RESEARCH CONTRIBUTION AND PERFORMANCE BY INDIAN SCIENTISTS IN THE FIELD OF NANOTECHNOLOGY: A BIBLIOMETRIC ANALYSIS

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ABSTRACT -
This paper deals with the biblio metric analysis of scientific output of nanotechnology in India. The aim of the study is to offer an overview of research trends in this field and to identify its most important aspects such as growth of literature, highly cited papers, pattern of citations and most prolific authors. The web of science core collection online database is the main source for data collection during the period 1989 - 2017.The data were further analyzed and tabulated as per the set objectives of the study to deduce it to meaningful findings and conclusion.
The study found that the growth of literature is gradual with the highest number of papers published in 2016. The citation pattern reveals that 76.60% research papers fall in the least cited category while 14.55% papers are not cited. Benelli G is the most prolific Indian scientist but the highest citation and average citations received by Sastry M. The present study shall help the researchers finding prolific Indian authors besides trends in nanotechnology. It will also aid the libraries and information centers in the collection management. The study provides quantitative information of different aspects of nanotechnology research conducted by Indian scientists and to show the progress and interest developed in nanotechnology researchers.

Keywords - Bibliometric analysis, Nanotechnology, Citation Impact, prolific scientists, India, scientific output.

INTRODUCTION

The term Nanotechnology at the present time is well known not only in all relevant scientific and technical areas and also to a large extent in the public domain.

Based on news in newspapers and television a series of commercially available products with "nano" as part of their names and this development might be considered in a positive sense by showing that nanotechnology is taken as new technology while on the other hand, it contains some risks that should not be ignored (Mohan, Prakasan, Kademani, Surwase, A. Kumar & V. Kumar, 2010). The notions and concepts behind nanoscience and nanotechnology started with a talk under the title "There's Plenty of Room at the Bottom" by physicist Richard Feynman at the American Physical Society meeting at the California Institute of Technology on December 29, 1959. In his speech, Feynman defined a process in which scientists would be able to manipulate and regulator individual atoms and molecules. A decade later, Professor Norio Taniguchi in 1974 coined the term nanotechnology (National nanotechnology initiative, n.d.). According to Professor Norio Taniguchi "Nanotechnology mainly consists of the processing of separation, consolidation, and deformation of materials by one atom or one molecule" (Nano werk, 2018).

Nanotechnology has made a great deal of excitement world-wide and is being mentioned as the chief technology of the 21st century. (Bhattacharya & Shilpa, 2011). Nanotechnology can be able to generate several new resources and strategies with a vast range of functions such as in medicine, electronics, biomaterials, and production. Nano-applications can offer solutions in areas that are burning concerns in developing and providing economies, i.e., environment, water purification, agriculture, energy, and in a host of other products and services. Nanotechnology provides a range of opportunities for countries like India that tends to handle developmental problems and to make economic growth through technological intervention (Bhattacharya & Shilpa, 2011).

On the other hand bibliometrics is a significant sub-discipline of quantitative research. This is a tool which is used by the library and information science experts traditionally for studying the communication processes, information flows etc. for better understanding and effective management and dissemination of information. The bibliometric method has been widely applied to analyze the scientific output and research trends in many fields (J. Wang, Zheng, Q. Wang, Xu & L. Wang, 2015). The bibliometric analysis sheds light on the pattern of growth of literature, inter-relationship among different branches of knowledge, publications output, authorship pattern, a degree of collaboration, a pattern of collection building, and their use (Rajendran, Babu & Gopalakrishnan, 2005).

