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SCIENTOMETRIC ASSESSMENT OF GLOBAL PUBLICATIONS OUTPUT ON GREEN TECHNOLOGY DURING 2006-2015

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ABSTRACT

This paper attempts to highlight the growth of green technology research in global based on the number of publications appeared in the web of science database. During the period (2006-2015) a total of 8610 publications were published by the scientists in the field. The average number of publication per year was 861. The highest numbers of publications (1512) were published in the year 2015. Authors from USA have contributed maximum number of publications compared with other countries and India stood 4th rank in terms of productivity in this field. This paper analysed the broad features of literature on green technology focusing on year wise growth of publications, most prolific authors, highly productive institutes, highly productive countries, language wise distributions of publications, high productive subjects and most preferred journals for publication.

Keywords: Green technology, relative growth rate and doubling time

1 Introduction

Scientometrics is a novel discipline which analyses scientific publications; to explore the structure and growth of scientific publications. The Bibliometric / Scientometric / Informetric techniques are widely and frequently used to analyse various quantitative or

qualitative aspects of publications. It is a scientific field that studies the evolutions of science through some quantitative and qualitative measures of scientific information, as more number of scientific articles is published in a given period of time, and their citation impact, etc. The history of science and technology, philosophy of science and sociology of scientific knowledge are the related fields of Scientometrics.

Scientometric is an academic discipline and number of research is being carried out for a quantitative study of the various aspects of literature of a given subject. It is a branch of Information Science which analyses quantitatively the published information based on bibliographic data elements. The Scientometric techniques are being used for a variety of purposes like determination of various scientific indicators, evaluation of scientific output, selection of journals for libraries and even forecasting the potential on particular field. The popularity in the adoption of Scientometrics techniques in various disciplines stimulated stupendous growth of literature on Scientometrics and its related areas.

The Scientometric techniques are used to understand the magnitude of the growth of a particular discipline. Especially the trends and pattern in growth, contribution of a particular author or institutions and the collaboration pattern, relative growth rate and so on.

2.Scientometric: An Overview

Scientometric is of recent origin and relatively a new area, which emerged as a research front in its own way in Information Science. The terms like 'Librametrics', 'Bibliometrics', 'Informetrics' and 'Scientometrics' have been used synonymously in order to study the growth of literature in a discipline and other aspects of literature quantitatively. Russians used the term Scientometrics in the late sixties for quantitative aspects of studies in science of science. Now, Scientometrics means studies of quantitative aspects of science of science and technology and would include "technometrics" also. There has been ever growing interest among scientometrists to publish data on individual scientists who are role model scientists or mentors.

3. Review of related Literature

Brij Gupta and AdarshBala (2013)1 analysed the research output of India in epilepsy research during 2002-11 on several parameters including the growth, rank and global publications share, citation impact, share of international collaborative papers, contribution of major collaborative partner countries, contribution of various subject-fields, contribution and

impact of most productive institutions and authors, media of communication and characteristics of high cited papers. The Scopus Citation Database has been used to retrieve the data for 10 years (2002-11).

Mini Devi and Lekshmi (2014)2 the article explores the Scientometric assessment of publication productivity of Jawaharlal Nehru Tropical Botanic Garden and Research Institute (JNTBGRI). The data for the study was taken from the Annual report of the JNTBGRI from 2001-2010 which were then tabulated and analysed. The scientists of JNTBGRI prefer mostly Indian journals to publish their articles.

Kumar (2014)3 made a Scientometric Study on Digital Literacy in Online Library Information Science and Technology Abstracts (LISTA) during the year 1997 to 2011. And, the study also examined the distribution of articles (age-wise, year-wise, and article-wise), authorship pattern, subject, language, and geographical distribution. Bradford's law used to determine the scattering of journal articles.

Gupta et al. (2013)4 analysed India's performance in science and technology (S&T), using publications data and applied different quantitative and qualitative measures. Its focuses on India's global publication share, growth rate, citation quality, international collaborative publications share, its publication share and distribution in various broad and narrow subjects using 15 years data from the Scopus international multidisciplinary database. The study suggests the need to increase the pace of Indian scientific research and also improve its quality.

Mu-Hsuan Huang and Hsiao-Wen Yang (2013)5 made a study on bibliometric analysis to explore papers and patents in the field of fuel cell. The research data were retrieved from the WoS (Web of Science) database and USPTO patent data from the period between 1991 and 2010, which consists of 20,758 papers and 8,112 patents. The results indicate that there is an upward growth in both papers and patents in fuel cell, with a higher growth rate for papers.

