKY-TUB*) *OR* (FULLERENETUB*) *OR* (SELF-ASSEMBLED-MONOLAYER*) *OR* (SELF-ASSEMBL*-DOT*) *OR* (SINGLE-ELECTRON*) *OR* (SINGLE-MOLECUL*) *OR* (ATOMICFORCE-MICROSCOP*) *OR* (CHEMICAL-FORCE-MICROSCOP*)

Note: *The whole search strings of Nanotechnology which were applied by Glanzel, et al. (2003) and Wilson, et al. (2002) for their study were also used to retrieve the data from Web of Science for the present study (2001-2015).*

For the statistical purpose, different kinds of tools and scientometric indices have been used to measure the Nanotechnology scientific literature output. In order to measure publication analysis such as Relative Growth Rate (RGR), Doubling Time (DT) and Exponential Growth Rate; For Country / Institutions like Activity Index (AI); For Journal Analysis such as Impact factor (IF), H-index (HI), Immediacy index (II), and Eigenfactor (EF). Moreover, the softwares such as HistCite, VOS viewer were used to analyze the scientific publications through different parameters during the period of study.

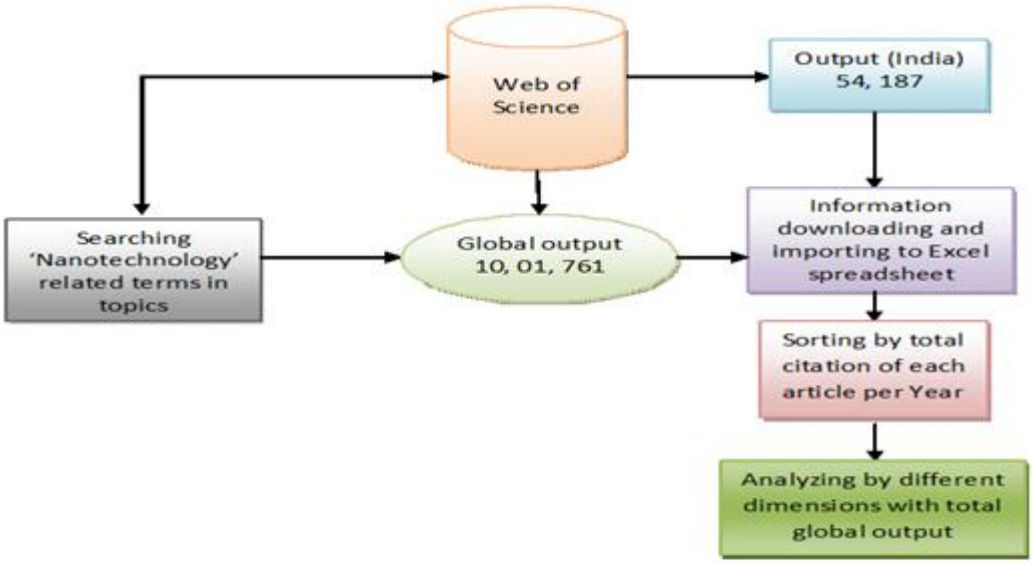

Chart1. *Diagram of searching technique*

Source: *The authors*

Results And Discussions

Document Type and Language – Wise Publications

According to the classification of document type identified through web of science database, a total of 10, 01,761 scientific publications distributed in 16 document types. It can be seen that Table 1 (fig.1) shows the detailed document-wise distribution of literature output globally from the year 2001 to 2015. The various forms of manuscripts such as Article, Proceedings paper, Review, Meeting abstract, Editorial material, News item, Correction, Letter, Book chapter, Biographical item, Book review, Reprint, Software review, Bibliography, Hardware review and Book. Naturally, the most common type of type is peer-reviewed journal articles among the other documents during the period of study. The major proportion of the research publications are articles with 9,02,428 (90.08%) which occupy the first place, and followed by proceeding papers with second rank (5.10%). Third rank is received by the review papers with 23027 (2.30%) and meeting abstracts got placed in fourth rank with 11271 (1.13%) and other types of documents such as Editorial material (6153, 0.61%), News items (3134, 0.32%), Corrections (2145, 0.22%), Letters (1201, 012%), Book chapters (1167, 0.11%), Biographical items (49, 0.004%), Book reviews (30, 0.003%), Reprints (25, 0.002%), Software reviews (18, 0.001%) occupy minimum level and the items such as Bibliography, Hardware review and Book carry no value at all.

