Nanomaterials: A Scientometric Analysis

S. Prabakar[1] and A. Thirumagal[2]

[1]*Librarian, Agni College of Technology, Chennai - 603 103, Tamil Nadu, India*

[2]*University Librarian, Manonmaniam Sundaranar University, Tirunelveli - 627 012, Tamil Nadu, India*

E-mail: moorthylibrarian@gmail.com

Abstract – The emergence of the nanomaterials in the growing innovative technologies stimulates to do an analysis on the research work on nanomaterials by means of Scientometric techniques. The research work has been conducted by means of the selection of database of sample of 10 years from 2003 to 2010 which reveals that the total no. publication is 16958, along with the total Global Citation Score of 208085 and 9969 as total Local Citation Score. It was proved that the literatures on nanomaterials published in 11 different documents and that too in 17 different languages throughout the world. The Chi-square test proves that the significant error value is lesser than the critical value which is a proven possibility to predict the future trend of the no. of publications. The different types of publication proves that the journal article alone may no longer stand as a mark of the research output and as well as for citations. English language research work tends to be at the first place among the other language publications. The authorship pattern proves that the multi authored papers plays a dominant role in the research publication. Bradford's Law has been utilized to find out the core journals which produced more articles. A suggestion has been given through this article to the global research society to enhance the scientists with exclusive opportunities to do more and more research on nanomaterials towards the betterment of the society.

Keywords: **Nanomaterials, Global Citation Score, Local Citation Score, Authorship Pattern, Degree of Collaboration, Bradford's Law**

I. Introduction

The scientific discoveries leads towards exponential growth of knowledge and the quantum of information grows increasingly. The growing demands of information technology for more powerful microelectronic circuits force the transition of nanomaterials. The nanomaterials are not only materials science developed through technology but also a product of engineering, which can be implemented in many more utilities such as, Nanoelectronics, Nanostructured materials which are implantable for repairing, replacing and replacing human tissues, nanocomposites assures multi-functionality and performance characteristic combinations which has attributes such as toughness, stiffness, corrosion-resistance, flame retardancy and recyclability and nanorobotics in an intention to work efficiently and effectively in all aspects of the day-to-day activities of the human-machine interaction [1].

The novel architectures in the development of sophisticated nanomaterials intends to be the back bone of the implementation of nanotechnology in all the phase of human activities, which leads to do this research to evaluate the publications on nanomaterials with scientometric analysis. The data on nanomaterials for ten years from 2003 to 2012 has been downloaded from Web of Science for the application of the Scientometric techniques on the bibliographic descriptions of the publications on nanomaterials worldwide.

II. Need For The Study

The substance of nanomaterials are beginning to be a vital part of the society in modern technologies, which leads to secure knowledge about current status of the factual global response of the society of scientists towards the requirement of the innovative technologies.

III. Review Of The Literature

The research publications of the faculty members of Jamia MilliaIslamia University, New Delhi has been analysed from 1971 to 2007 in order to retrieve the results about the no. of publications, authorship, testing of Lotka's law and Bradford's law which reveals the publications published in 347 journals and in 26 countries. The values derived from the application of Lotka's equation are almost

equal to the observed values. The Bradford's law segregates the core journals from other journals [2]. Authorship pattern and degree of collaboration has been found for the Indian Chemistry literature downloaded from Web of Science from 2000 to 2009 which reveals that an average number of authors per article is 3.55%, and degree of collaboration is 0.03. The study also denotes that the multi-authored articles are predominant over the solo research [2]. A bibliometric study has been conducted on the Indian contributions on Nanotechnology reveals that India produced 332 publications for which it receives a Global Citation Score of 4594. It also reveals that the scientist M. Sastry contributes the maximum no. of publications (12nos.); the degree of collaboration is 0.11; Journal article (66.7%) leads from the first among the types of documents and Digest Journal of Nanomaterials and Biostructures produced more no. of articles (5.1%). The research was concluded that Nanotechnology will have major impact in the future of India [2].