Santhanakarthikeyan, et al. (2013)6 discussed the origin and development of Scientometric study by comparing and contrasting currently available e-resources with pre-internet era. They also briefly touch upon the prospects of fast emerging wireless technology and the necessity of existing methods of study to be constantly transformed to ensure the compatibility of the existing sources with the anticipated technological advancements.

ShadiAsadzandi (2013)7 made a Scientometric study on quantity and quality of publication trends of media literacy based on Scopus reports. The population under the study was composed of 510 documents on media literacy published through 2011. The results were

analyzed based on date of publication, type of document, language of the documents, source of publications, subject areas, authors and their affiliations.

Kalaiappan et al. (2010)8 made a bibliometric analysis of remarkable contributions of Prof. G.N. Ramachandran (popularly known as GNR), an eminent biophysicst and crystallographer so as to understand the nature and magnitudes of his contributions to the field. This paper also examines the contributions of GNR in the fields of biophysics and crystallography, magnitude of his collaborations, and year-wise distribution of his productivity.

Kanagavel, et al. (2013)9 made a Scientometric analysis of research productivity in Wind Power and a sum of 325 records were obtained from the Web of Science for 5 calendar years spanning from 2008 to 2012. The study gives an analytical view of the research literature output in Wind Power research in context of the India by language and forms of publications and prolific authors.

Satish Kumar, et al. (2012)10 presented Scientometric portrait of Dr. SwaranJeet Singh Flora, a well-known scientist of Defense Research Development Establishment (DRDE), Ministry of Defense, Gwalior, India. He has published a total of 278 articles in national and international journals on various domains like arsenic, lead, drug development for metal toxicity, oxidative stress and role of antioxidants, etc. The scientist has collaboration research along with high productivity.

Sujit Bhattacharya and Shilpa (2011)11 made through bibliometric and other innovation indicators (standards, products/processes developed), the present state of development of nanotechnology research and innovation in India. The findings are discussed in the context of China's activity in this field.

Gupta and AdarshBala (2011)12 examined India's performance in S&T on several quantitative measures including India's global publication share, rank and growth rate, its publication share in various subjects in terms of national and global context using 15 years publications data (1996-2010) from the Scopus database.

4. Green Technology

Green technology is a recent trend, and erode the pollution in all aspect of human life, like protection of forest and environment. It is benefit of nature and also clean and green human and earth. To ensure the earth remains healthy for all life and conventional and non conventional sources of energy. This technology helps recycle waste materials, water, air and conserve energy and rejuvenate the ecosystems.

Green technologies encompass various aspects of technology which help us reduce the human impact on the environment and create ways of sustainable development. Social equitability, economic feasibility and sustainability are the key parameters for green technologies. Today the environment is racing towards the tipping point at which we would have done permanent irreversible damage to the planet earth. Green technology uses renewable natural resources that never depletes. Green technology uses new and innovative energy generation techniques.

This is clear from the scientometric evidence from 2006 to 2015, that the number of publications in the Web of Science database was increased from 381 to 1512. Therefore the present study has been undertaken to know the growth and development of publications in the field of green technology.

5. Need for the study

Bibliometric analysis of scientific publications is an important aspect of research endeavor in Information Science in recent years. The bibliometric studies are used to identify the pattern of publications, authorship, citations, secondary journal coverage, and so on. These factors can give an insight into the dynamics of a subject, which consequently leads to better information handling and management. Bibliometric analysis has received adequate attentions in recent years and it has been widely applied to evaluate the research performance of the scientists and the growth of various disciplines. Further, bibliometric data could be used for the identification of emerging research areas, and in the evaluation of research performance of individual scientists, research groups and countries. It aims to integrate the cognitive or intellectual structure of research with a view to appraise the relations among the authors, institutions, journal articles and as a means of assisting the peer review procedure. Bibliometric analysis of literature in various disciplines has been carried out by using primary journals or secondary sources to examine the quantitative aspects of literature growth in a particular field of knowledge. Quantitative measurement of publications, citations and other parameters have been largely applied and used in evaluating scientific research.