Table1. *Distribution of document type of the Nanotechnology research output*

Sl. No	Document Type	No of Records	%	Cum. %
1	Article	902428	90.08	90.08
2	Proceedings paper	51106	5.10	95.18
3	Review	23027	2.30	97.48
4	Meeting abstract	11271	1.13	98.61
5	Editorial material	6153	0.61	99.22
6	News item	3134	0.32	99.54
7	Correction	2145	0.22	99.76
8	Letter	1201	0.12	99.88
9	Book chapter	1167	0.11	99.99
10	Biographical item	49	0.004	99.994
11	Book review	30	0.003	99.997
12	Reprint	25	0.002	99.999
13	Software review	18	0.001	100
14	Bibliography	5	0	
15	Hardware review	1	0	
16	Book	1	0	
Total		**1001761**	**100**	

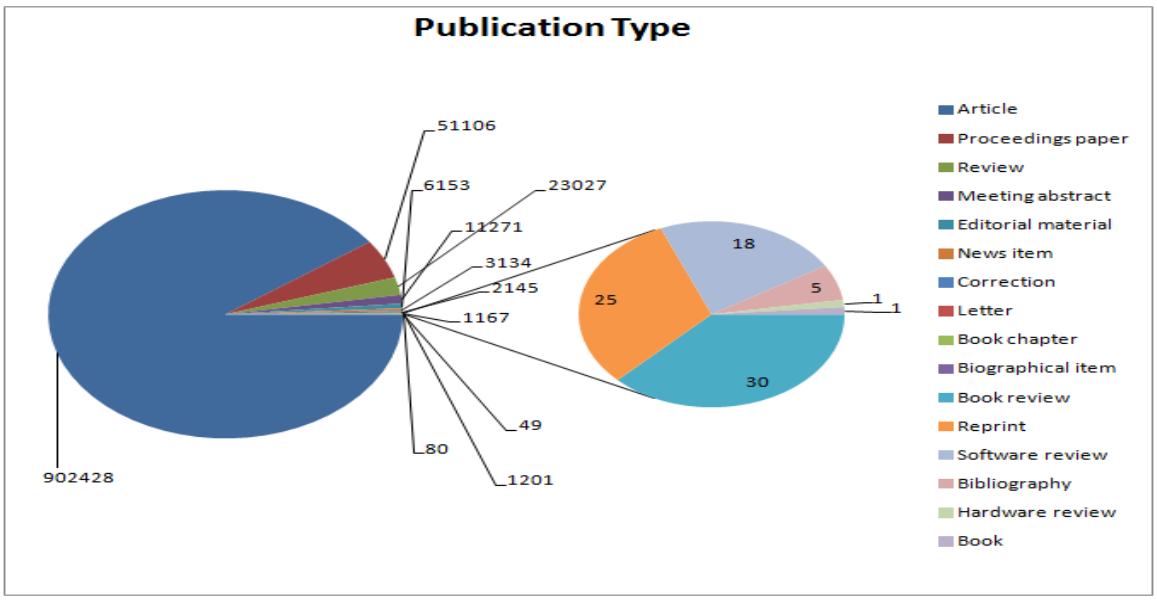

Fig1. *Document Type*

Source: *The authors*

It is analyzed language wise contributions and the huge number of (98.06%) literature output of Nanotechnology i.e. 9,82,381 which was written in English and occupied first rank, and followed by Chinese language with 14,310 record count (1.42%) got placed second. The languages such as Japanese, German, Korean, French, Polish, Portuguese, Spanish, Russian, Ukrainian and Czech occupy 0.12% to 0.013% and the other languages such as Romanian, Serbo Croatian, Turkish, Croatian, Italian, Malay, Hungarian, Estonian, Slovenian, Slovak and Serbian occupy 0.004% to 0.001%. There are no publications in languages such as Welsh, Danish, Persian, Finnish and Icelandic. The findings revealed that the maximum number of research papers on Nanotechnology is written in English language during the period of study throughout the world.

Activity Index on Nanotechnology

In order to compare India's research performance with world's one, Activity Index (AI) suggested by Price and elaborated by Karki and Garg has been used. Activity Index was used to compute the relative research effort of a country to a given field.

Table2. *Activity Index on Nanotechnology literature*

PY	World Records	Indian Records	Activity Index
2001	17350	401	41.17
2002	21067	456	38.09
2003	26455	622	31.81
2004	33472	907	50.00
2005	40569	1115	50.74
2006	47859	1585	61.21
2007	54723	2120	71.61
2008	63173	2753	80.63
2009	69874	3300	87.37
2010	76957	3955	94.92
2011	89356	5148	106.62
2012	98020	5781	108.99
2013	110853	7359	122.78
2014	122888	8872	133.52
2015	129145	9813	140.41
2001-2015	1001761	54187	81.324*
CAGR	0.1541	0.2565	

**Publication Year, Average Activity Index*

It is assessed from the table 2 (Fig.2) that the Activity Index (AI) between Indian output and World output on Nanotechnology research during 2001-2015 was carried out. Activity Index (AI) for India has been measured to analyze how India's research performance differs over the period. The data depicts that the Activity Index (AI) ranged from 31.81 in 2003 to 140.41 in 2015 and the average Activity Index was 81.324 during the study period. Activity Index for 10 out of 15 years of study is less than 100 which reflects the lower activity of Nanotechnology research on world's average. The Activity Index was peek in 2015 (140.41) whereas the least was in 2003 (31.81).