REVIEW OF LITERATURE

Selvaraja and Nischitha (2012) conducted a bibliometric analysis in the field of telemedicine. The study shows that during the year 1996 to 2005 more contribution was made in the field of telemedicine. Rajendran and Gopalakrishnan (2005) investigated the global output of 'fiber optics' research. The articles contributed by the Indian authors is about 2% of the total literature. Rajendiran and Parihar (2007) carried out study in the field of laser science and technology. The share of India against world output in terms of percentage steadily increased from 0.71% in the year 1995 to 1.64 % in the year 2005. Patra and Bhattacharya (2005) mapped oncology research in India and the data for the study has been taken

from PubMed. After observing for the last few years trends, it was seen that on an average 500 papers were published per year. The contribution of India in cancer literature is very less i.e., about 0.4% in comparison to other countries. Maharana (2015) aimed to analyze Indian researchers' publications on tuberculosis (TB) which were indexed in the WoS database. The study reveals that the total of 5,073 documents was published by the Indian researchers with an annual average growth rate percentage (AAGRP) of 8.85. Furthermore, the number of publications increased almost double from 2004 to 2013. Kolle and Shankarappa (2017) mapped the articles in malaria research for the period 1991-2015. The most productive journal with 154 articles and accounts for 9.53% of the total articles is Proceedings of the National Academy of Sciences. Siwach and Kumar (2015) measured the research contributions of Maharshi Dayanand University (MDU), Rohtak as listed in Scopus. The study explores that during 2000-13, the MDU has published 1247 papers. The highest numbers of papers i.e., 219 were published in the year 2013 while as the lowest number of papers i.e., 30 published in 2001. The C.S. Pundir is the most productive author with 141 publications. Sevukan and Sharma (2008) examined the research output of biotechnology faculties in central universities of India. The output steadily increased from 15 articles in 1997 to 43 articles in 2006. The maximum number of articles were published by R. Prasad of JNU (21). Garg and Sharma (2017) mapped library and information science research in India. The Academic institutions contributed about 86% of papers and the prolific institutions contributed about 44% of the total output in which Mysore University topped with 110 papers. The most prolific author was identified as B.M. Gupta with 31 papers and K.C. Garg is the most highly cited author. Gupta and Verma (2011) measured research output of India in computer science. India ranks at 13th position with its global publication share of 1.72% and the annual average growth of India is 28.68%. There are about 22 most productive Indian authors in the field that has contributed to 1,123. Based on publications output of India, 100 papers are identified as highly cited ones, who have received citations from 45 to 1,880 during 1999–2009 and have together received 12,630 citations with an average of 126.3 citations per paper. Garg and Tripathi (2014) carried the bibliometric study of Indian scholarship. The study shows a steep rise in output during 1995-2014 as compared to the output in 1970-1994. Among all authors, B.M.Gupta with 79 papers(9.4%) of CSIR-NISTADS topped the list with the highest number of papers, but the impact as seen in terms of citation per paper(CPP)was highest for S. Arunachalam of MSSF with 25.5 CPP . Mohan, Kademani, A. Kumar and V. Kumar (2010) aimed to analyze the growth and development of Indian research in the field of Nano science and Nanotechnology in terms of publication output according to the Science Citation Index. The study draws out that Indian scientists contributed to a total of 8326 (2.81 percent) papers. The greatest growth was found during 2006-2008 with 4786 publications, the maximum numbers of publications (1890) were published in 2008 and the annual average number of documents published was 308.37. Among the list of prolific authors in Nano science and nanotechnology research in India, the three top researchers are N.R. Rao with 198 publications. Nazim and Ahmad (2008) perform bibliometric analysis on scientific output in the field of