IV. Objectives

1. To analyze the Year-wise distribution of Research publications along with Local Citation Score and Global Citation Score;

2. To forecast the future tend of the publications of literatures on nanomaterials;

3. To know the different types of publications on nanomaterials;

4. To retrieve the language-wise publications;

5. Authorship Pattern;

6. Ranking of top ten Scientists in nanomaterials;

7. Year-wise publications of the top ten authors along with deviation;

8. Degree of Collaboration of Authors;

9. Testing and Application of Lotka's Law;

10. Application of Bradford's Law towards ranking of Journals.

V. Hypotheses

1. The significant value of the publication trend of the future is predictable.

2. There is no significant difference in the distribution of publication by authors between the prediction of Lotka's Law and the distribution obtained empirically from the database on nanomaterials.

VI. Methodology

Data on nanomaterials has been downloaded from Web of Science for ten years and a few scientometric techniques applied towards scientometric analysis. The type of research is descriptive research and the 10 years data which has been taken for the research is on the basis of judgement sampling.

VII. Limitations

Research publications on nanomaterials indexed in Web of Science alone has been utilized and that too only for 10 years has been downloaded, i.e, from 2003 to 2012, for this research work.

VIII. Analysis and Interpretation

Table I Year-Wise Publication of Records with Local Citation Score And Global Citation Score

Publication Year	Recs	LCS	GCS
2003	653	775	17676
2004	852	1191	21641
2005	1069	1177	24220
2006	1333	1252	26553
2007	1499	1447	28735
2008	1722	1228	25108
2009	1910	1272	25611
2010	2235	1009	20395
2011	2746	508	13919
2012	2939	110	4227
Total	16958		

The Average no. of Articles published from 2003 to 2012 is 16958. The deviation of the year to year publication is 3.02765 and the percentile analysis is 0.178538. As the deviation between the published article is less, so the possibility of predicting the future trend of publication is high and the same has been analyzed and predicted for the next 10 years. The findings reveals that 2007 publications were the most local citation score 1447 (%) leaving 2009 in the second place in local citation score of 1272 (%) and the year 2006 in the third place with 1252 (%). The articles published in the year 2007 was the most cited articles at Global level with a score of 28735 (%) and as well as Local Citation Score with 1447 citations.

The Chi Square Calculated value is 57.46137. The table value 0.01 level of significance with 9 as degree of freedom is 21.67. As the Chi Square Test denotes the value as 57.46137 which is greater than the table value of 21.67 for a degree of freedom of 9, which reveals that we can go ahead towards the prediction of the no. of publications for the future. Therefore, the Hypothesis 1 can be accepted and the future trend is as follows:

TABLE II Chi Square Test To Confirm The Possibility Of Future Trend Prediction

YEAR	OBSERVED FREQUENCY	EXPECTED FREQUENCY	$(O-E)^2$	$(O-E)^2/E$
2003	653	560.8181818	8497.4876	15.15195
2004	852	813.0363636	1518.16496	1.867278
2005	1069	1065.254545	14.0284298	0.013169
2006	1333	1317.472727	241.096198	0.182999
2007	1499	1569.690909	4997.20463	3.18356
2008	1722	1821.909091	9981.82645	5.478773
2009	1910	2074.127273	26937.7617	12.98752
2010	2235	2326.345455	8343.99207	3.586738
2011	2746	2578.563636	28034.9359	10.87231
2012	2939	2830.781818	11711.1749	4.137081

It was predicted that an average of 4218 articles will be published in the next 10 years on the basis of the last 10 years which very clearly reveals that it will be an increasing trend of publication growth on nanomaterials which is a good sign of the scholarly work around the world.