It was calculated the Compound Annual Growth Rate (CAGR) and estimated for the period of 15 years is equal to 15.42% whereas India's research output is equal to 25.66%. Further, it was witnessed that the Activity Index has shown the upward trend during the period of study. The trend line displays the exponential growth equation is $y = 31.84e^{0.104x}$ and the R square value is $R^2 = 0.949$ and shows the positive growth during the period of study.

Relative Growth Rate, Doubling Time and Exponential Growth Rate

Relative Growth Rate is (RGR) increased in number of articles/pages per unit of time. The Relative Growth Rate (RGR) can be used to determine the doubling time for publications, which enables how long it will take for a value to get it doubled. The relative growth rate and the doubling time models have developed by Garg and Padhi (1999) to measure the publications. The growth rate of total research output published by faculty members from Periyar University has been evaluated as per the following equation.

$$R(a) = \frac{(W2 - W1)}{(T2 - T1)}$$

Where, R (a) = Relative Growth Rate over the specific period of interval, w1= logw1 (Natural log of initial number of publications), w2= log w2 (Natural log of final number of publications), T2- T1 = Unit difference between the initial and final time R (a) = per unit of publications per unit of time (Year).

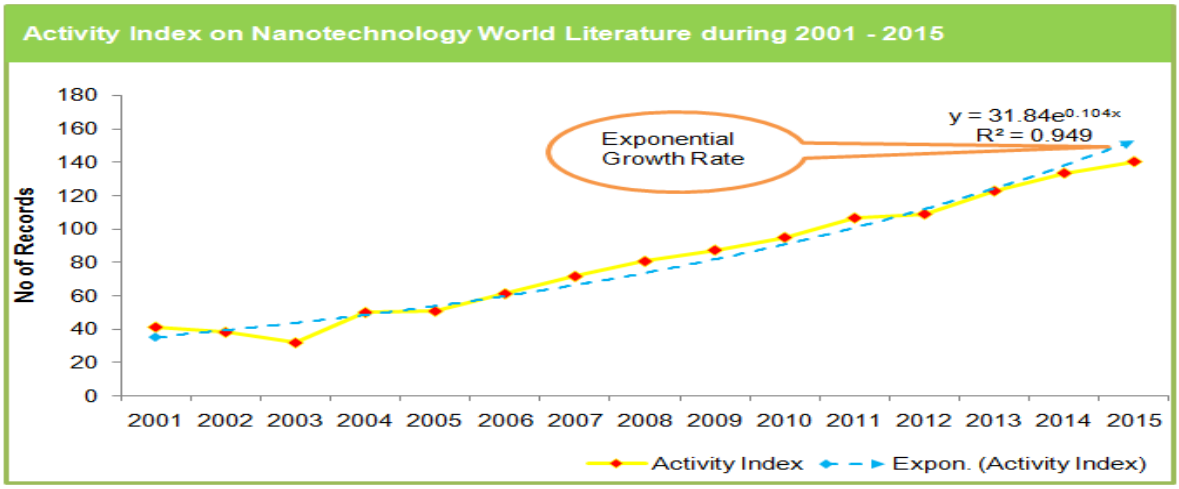

Fig2. *Activity Index on Nanotechnology Literature*

Source: *The authors*

Doubling Time (DT)

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

$$\text{Doubling Time (DT} = \frac{0.693}{\text{RGR}}$$

Table3. *Relative Growth Rate, Doubling Time and Exponential Growth Rate*

Sl. No	PY	TR	TP	RGR	DT	EGR
1	2001	17350	1.73	-	-	-
2	2002	21067	2.10	0.6	1.155	1.21
3	2003	26455	2.64	0.9	0.77	1.26
4	2004	33472	3.34	1.08	0.64	1.27
5	2005	40569	4.05	1.23	0.56	1.21
6	2006	47859	4.77	1.36	0.50	1.18
7	2007	54723	5.46	1.48	0.46	1.14
8	2008	63173	6.32	1.57	0.44	1.15
9	2009	69874	6.98	1.68	0.41	1.11
10	2010	76957	7.68	1.77	0.39	1.10
11	2011	89356	8.92	1.80	0.38	1.16
12	2012	98020	9.78	1.87	0.37	1.10
13	2013	110853	11.07	1.91	0.36	1.13
14	2014	122888	12.27	1.96	0.35	1.11
15	2015	129145	12.89	2.05	0.33	1.05
Grand Total		1001761	100	1.518	0.508	1.155