nanotechnology. The study shows 2675 articles were published during the period 1991-2006 with an average of 167 articles published each year, thus revealing an upward trend in the number of articles published and also shows a rapid growth in research from the beginning of 21st century. Thirumagal (2012) presents a bibliometric study on publication on nanotechnology in India. The study draws that the leading author of the field is Sastry .M with 12 publications. It is also found that India ranks first which has produced 332(73.9%) publications. There are about 403 institutions that publish research output in nanotechnology in India, the most prolific institute is Indian Institute of Technology (IIT) with 51 publications followed by Indian Institute Science (IIS) with 21 publications. Makhoba and Pouris (2017) study reveals a steady increase in research output of South Africa since the introduction of the National Nanotechnology Strategy in 2005 and its associated government support. The nanotechnology area grew at an average annual growth rate of 25.95% and the citation growth was much higher at an average annual growth rate of 144%. Li, Guo and Jovanovic (2014) their study shows that the publication trend of papers on nanosafety topics first emerged in 2003 then; the publications have a sharply increasing trend which can be approximated by the linear growth curve. In the list of countries/territories, India has published 10 papers (3. 42%). Lavrik, Shaburova and Zibareva (2015) examined publications on Nano science and nanotechnology (NS&NT) produced by the researchers of the Siberian Branch of the Russian Academy of Sciences (SBRAS). The study lays out that the researchers affiliated with SBRAS published approximately 4000 works on NS&NT, and there are about 25 articles that received more than 50 citations by March 2014. Shackleton, Gok, and Shapira (2014) analyzed the development of Russian nanotechnology outputs in terms of publications and patents developed by researchers at Georgia Institute of Technology and the Manchester Institute of Innovation Research. The output of Russian nanotechnology publications recorded in the WOS increased gradually with up-to 33,538 between 1990 and 2012 and the highest number of 3500 papers published in 2012. Liu and Jia (2013) investigated the applications and development of nanotechnology applied in oncology and literature harvested from PubMed. The study reveals that of 2,543 articles published from 2002 to 2011, the annual number of articles increased from the minimum 46 in 2002 to 658 in 2011. In the list of top 10 countries/territories, India published 98 publications and attained 4th rank. Lokhande (2013) analyzed the Nanotechnology literature indexed in Scopus database. A total of 36900 documents were published between 2006 to 2010 in which the highest number of documents published and Annual Growth Rate (AGR) of the number of documents found in the year 2008 is 8552 and 31.18% respectively. In the list of top ten ranked nations contributed over 80% of the total literature, and India ranks 8th with 1227 documents. Bajwa and Yaldram (2012) conducted a bibliometric study on research produced by Pakistan in Nano science and nanotechnology. The study indicates that a total of 1565 publications were produced. Liu and Chen (2018) evaluated the role of Nanomaterials and nanotechnologies (NNS) in wastewater treatment with bibliometric techniques from 1997 to 2016. The study reveals that India (105) publications occupies 4th place in the list of top 20 most productive countries. Darvish and Tonta

(2016) aimed to analyze the diffusion and adoption of nanotechnology knowledge within the Turkish scientific community by using social network and bibliometrics analysis. A total of 10,062 articles were published between 2000 and 2011 as indexed in WOS. The publication increased eight fold from 215 papers in 2000 to 1748 in 2011. The present study was taken up to quantify the strength of scientific output in the field of nanotechnology in India and the aim of the study is to provide an overview of the growth of nanotechnology research in India and to describe its most important aspects such as growth of literature, prolific authors, highly cited papers etc.

OBJECTIVES OF THE STUDY

The study has the following aspects.

1. To find the year wise contribution of articles.
2. To identify the highly cited papers and examine the pattern of citation.
3. To find the most prolific authors and their citation impact.

SCOPE OF THE STUDY

The project revolves around the bibliometric analysis of Nanotechnology in India. The data for the study was retrieved from the web of science core collection and the study was limited to the time periods 1989-2017. The main focus of the study was on research articles.

METHODOLOGY

The data for the study was downloaded from the web of science core collection database on 23rd May 2018 for the records related to the study field Nanotechnology. With the aim of covering all the available citations on the subject, the advanced search option was employed and the query was submitted by defining the terms (title (nanotechnology) and affil (india)) and pubyear after 1988 and pubyear before 2018". The data was further refined by selecting "Articles' ' in the document type refinement option.

This means those records having the term 'Nanotechnology' either in article title or keywords and the author affiliation from 'India' published during 1989 to 2017 and the document type selected as Articles only were retrieved and the total number of such records were 1333. The data thus retrieved was harvested, tabulated, thus analyzed in tune with set objectives.