6. Objectives for the Study

The main objective of this study is to analyse the global research performance in the field of green technology as reflected in the publication output during 2006-2015. In particular, the study focuses on the following aspects:

- Document types used for communications
- Annual growth of publications
- Most prolific authors
- Geographical distribution of research output
- Highly productive institutes
- Language-wise distribution of publications
- Most preferred source titles for publication in the field and
- High productive subject areas
- Limitation of the study

7. Limitation of the study

This paper is focus on the growth of green technology research in global based on the number of publications appeared in the web of science database. During the period (2006-2015)

8. Materials and Methods

The Web of Science database was used for retrieving data on green technology in topic field. A total of 8610 publications were downloaded and analysed by using the Microsoft excels per the objectives of the study. The Web of Science database allows us to refine the results in terms of publication years, countries, institutes, authors, language, subjects and source titles.

9 Data analysis and interpretations

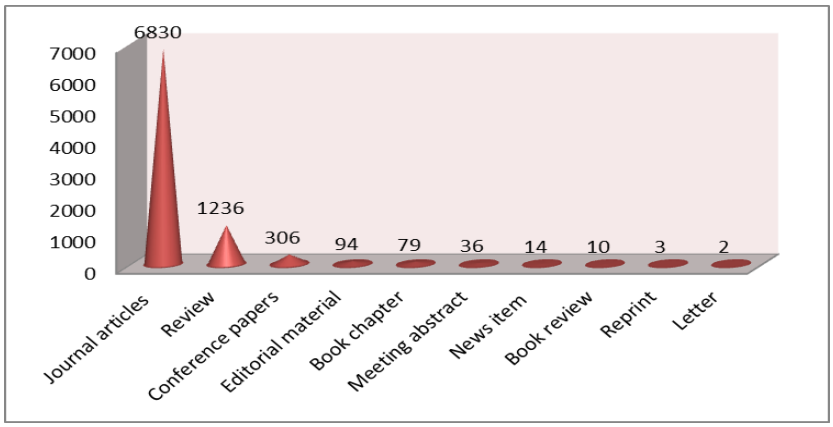
9.1 Forms of publications

Table 1 Forms of publications

S. No.	Forms of publications	No. of publications	Percentage
1	Journal articles	6830	79.33
2	Review	1236	14.36
3	Conference papers	306	3.55
4	Editorial material	94	1.09
5	Book chapter	79	0.92
6	Meeting abstract	36	0.42
7	News item	14	0.16
8	Book review	10	0.12
9	Reprint	3	0.03

10	Letter	2	0.02
Total		**8610**	**100.00**

Figure 1 Form of publications



The table 1 reveals that the major source of publications covered by web of science databases on green technology research is Journal articles with 6,830 publications (79.33%) followed by Review with 1236 publications (14.36%). Conference papers ranks the third position with 306 publications (3.55%), Editorial material with 94 publications (1.09%) and remaining forms are less than one percentage as seen in the table. The results indicate that the research outputs on green technology of the period covered by the study are mostly published in the form of journal articles.

9.2 Growth of publications

Relative Growth Rate (RGR) and Doubling Time

The Relative Growth Rate (RGR) is the increase in number of articles or pages per unit of time. This definition derived from the definition of relative growth rates in the study of growth analysis in the field of green technology. The mean relative growth rate (R) over the specific period of interval can be calculated from the following equation.

Relative Growth Rate (RGR)

$1 - 2\ R = \text{Log}\ W_2 - \text{Log}\ W_1 / T_2 - T_1$

Whereas

1-2 R- mean relative growth rate over the specific period of interval

$Log_e W_1$ - log of initial number of articles

$Log_e W_2$ - log of final number of articles after a specific period of interval

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

The year can be taken here as the unit of time.

Doubling Time (DT) = 0.693/R

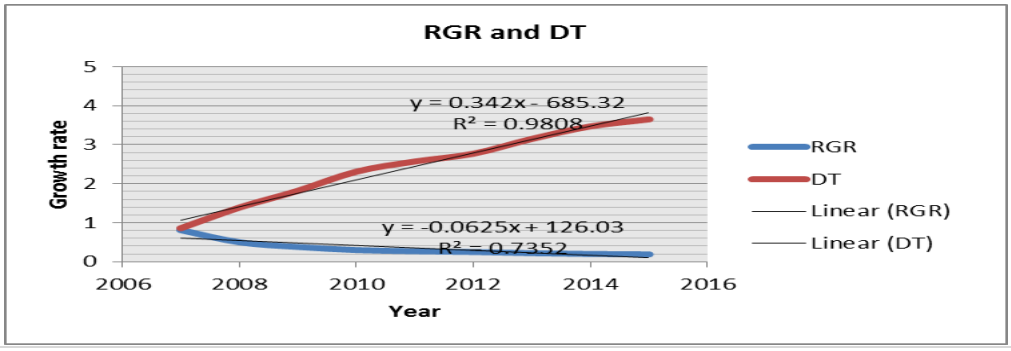
Table 2 Relative growth rate (RGR) and Doubling time (DT) of publications