PY- Publication Year, TR -Total Records, TP – Total percentage, RGR – Relative growth rate , DT- Doubling time, EGR – Exponential growth rate

Table 3 (Fig.3) predicts the relative growth rate and doubling time for total output on Nanotechnology at global level. It is identified that the relative growth rate has been progressed from 0.6 in 2001 to 2.05 in 2015 and its average relative growth rate was 1.518 and the doubling time showed the decline trend ranging from 1.155 in 2001 to 0.33 in 2015. During the period of study, the average value of doubling time has been arrived at 0.508. Further, the exponential growth rate of worldwide Nanotechnology research has been measured during the fifteen

years from 2001 to 2015. It is observed that the highest number of exponential growth rate was 1.27 with 33,472 research output in the 2004 and it is noticed that this particular year's research articles which has highly increased with other publications. Except the period 2002-2005, it seems that there was a fluctuation trend after 2006.

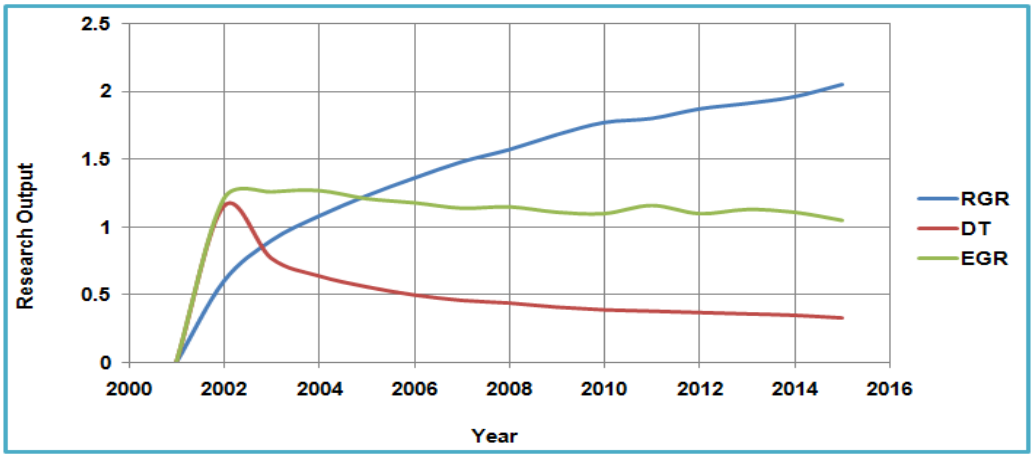

Fig3. *Relative Growth Rate, Doubling Time and Exponential Growth Rate*

Source: *The authors*

Ranking of Continent – Wise Contribution

It is noteworthy to measure that the country – wise distribution of scholarly publications play a vital role to lead the different continents in a subject. An attempt has been made to know the participation of various countries in bringing out research output on Nanotechnology. A total number of 135 countries had contributed 10, 01,761 scientific publications on Nanotechnology during the period of study.

Table4. *Ranking of Continent – wise contribution*

S. No	Country	No of Records	%	Cum.%	Rank	No of countries
1	Europe	232122	23.17	23.17	2	42 (31.11)
2	Africa	7606	0.76	23.93	7	32 (23.70)
3	Northern America	221431	22.10	46.03	3	2 (1.48)
4	Latin America	24800	2.48	48.51	5	20 (14.81)
5	Middle East	48001	4.79	53.3	4	13 (9.63)
6	Asiatic Region	446070	44.53	97.83	1	21 (15.56)
7	Pacific Region	21731	2.17	100	6	5 (3.70)
Total		1001761	100			135

Source: *countries have been grouped on the basis of their output.*

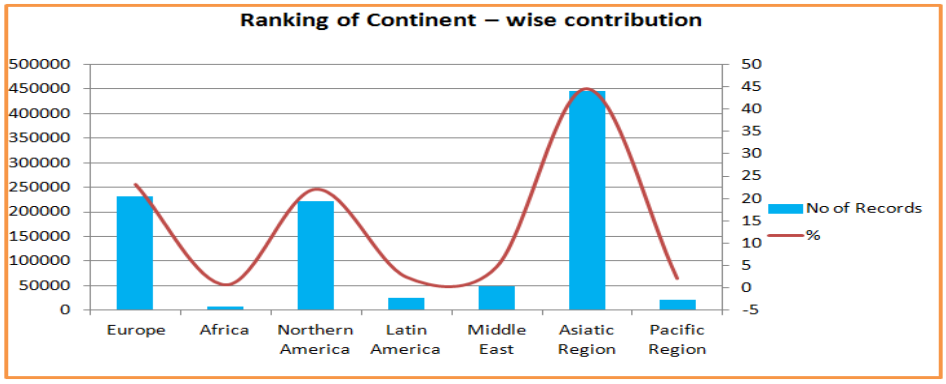

Fig4. *Continent – wise contribution of the Nanotechnology literature*

Source: *The authors*

It is found that authors from 135 countries have contributed their research output on Nanotechnology. For analysis, the countries have been classified under seven regions according to SCImago journal report.