DATA ANALYSIS

Chronological Contribution of Articles

The traces of research on nanotechnology dates back to *1993* (1 paper) as per the Web of Science, but the maximum contribution in this field was appeared in the year *2016* with 223 papers followed by the year *2017* (219), *2015* (178), *2014* (132), *2013* (122). Moreover, the top five highest citations received by research papers were found in the year *2009* with 2911 citations followed by the year *2011* (2847), *2003* (2759), *2010* (2609) and *2012* (2417), further the paper with least citation i.e., 9 was published in the year *1993*. Thus, the scenario of citations portrays that many new fields are emerging in nanotechnology and can emerge in the future. After finding the average citations of all the papers published from *1993 to 2017*, it was found that the most productive year in terms of performance is *2003* with average citation 197.07 followed by the years *2001* (179), *2002* (95.86), *2008* (48.55), *2009* (45.48) while as the least performing year is

2017 with average citation 1.85. The lesser citation for *2017* may be because of a very short citation window of less than one year. (Table 1).

Table 1. Year Wise Distribution of Articles and Their Citations

Sr. No	Year of Publication	Total No of Papers	Total citations per year	Average Citations in a Year
1	1993	1	9	9
2	2001	3	537	179
3	2002	7	671	95.86
4	2003	14	2759	197.07
5	2004	9	246	27.33
6	2005	19	794	41.79
7	2006	24	901	37.54
8	2007	25	911	36.44
9	2008	49	2379	48.55
10	2009	64	2911	45.48
11	2010	62	2609	42.08
12	2011	91	2847	31.28
13	2012	91	2417	26.56
14	2013	122	2152	17.64
15	2014	132	1866	14.14
16	2015	178	1975	11.09
17	2016	223	1380	6.19
18	2017	219	405	1.85

Highly Cited and Citation Pattern of Papers

A. Citation Pattern of Papers

The publication data was subjected to an examination of citations received by the paper. It is observed that of the *1333 papers* about 194 (14.55%) of papers did not get any citations and the rest *1139* (85.45%) papers have received 1 to 787 citations. On the basis of citations received by the papers, the papers can be divided into six categories i.e., not cited, barely cited, less cited, moderately cited, highly cited and very highly cited. The papers that received citations i.e., 0, and between 1-50, 50-100, 100-200, 200-400 and 400-800 fall in the category of not cited, barely cited, *less cited*, *moderately cited*, *highly cited and very highly cited* respectively. In the category of not cited, it contains *194* (14.55%) *papers* followed by *1021* (76.60%), *74* (5.55%), *25* (1.88%), *12* (0.90%), and *7* (0.52%) *papers* that fall under the category of barely cited, less cited, moderately cited, highly cited and very highly cited respectively. (Table2).

Table 2. Category and Citation Pattern of Papers

Category of papers	Range of citation	No. of papers with %age
Not Cited	0	194 (14.55)
Barely Cited	1-50	1021 (76.60)

Less Cited	50-100	74 (5.55)
Moderately Cited	100-200	25 (1.88)
Highly Cited	200-400	12 (0.90)
Very High Cited	400-800	7 (0.52)

B. Highly Cited Papers

The study was keen to identify highly cited papers and their average citation rate. It was observed that the papers that fall in the category of very highly cited and highly cited categories are only nineteen in number. The papers from rank 1 to rank 7 falls in the category of very highly cited and the remaining 12 ranks (i.e., 8 to 19 rank) obtained by highly cited papers. It can also be observed that among the list of top 19 papers, the journal '*Colloids and Surfaces B Biointerfaces*' published the six papers that are placed at rank 1, 10, 15, 17, 18, 19 followed by '*Journal of Materials Chemistry'*, published only two papers (i.e., on 7 and 8 rank).The highest citation i.e., 787 received by the paper '*Extracellular biosynthesis of silver nano-particles using the fungus Fusarium oxysporum*' (49.19 average citation) and the least citation i.e., 214 obtained by the paper '*Studies on silver nanoparticles synthesized by a marine fungus, Penicillium fellutanum isolated from coastal mangrove sediment*' (21.4 average citation). In terms of average citation received by the highly cited papers, the paper ranked 3rd and 16th received the highest and the lowest average citations i.e., 63.56 and 17.85 respectively. (Table 3).