III. Publication Trend Analysis

PUBLISHED ARTICLES		FUTURE TREND ANALYSIS	
YEAR	NO. OF ARTICLES	YEAR	EXPECTED NO. OF ARTICLES
2003	653	2013	3083
2004	852	2014	3335
2005	1069	2015	3587
2006	1333	2016	3840
2007	1499	2017	4092
2008	1722	2018	4344
2009	1910	2019	4596
2010	2235	2020	4849
2011	2746	2021	5101
2012	2939	2022	5353

IV. Types of Publications

The research publications of nanomaterials are of 11 types of documents. The articles published in journals have the credit of being not only published maximum no. of publications with a publication count of 13144 (77.5%), but

DOCUMENT TYPE	RECORDS	PERCENTAGE	LCS	GCS
Article	13144	77.50914023	7330	138389
Article; Proceedings Paper	2512	14.81306758	1211	24426
Review	1085	6.39816016	1350	42777
Editorial Material	95	0.560207572	36	1244
Meeting Abstract	54	0.318433778	0	3
Review; Book Chapter	32	0.188701498	32	1066
News Item	21	0.123835358	0	3
Letter	10	0.058969218	8	139
Article; Book Chapter	3	0.017690765	2	34
Biographical-Item	1	0.005896922	0	0
Correction	1	0.005896922	0	4
TOTAL	16958	100		

TABLE V LANGUAGEWISE PUBLICATIONS

LANGUAGE	NO. OF RECORDS	PERCENTAGE ANALYSIS	LCS	GCS
English	16063	94.722255	9862	206339
Chinese	695	4.0983607	84	1474
Japanese	84	0.4953414	13	117
German	30	0.1769077	0	40
Korean	23	0.1356292	5	49
French	17	0.1002477	0	17
Polish	14	0.0825569	1	25
Spanish	9	0.0530723	0	7
Czech	5	0.0294846	1	7
Russian	5	0.0294846	1	2
Ukrainian	4	0.0235877	0	0
Italian	2	0.0117938	0	0
Rumanian	2	0.0117938	0	2
Serbo-Croatian	2	0.0117938	0	0
Croatian	1	0.0058969	0	0
Persian	1	0.0058969	0	0
Portuguese	1	0.0058969	2	6
Total	16958	100		

also with a maximum no. of Global Citation Score of 138389 and Local Citation Score of 7330. The articles published in proceedings are in the second place with the publication count of 2512 (14.8%) and third place in the Global Citation Score of 24426 and Local Citation Score with a citation count of 1211. All the reviews published on nanomaterials are in the third place with a publication of 1085 (6%), but in the second place with the Global Citation Score of 1350 and Local Citation Score of 24426. The Editorial Material were 95, Book Chapter Review were 32, News Item were 21, letters were 10, Book Chapter Article were 3, Bibliographical item and corrected publication were 1 publication each.

The total research publications (16958) on nanomaterials were published in seventeen different languages. Among them English language publications were the maximum literature output with a record count of 16063 (94.7%) with a citation count of 206339 as Global Citation Score and 9862 as Local Citation Score. Chinese language literatures were in the second place with 695 records (4%) with 1474 Global Citation Score and 84 Local Citation Score. The Japanese language literatures were in the third place with 84 (0.49%) with 117 Global Citation Score and 13 Local Citation Score. German language with 30 (0.17%), Korean 23 (0.13%), French 17(0.10%), Polish 14 (0.08%), Spanish 9 (0.05%), Czech 5 (0.029%, Russian 5 (0.029%), Ukrainian 4(0.023%), Italian 2 (0.011%), Rumanian 2 (0.011%), Serbo-Croatian

VI. AUTHORSHIP PATTERN

AUTHORSHIP	NO. OF PUBLICATIONS
1	936
2	2449
3	3177
4	3302
5	2701
6	1860
7	1072
8	623
9	356
10	209
11	121
12	51
13	38
14	13
15	11
16	13
17	7
18	2
19	5
20	1
21	2
22	2
23	0
24	1
25	2
26	2
27	1
30	1
Total	16958