Table 4 (fig.4) indicates the continent wise distribution of total research productivity on Nanotechnology and findings revealed that out of 10, 01,761 research publications, the huge number of (44.53%) research output were

produced by Asiatic Region i.e. 21 countries (15.56%) and occupied first rank in the global level, and followed by Europe with second position producing 2, 32,122 (23.17%) research literature from 42 countries (31.11%). The third rank has been received by Northern America with 2,21,431 (22.10%) scholarly papers by 2 countries (1.48%). 13 countries (9.63%) from Middle East have produced 48,001 (4.79%) research articles and ranked fourth place, and followed by Latin America which published 24,800 (48.51%) publications from 20 countries (14.81%) and ranked fifth place. Pacific region has produced 21,731 research articles by 5 countries (3.70%) and occupied sixth rank and 7,606 (0.76%) research papers were produced by 32 (23.70) countries and placed last. It was identified that the researchers and scientists from the Asian countries have shown interest to publish their research work and tries to occupied first rank and followed by European countries which have involved in research eagerly.

Ranking of Countries

Out of 135 countries, only top 50 countries were taken for research output on Nanotechnology for analysis during the period of study. Table 5 (Figure 3) represents the global wise distribution of research articles. It is found that out of 50 (selected) countries, the maximum number of publications yielded by China were 2,43,798 (24.34%) and occupied first rank, and followed by United States which stand in second position by contributing 2,28,725 (22.83%) publications. Japan is in third rank with the contributions of 75, 283 (7.51%), and followed by Germany which contributed 71,130 (7.1%), South Korea contributed 61,098 (6.10%). India has been ranked sixth position with 54,190 (5.41%) research output. The exponential trend line has exactly fit on the growth of literature and the y value is $13281e^{-0.12x}$ and the R^2 value is 0.916. The same work was carried out by Velmurugan (2018) with scholarly publications of Nephrology by Indian Scientists which was retrieved from Science Citation Index Expanded. The results reveal that USA got ranked first with 32.2% based on record count. Further, during 2017 on fossil fuel with top ten countries and found the majority of (6.9%) productive papers were from USA and ranked first among them.

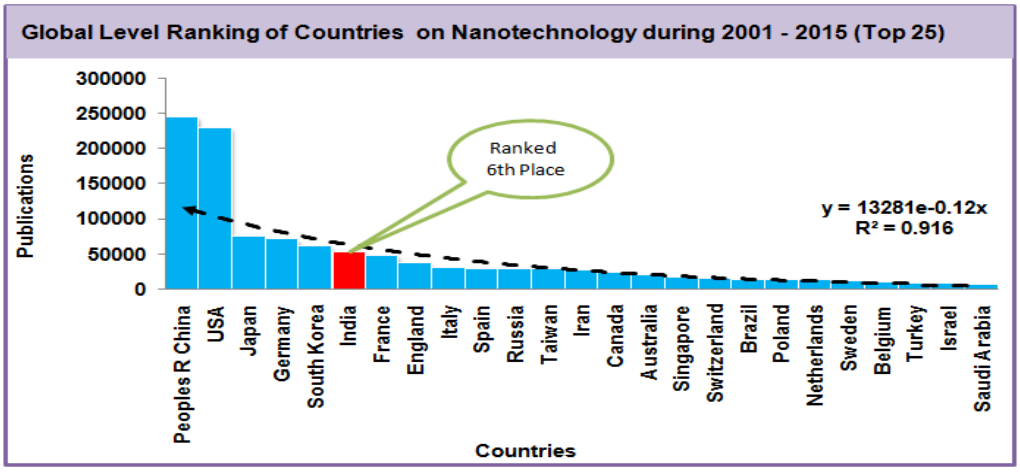

Fig5. *Ranking of Countries (Top 25)*

Source: *The authors*

Table5. *Global*

Rank	Countries/Territories	Total Records	Total percent %
1	Peoples R China	243798	24.34
2	USA	228725	22.83
3	Japan	75283	7.51
4	Germany	71130	7.1
5	South Korea	61098	6.10
6	India	54190	5.41
7	France	48383	4.83
8	England	37324	3.73
9	Italy	30668	3.06
10	Spain	29011	2.90

Level distribution of Nanotechnology

Productive Authors on Global Nanotechnology (Top 10)

Table 6 represents the research productivity of the authors and the analysis has been made accordingly. Out of 99,950 total authors, only top 10 most prolific authors have been taken for the present study. Most of the research papers was published by Zhang, Y with 5493 (0.548%) and was ranked first and followed by Wand, Y who occupied the second place with output of 5412 (0.540%) papers. The third rank was occupied by Liu, Y with 5,178 (0.517%). The fourth rank went to Wang, J (4813), Li (4486), Y, and Wang, L (4036) who has less than 0.5 percent. The authors i.e. Zhang J (3962), and Li J (3900), Zhang L (3672), Anonymous (3451), Wang H (3318), Wang X (3302), Liu J (3260) and Kim J (3132) have contributed less than 0.4 percent and they were ranked fifth position.