Table 3. Highly Cited Papers

Rank	Name of cited paper	Journals	Total No. of Citations	Average citation	Category
1	Extracellular biosynthesis of silver nanoparticles using the fungus Fusarium oxysporum	COLLOIDS AND SURFACES BBIOINTERFACES	787	49.19	Very Highly Cited
2	Biosynthesis of nanoparticles: technological concepts and future applications	JOURNAL OF NANOPARTICLE RESEARCH	608	55.27	Very Highly Cited
3	Biological synthesis of metal nanoparticles by microbes	ADVANCES IN COLLOID AND INTERFACE SCIENCE	572	63.56	Very Highly Cited
4	Geranium leaf assisted biosynthesis of silver nanoparticles	BIOTECHNOLOGY PROGRESS	494	30.88	Very Highly Cited
5	Biosynthesis of metal nanoparticles using fungi and actinomycete	CURRENT SCIENCE	444	27.75	Very Highly Cited
6	Biogenic synthesis of silver nanoparticles and their	NANOMEDICINE-NANOTECHNOLOGY	417	46.33	Very Highly

	synergistic effect with antibiotics: a study against gram-positive and gram-negative bacteria	BIOLOGY AND MEDICINE			Cited
7	Bioreduction of chloroaurate ions by geranium leaves and its endophytic fungus yields gold nanoparticles of different shapes	JOURNAL OF MATERIALS CHEMISTRY	403	25.19	Very Highly Cited
8	Science and technology of nanomaterials: current status and future prospects	JOURNAL OF MATERIALS CHEMISTRY	396	22	Highly Cited
9	Coalescence of nanoclusters and formation of submicron crystallites assisted by Lactobacillus strains	CRYSTAL GROWTH & DESIGN	381	22.41	Highly Cited
10	Biosynthesis of silver nanocrystals by Bacillus licheniformis	COLLOIDS AND SURFACES BBIOINTERFACES	354	32.18	Highly Cited
11	Biosynthesis of Au, Ag and Au-Ag nanoparticles using edible mushroom extract	SPECTROCHIMICA ACTA PART A-MOLECULAR AND BIOMOLECULAR	323	32.3	Highly Cited
12	Intracellular synthesis of gold nanoparticles by a novel alkalotolerant actinomycete, Rhodococcus species	NANOTECHNOLOGY	286	17.88	Highly Cited
13	Antimicrobial activity of metal oxide nanoparticles against Gram-positive and Gram-negative bacteria: a comparative study	INTERNATIONAL JOURNAL OF NANOMEDICINE	271	38.71	Highly Cited
14	Gold nanotriangles biologically synthesized using tamarind leaf extract and potential application in vapor sensing	SYNTHESIS AND REACTIVITY IN INORGANIC METAL-ORGANIC AND NANO-METAL	263	18.79	Highly Cited
15	Biosynthesis, purification and characterization of silver nanoparticles using Escherichia coli	CHEMISTRY COLLOIDS AND SURFACES B-BIOINTERFACES	239	23.9	Highly Cited

16	Functional finishing in cotton fabrics using zinc oxide nanoparticles	BULLETIN OF MATERIALS SCIENCE	232	17.85	Highly Cited
17	A novel extracellular synthesis of monodisperse gold nanoparticles using marine alga, Sargassum wightii Greville	COLLOIDS AND SURFACES BBIOINTERFACES	222	18.5	Highly Cited
18	Plant extract mediated synthesis of silver and gold nanoparticles and its antibacterial activity against clinically isolated pathogens	COLLOIDS AND SURFACES BBIOINTERFACES	223	27.88	Highly Cited
19	Studies on silver nanoparticles synthesized by a marine fungus, Penicillium fellutanum isolated from coastal mangrove sediment	COLLOIDS AND SURFACES BBIOINTERFACES	214	21.4	Highly Cited

Prolific Indian Authors and Their Citation Impact

During the period of study 4114 authors from India contributed to 1333 articles. Generally, in a given subject, most authors published only a few articles whereas a few prolific authors published many articles. The top twelve authors according to the number of publications they have made, were taken as the most prolific authors.