TABLE VII RANKING OF AUTHORS FOR THE TOP 10 SPOT WITH CITATION SCORES

Rank	Author	Recs	Tlcs	Tgcs
1	Zhang L	95	49	1039
2	Wang J	81	180	1093
3	Wang Y	78	23	605
4	Liu Y	71	40	422
5	Zhang Y	69	33	472
6	Kim JH	64	39	643
7	Li Y	63	30	777
8	Wang L	59	35	496
9	Li J	57	31	696
10	Kim J	55	30	776

2 (0.011%), Croatian 1 (0.005%), Persian 1 (0.005%) and Portuguese 1 (0.005%) were the remaining languages in which literatures published on nanomaterials in Web of Science.

Out of the total no.of publications of 16958, the single author published 936 (5.5%) publications, whereas, the multi-authored papers published 16022 (94.57%) publications. Therefore, it has been proved that single authored research publications were dominated by the multi-authored research publications on nanomaterials.

The ranking of the authors has been done on the basis of publishing maximum no. of publications. Out of the top ten authors, it was revealed that Zhang L. published 95 publications with 49 Total Local Citation Score and 1039 Global Citation Score with a break up figure of 11 Chinese language records and 84 records in English. Out of that 86 were research articles in journals, 4 in Proceedings and

5 as reviews. Wang J involved in publishing 9 Chinese publications and 72 English Publications. Out of that 72 were journal articles, 7 articles in proceedings, 1 was review and 1 was book chapter. Wang J was the first in Total Global Citation Score of 1093 and Total Local Citation Score of 180. Wang Y involved in publishing 5 Chinese publications and 73 English Language publications. Out of that 68 were journal articles, 7 articles were published in proceedings and 3 were reviews. Liu Y involved in publishing 7 articles in Chineseand 64 articles in English language. Out of that 63 were journal articles, 5 articles were published in proceedings and 3 were reviews. Zhang Y involved in publishing 10 Chinese publications and 59 English publications. Out of that 59 were journal articles, 6 were published in proceedings

TABLE VIII YEAR-WISE PUBLICATION OF THE TOP TEN AUTHORS AND DEVIATION FOR THE 10 YEARS

YEAR	Zhang L	Wang J	Wang Y	Liu Y	Zhang Y	Kim JH	Li Y	Wang L	Li J	Kim J
2003	1	0	0	1	2	1	2	2	1	0
2004	2	2	4	0	3	2	3	2	3	1
2005	6	3	5	1	4	4	7	0	1	1
2006	10	9	9	7	7	7	3	3	7	7
2007	4	6	8	9	4	2	7	7	5	6
2008	15	5	6	8	5	10	5	1	7	6
2009	12	10	7	6	8	7	7	9	5	3
2010	14	10	8	10	9	10	6	9	6	5
2011	15	15	10	8	15	9	8	12	8	6
2012	16	21	21	21	12	12	15	14	14	20
Total	95	81	78	71	69	64	63	59	57	55
Deviation	5.77831	6.36745	5.45283	6.0818	4.17532	3.921451	3.6833	4.954235	3.802046	5.6814
Percentile	60.8243	78.6105	69.9081	85.66	60.5119	61.27267	58.465	83.97008	66.70257	103.3

and 4 were reviews.Kim J.H. involved in publishing all the 64 articles in English Language. Out of that 50 were Journal articles, 13 articles were published in proceedings and 1 as Editorial. Liu.Y. involved in publishing 9 articles

in Chinese language and 4 articles in English. Out of that 56 articles were published in English, 5 articles in proceedings, 1 as meeting abstract and 1 as review.Wang L.involved in publishing 7 articles in Chineselanguage and 52 articles in