Research papers which were published by Xu J (1990), Wang W (1877), Zhao Y (1869), Yang H (1839), Zhang W (1773), Chen X (1769), Li W (1731), Liu H (1731), Li Q (1691), Li C (1596), Wang F (1594), Li Z (1537), Lee H (1531), Chen W (1529), Lee Sh (1522) and Liu X (1516) have got least position since they have published less than 0.2 percent. The same work was conducted by the author Velmurugan (2018) with twenty six year analysis of Fossil Fuel related highly cited works during 1991-2016 and among top ten highly cited authors, ‘‘Venkataraman C’’ who ranked first with global citations.

Table6. *Top ten Productive Authors of the Nanotechnology in Global*

Sl. No	Authors	Records	%
1	Zhang Y	5493	0.548
2	Wang Y	5412	0.540
3	Liu Y	5178	0.517
4	Wang J	4813	0.48
5	Li Y	4486	0.448
6	Wang L	4036	0.403
7	Zhang J	3962	0.396
8	Li J	3900	0.389
9	Zhang L	3672	0.367
10	Anonymous	3451	0.344

Productive Organizations on Global Nanotechnology

Researchers analyzed in terms of institutions’ / organizations’ research output on Nanotechnology based on the data retrieved from the Web of Science database. It can been seen from the table 000 that out of the 97, 376 organizations, only 25 top most productive organizations have been taken for the study. The table represents research output, h-index and ranking of the institution. Table 7 indicates the major proportion i.e. 42, 843 (4.277%) research articles was produced by ‘‘Chinese Academic Science’’ and its h-index is 495 by which it got ranked first. The next productive institution is ‘‘Russian Academy of Science’’ with 14242 (1.422&) and got 390 h-index and third place occupied by ‘‘Centre Nationnal de la Recherche Scientifique’’ (CNRS) from France with 9, 567 (0.955%) publications and its h-index is 811. It has been ranked first based on the h-index. It was analyzed country wise distribution of papers and identified that the most of the research papers on Nanotechnology were published from China and followed by United States.

Table7. *Top ten Productive Organizations (Global)*

Sl. No	Organizations	Country	Records	%	h-index	Rank
1	Chinese Academic Science	China	42843	4.277	495	IV
2	Russian Academy of Science	Russia	14242	1.422	390	V
3	Centre Nationnal de la Recherche Scientifique	France	9567	0.955	811	I
4	Zhejiang University	China	8019	0.8	495	IV
5	National University of Singapore	Singapore	7832	0.782	349	VI
6	Nanyang Technology University	Singapore	7664	0.765	349	VI
7	Indian Institute of Technology	-	7555	0.754	114	X
8	Tsinghua University	China	7514	0.75	495	IV
9	Jilin University	China	7409	0.74	495	IV
10	Nanjing University	China	7255	0.724	495	IV

Research Areas on Nanotechnology (Global)

Table 8 shows that out of 132 research areas on nanotechnology, the top 10 research fields with more than 31,000 records have been taken into consideration for the present study. In this context, the maximum number of (40.44%) research publications was produced from the department of ''Chemistry'' and ranked first. The most productive research field is ''Materials Science'' and got second position with 3, 57, 254 (35.66%) literature output.

The third major field is ''Physics'' with 3, 19, 563 (31.9%) research articles which were produced and ranked accordingly. Science technology and other topics with 1, 68,879 (16.86%) and has got fourth place and the fifth rank was received by Engineering with 1, 02, 661(10.25%). It shows that the most of the researchers are from Science disciplines such as Chemistry, Physics, Material science and Engineering who were actively involved in research and publish their papers effectively.