It can be observed from Table 5 that the author *Benelli G.* got the first rank with 28 papers & received 573 citations. The second rank is shared by three authors by having equal number of papers are *Kumar A*, *Kumar S and Singh S* with 23 papers and achieved citations of 335, 529 & 448 respectively, *Kumar R* got the third rank with 19 papers and also received 1792 Citations which is among the top second highest citation. The authors *Kumar P and Murugan k* shared the fourth rank by publishing the same number of papers i.e., 17 and got 144 & 347 citations respectively. *Kumar V and Govindarajan M* occupy fifth and sixth rank with 15 articles (77 Citations), 13 articles (279 Citations) respectively. And finally, the last seventh rank in the list of prolific authors shared by *Das S* (163 Citations), *Ghosh S* (285 Citations) & *Sastry M* (3083 Citations) by publishing 12 papers, among which the *Sastry M* obtained the highest number of citations.

It is generally believed that prolific authors get more citations as compared to non- prolific authors. Now in order to find the citation impact of the articles of the most prolific authors, divide the total citations of papers of the most prolific authors with the total number of the papers of each author. This gave us the average citation of each paper of the most prolific authors. The value of average citations would be a more accurate

measure of impact. Thus, the average citation of all the twelve most prolific authors is 20.46, 14.56, 23, 19.48, 96.31, 8.47, 20.41, 5.13, 21.46, 13.58, 23.75, 256.91 respectively. The minimum and maximum average citations of the most prolific authors are 5.13 and 256.91 respectively. (Table 5). This lays out that the research conducted on nanotechnology by Indian authors is good and is going on as being a developing country.

Table 5. Prolific Authors and Their Citation Impact.

Rank	Name of Author	No. of Papers	Total Citations	Average Citation
1	BENELLI G	28	573	20.46
2	KUMAR A	23	335	14.56
2	KUMAR S	23	529	23
2	SINGH S	23	448	19.48
3	KUMAR R	19	1792	96.31
4	KUMAR P	17	144	8.47
4	MURUGAN K	17	347	20.41
5	KUMAR V	15	77	5.13
6	GOVINDARAJAN M	13	279	21.46
7	DAS S	12	163	13.58
7	GHOSH S	12	285	23.75
7	SASTRY M	12	3083	256.91

CONCLUSION

India, being a developing country is doing well in the field of nanotechnology. The study reflects the asynchronous growth of literature on nanotechnology with fluctuation in the annual research output while as the overall scenario indicates gradual growth in research. The interest of research on nanotechnology was found in the last decade of the 20th century (1993) with one publication and starts in the 21st century with the highest number of papers (223) published in 2016. As rapid growth in the research process in nanotechnology will lead to the emergence of new frontiers and technological innovations that shall be revolutionary for different shades of society. The gadgets which are formed by using nanotechnology will not only be cheaper but with less weight and definitely smaller in size. By using such types of gadgets, it will influence every sector of society and finally lead to the overall development of a society. In citation

pattern of papers, the highest number of papers (1021; 76.60%) fall in the barely cited category that obtained citations between 1 to 50 followed by not cited papers (194; 14.55%), clearly delineates that with an increasing number of studies the standard has declined. The paper '*Extracellular biosynthesis of silver nano-particles using the fungus Fusarium oxysporum*' emerged as the most influential by obtaining the highest number of citations (787). As we know nanotechnology is a newly emerged field of science and technology. At present-day *Benelli. G* with 28 papers is the top prolific Indian scientist on nanotechnology, belongs to the institution which sponsors research processes and is associated with certain research projects. Based on present production and performance it can be safely said that, if Indian Scientists collaborate with other national, international scientists and with other global institutions will lead to rapid growth in research in this field, which also leads to an increase in the number of publications of Indian scientists. In the future, any existing scientist can overtake the position of a present leading scientist; also, the new scientists can emerge. It can also be observed that highest citation (C.I) which also receives highest Average Citation (A.C), *Sastry M received* (3083 C.I; 259.91 A.C) is comparatively higher than the top prolific scientist *Benelli. G* (573C.I; 20.46 A.C), the reason behind it can be, that the citation and average citation depends on the quality, new innovation and ideas produced by the paper.

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