TABLE IX DEGREE OF COLLABORATION OF AUTHORS

YEAR	NO. OF SINGLE AUTHOR	NO. OF MULTI AUTHORED ARTICLES	TOTAL NO. OF AUTHORS	TOTAL NO. OF ARTICLES
2003	50	2644	2694	653
2004	70	3338	3408	852
2005	84	4354	4438	1069
2006	98	5442	5540	1333
2007	104	6153	6257	1499
2008	109	7214	7323	1722
2009	97	8448	8545	1910
2010	117	9723	9840	2235
2011	117	12466	12583	2746
2012	90	13734	13824	2939
	936	**73516**	**74452**	**16958**

C=NM/NM+NS 73516/74452
DOC 0.987428142

TABLE X TESTING AND APPLICATION OF LOTKA'S LAW THROUGH LOTKA PROGRAMME

No. of Authors	No. of Records
30	1
27	1
26	2
25	2
24	1
22	2
21	2
20	1
19	5
18	2
17	7
16	13
15	11
14	13
13	38
12	51
11	121
10	209
9	356
8	623
7	1072
6	1860
5	2701
4	3302
3	3177
2	2449
1	936
Total Records	16958

=======LOTKA RESULTS=======
C-Value:0
Beta: 1.26
 1%: 0.2976 1   Failed
 5%: 0.2483 1   Failed
10%: 0.2227 1   Failed
============**DATA**============

English.out of that 51 were journal articles, 4 were published in proceedings, 2 were meeting abstracts and 2 as reviews. Kim .J. published all the 55 articles in English Language. Out of those publications, 40 were journal articles, 12 were published in proceedings and 3 were published as reviews.

The year-wise publication of the top ten authors were found in order to find out the percentile deviation analysis for the 10 years time. The analysis reveals that Zhang L, Zhang Y and Kim J.H. have more or less closely associated with 61% of deviation. Li. Y, have the low deviation of 58% and Kim J's publications deviates to 100%. All the top ten authors have more deviations, therefore, the future publication trend

of the scientists may not be possible to analyse.

The degree of collaboration has been analysed through Subramanyan's (1983) formula (C=Nm/Nm+Ns). The degree of Collaboration of the single author and multi authored publications on nanomaterials from 2003 to 2012 has been calculated and found that the collaboration is 0.987428142.

The application and testing of Lotka's law has been done the beta value is less by 0.01 value, as it reveals as 1.26 and the significant critical value failed at three levels (i.e, 1%, 5% and at 10%). Therefore, the hypothesis no.2 is rejected as the prediction of the Lotka's Law is having significant difference from the actual no. of publications.

TABLE XI CORE JOURNALS ANALYSIS:TABLE OF (ZONE 1) CORE JOURNALS

NAME OF THE CORE JOURNAL	NO. OF RESEARCH PUBLICATIONS
JOURNAL OF NANOSCIENCE AND NANOTECHNOLOGY	325
JOURNAL OF ALLOYS AND COMPOUNDS	320
JOURNAL OF MATERIALS CHEMISTRY	264
MATERIALS LETTERS	230
JOURNAL OF POWER SOURCES	210
MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING	206
RARE METAL MATERIALS AND ENGINEERING	201
APPLIED SURFACE SCIENCE	170
THIN SOLID FILMS	169
MATERIALS CHEMISTRY AND PHYSICS	165
ELECTROCHIMICA ACTA	162
SURFACE & COATINGS TECHNOLOGY	161
JOURNAL OF MATERIALS SCIENCE	156
NANOTECHNOLOGY	122
MICROELECTRONIC ENGINEERING	119
JOURNAL OF APPLIED PHYSICS	116
APPLIED PHYSICS LETTERS	103
COMPOSITES SCIENCE AND TECHNOLOGY	95
JOURNAL OF CRYSTAL GROWTH	93
MATERIALS RESEARCH BULLETIN	90
CHINESE JOURNAL OF INORGANIC CHEMISTRY	89
CERAMICS INTERNATIONAL	88
JOURNAL OF NON-CRYSTALLINE SOLIDS	88
JOURNAL OF THE EUROPEAN CERAMIC SOCIETY	86
JOURNAL OF INORGANIC MATERIALS	84
SENSORS AND ACTUATORS B-CHEMICAL	83
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION B-BEAM INTERACTIONS WITH MATERIALS AND ATOMS	81