Table8. *Research Areas on World Nanotechnology*

Sl. No	Research Areas	Records	%
1	Chemistry	405069	40.44
2	Materials Science	357254	35.66
3	Physics	319563	31.9
4	Science Technology and other topics	168879	16.86
5	Engineering	102661	10.25
6	Polymer Science	58327	5.822
7	Electrochemistry	42134	4.206
8	Metallurgy Metallurgical Engineering	32740	3.268
9	Biochemistry Molecular Biology	31300	3.124
10	Optics	31137	3.108

Source Titles on Nanotechnology (Global)

Source titles along with total output and their h-index, impact factor, and immediacy index have also been systematically evaluated during the period of study at global level. Table 9 (fig.6) illustrates that out of 7,599 source titles, only top 10 were selected and more than 9,000 record counts were taken for research purpose. Based on the research output, the major proportion of the scholarly papers was published in 'Abstracts of Papers of the American Chemical Society and the total output is 23, 676 (2.36%) and occupied first rank, and h-index is 412 (2^{nd} rank), impact factor is 12.113 (4^{th} rank) and its immediacy index is 2.61 (2^{nd} rank). 'Applied Physics Letters' is another major source with 22, 324 (2.228%) research articles which were produced on Nanotechnology and got placed in second position, h-index is 69 (40^{th} rank) , impact factor is 3.302 (35^{th} rank) and its immediacy index is 0.66 (28^{th} rank). The third most productive source is ''Journal of Physical Chemistry C'' with 16, 486 (1.646%) papers on global output and its h-index is 152 (25^{th} rank) and it impact factor is 4.772 (22^{nd} rank) and its immediacy index is 0.77 (24^{th} rank). It was identified that the source journal ''Advanced Materials'' has produced only 6, 124 (0.61%) scholarly articles on Nanotechnology. It was comparatively less with other productive source journals, impact factor is 17.493 (1^{st} rank), h-index score is 315 (4^{th} rank) and its immediacy index score is 3.44 (1^{st} rank). Similarly, ''Physical Review Letters'' has published less research papers i.e. 5, 998 (0.59), impact factor is 7.512 (11^{th} rank), immediacy index is 2.53 (3^{rd} rank), and it is very interesting to note that its h-index is 452 (1^{st} rank). The findings of the study revealed that the ranking system is very effective since, it gave the importance to quality of the papers rather than the quantity. The same work was done by author Velmurugan (2018) using Nephrology publications during 2011-2016 and found the journals namely, ''The American Journal of Kidney Diseases'' was ranked first (5.5%) based on the global citations.

Table9. *Source Titles on Nanotechnology (Global)*

Sl. No	Source Titles	TR	TP	h-i	IF	II	Rank			
							IF	TR	h-i	II
1	Abstracts of Papers of the American Chemical Society	23676	2.363	412	12.113	2.61	4	1	2	2
2	Applied Physics Letters	22324	2.228	69	3.302	0.66	35	2	40	28
3	Journal of Physical Chemistry C	16486	1.646	152	4.772	0.77	22	3	25	24
4	Physical Review B	16428	1.640	313	3.736	0.93	30	4	5	20
5	Journal of Applied Physics	16309	1.628	240	2.183	0.45	43	5	13	36

6	Langmuir	13695	1.367	241	4.457	0.68	25	6	12	27
7	RSC Advances	13441	1.342	45	3.84	0.60	28	7	41	30
8	Nanotechnology	11293	1.127	128	3.821	0.68	29	8	29	27
9	Journal of Nanoscience & Nanotech	10872	1.085	74	1.556	0.59	50	9	39	31
10	Journal of the American Chemical Society	9878	0.986	412	12.113	2.61	4	10	2	2