PROGRESS IN CHEMISTRY	78
JOURNAL OF APPLIED POLYMER SCIENCE	76
JOURNAL OF PHYSICAL CHEMISTRY	76
WEAR	76
ACTA MATERIALIA	74
JOURNAL OF MAGNETISM AND MAGNETIC MATERIALS	73
BIOMATERIALS	72
MATERIALS TRANSACTIONS	71
JOURNAL OF NANOPARTICLE RESEARCH	70
JOURNAL OF PHYSICS D-APPLIED PHYSICS	69
PHYSICAL CHEMISTRY CHEMICAL PHYSICS	69
DENTAL MATERIALS	67
INTERNATIONAL JOURNAL OF HYDROGEN ENERGY	67
SOFT MATTER	67
JOURNAL OF SOL-GEL SCIENCE AND TECHNOLOGY	65
JOURNAL OF THE AMERICAN CERAMIC SOCIETY	65
OPTICS EXPRESS	65
POLYMER	65
JOURNAL OF CERAMIC PROCESSING RESEARCH	63
JOURNAL OF COMPUTATIONAL AND THEORETICAL NANOSCIENCE	63
JOURNAL OF NUCLEAR MATERIALS	62
MATERIALS & DESIGN	62
ELECTROCHEMISTRY COMMUNICATIONS	60
JOURNAL OF COLLOID AND INTERFACE SCIENCE	59
TOTAL	5710

ZONE	NO. OF JOURNALS	NO. OF ARTICLES
Zone 1	51	5710
Zone 2	186	5664
Zone 3	1662	5584
TOTAL	1899	16958

S. Prabakar and A. Thirumagal

The Bradford's Law has been applied to find out the core journals. The finding reveals that the web of science database published a total no. of 1899 journals in which 16958 research publications were published. In order to find out the core journals, according to the Bradford's Law the database has been segregated into three zones. The selection of the core journals has been valued according to the more no. of articles (5710) published in less no. of journals (51) which are stated in Zone 1. The Zone 2 consists of 186 journals and 5664 articles. It reveals that the no. of journals are more than Zone 1 and lesser than Zone 3. The remaining no. of articles (5584) and the journals (1662) responsible for the publication are in the 3rd Zone.

IX. CONCLUSION

The publications of any research on any subject should be evaluated to know the real status of the quality of the research work. The emergence of Nanomaterials tends to do the scientometric study in order to know the year-wise research output as well as the utilization through the no. of citations and also to forecast the future trend. It was revealed about the different types of publications and the languages used for this purpose. Bradford's law has been applied to find out the core journals. Through the research it is suggested that the scientists doing research around the worldshould be encouraged exclusively to do many more research in order to yield innovative results on nanomaterials which can be implemented for the benefit of the society.

REFERENCES

[1] Diwan, Parag and Ashish Bhardwaj, "The Nanoscope: Encyclopedia of Nanoscience & Nanotechnology", New Delhi: Pentagon Press, Vol.1-6, 2005.

[2] Shailendra Kumar, and Shehbaz Husain Naqvi, "Research Output in the Field of Natural Sciences: A Bibliometric Case Study of Jamia Millia Islamia University", New Delhi, Pub.SAGE, *IFLA Journal,* 2010.

[3] Pradhan, Pallab, Saroj Panda and Rajesh Chandrakar, "Authorship Pattern and Degree of Collaboration in Indian Chemistry Literature", 8th International CALIBER-2011, Ahmedabad:INFLIBNET.

[4] Thirumagal, "Bibliometric Study of Nanotechnology in India", *SRELS Journal Information Management,* Vol.49, No.5, October 2012.