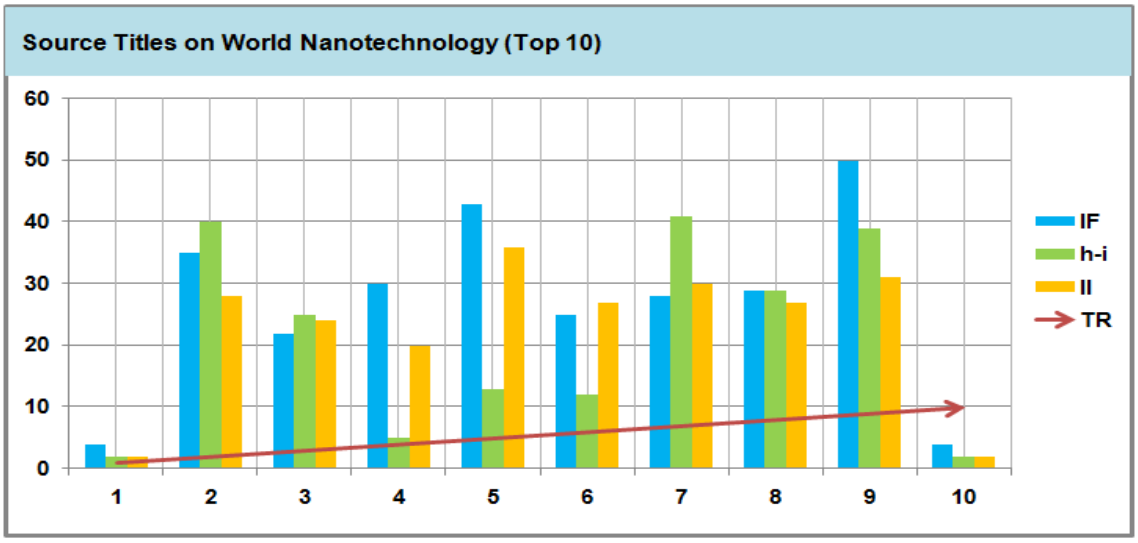

Fig6. *Source Titles on Nanotechnology (Global)*

Source: *The authors*

Funding Agencies on Global Nanotechnology

Funding agencies play a vital role in enhancing the research and development of the any organization which is not an exception in Nanotechnology research. It is evident from the below table 10 that a total of 99, 900 funding agencies had funded for research on Nanotechnology during the period of study. Only top leading 10 funding agencies with more than 4, 000 record counts have been selected for the present study. Based on the data analysis, the maximum number of (14.264%) literature output was funded by National Science Foundation from United States and got ranked first and followed by Fundamental Research Funds for the Central Universities from China which occupied second with 13, 569 (1.355%) records. The third rank was retained by National Basic Research Program with 13, 445 (1.342%). Among the 10 funding institutions which fund for Nanotechnology research areas, the predominant country ‘‘China’’ got ranked first and followed by USA, and Europe got ranked second respectively. Germany got occupied third rank. Brazil, Kenya, UK, Australia, Korea, Taiwan, and Japan have funded for the research at very minimum levels. It was noted that ‘India’ occupied 35th rank among the funding agencies across the globe during the period of study.

Table10. *Funding Agencies on Global Nanotechnology*

Sl. No	Funding agencies	Country	Records	%
1	National Science Foundation	USA	142890	14.264
2	Fundamental Research Funds for the Central Universities	China	13569	1.355
3	National Basic Research Program	China	13445	1.342
4	National Institutes of Health	USA	6261	0.625
5	National Basic Research Program	China	5558	0.555
6	Russian Foundation for Basic Research	Russia	5395	0.539
7	National Institutes of Health	China	5123	0.511
8	Program for New Century Excellent Talents in University	China	4830	0.482
9	Ministry of Education Science and Technology	Kenya	4775	0.477
10	China Postdoctoral Science Foundation	China	4754	0.475

CONCLUSION

This paper highlights the findings of the study. The inferences drawn from the analysis are discussed and various fruitful measures are also given to enhance the quality of Nanotechnology research in global level. Based on the study, the researcher has come out the logical findings. It is analyzed and found a total of 10, 01,761

research papers were on Nanotechnology for the period of recent 15 years (2001-2015). The maximum number of papers (12.89%) was found in 2015. It is observed that the majority of 5, 50,262 (54.93%) scholarly publications was produced in period (block -3) and ranked first. The Activity Index (AI) ranges were from 31.81 in 2003 to 140.41 in 2015 and the Average Activity Index was 81.324. The Activity Index was high (140.41) in 2015 whereas the least (31.81) in 2003. The compound annual growth (CAGR) for the period of 15 years of global-wise Nanotechnology literature output was equal to 15.42% whereas Indian research output of nanotechnology was equal to 25.66%. The huge number of (44.53%) research output was produced by Asiatic Region with 21 countries and ranked the first. Europe and Northern America have obtained second and third ranks respectively. A total number of 135 countries has contributed 10, 01, 761 scientific publications on Nanotechnology during the period of study. It is found that a majority of records was from China (24.34 %) and ranked first and followed by United States with 22.83%. India has got sixth position with a total output of 54, 190 (5.41%) contributing a share of total output. The majority of (29.07%) papers was produced by G8 Countries and ranked first and followed by BRICS Nations which were placed fourth with 18.11% papers. SAARC Countries had gained 6th position with publications of 3.07% of papers. It is found that the China leads the BRICS Nations in terms of research output with 70.98% and stood first rank and India comes next with 15.78% scholarly publications. Among the SAARC Countries, India ranked first with 93.44% of research publications though it has been ranked sixth in global level. The second most productive country is Pakistan with 5.10% publications and it is ranked 43rd position globally. Among the G8 Countries, the United States has produced the major proportion of (41.50%) papers and ranked first and placed second globally. Japan has been identified second most productive country and ranked the third in global level. It is found that the relative growth rate of Nanotechnology (global level) has been progressed from 0.6 in 2001 to 2.05 in 2015 and its average relative growth rate was 1.518 and the doubling time showed the decline trend ranging from 1.155 in 2001 to 0.33 in 2015. It is observed that the highest number of exponential growth rate was 1.27 with 33, 472 research output in 2004 and it is noticed that except the period 2002 to 2005, there was a fluctuation trend after 2006.

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