Year	No. of Publications	Cumulative Total	W1	W2	RGR	DT
2006	381	381	-	5.94	-	-
2007	473	854	5.94	6.75	0.81	0.86
2008	555	1409	6.75	7.25	0.50	1.39
2009	641	2050	7.25	7.63	0.38	1.82
2010	736	2786	7.63	7.93	0.30	2.31
2011	866	3652	7.93	8.20	0.27	2.57
2012	1001	4653	8.20	8.45	0.25	2.77
2013	1153	5806	8.45	8.67	0.22	3.15
2014	1292	7098	8.67	8.87	0.20	3.47
2015	1512	8610	8.87	9.06	0.19	3.65

During 2006-2015, a total of 8610 publications were published on green technology research by various countries. The average number of publications were produced per year was 861. The highest numbers of publications (1512) were published in 2015.

The year wise RGR is found to be in the range of 0.81 to 0.19. It has been observed from Table 2 and figure 2 that RGR is downward trend from 2007 (0.81) to 2015 (0.19). The doubling time (DT) was upward trend from 2007 (0.86) to 2015 (3.65).

Figure 2 Relative growth rate for research output



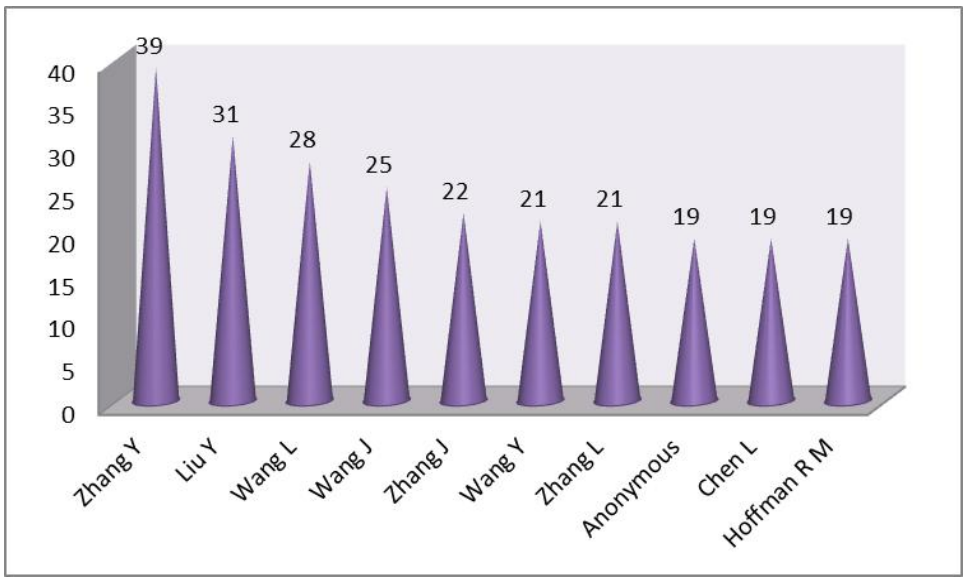
9.3 Most prolific authors

Table 3 Identification of most prolific authors

Rank	Author	No. of publications	Percentage
1	Zhang Y	39	0.45
2	Liu Y	31	0.36
3	Wang L	28	0.33
4	Wang J	25	0.29
5	Zhang J	22	0.26
6	Wang Y	21	0.24
7	Zhang L	21	0.24
8	Anonymous	19	0.22
8	Chen L	19	0.22
10	Hoffman R M	19	0.22
11	Clark J H	18	0.21
12	Kumar A	18	0.21
13	Kim H	17	0.20
14	Li Y	17	0.20
15	Li J	16	0.19
16	Li L	16	0.19
17	Li X	15	0.17

Zhang, Y is the most productive author with 39 (0.45%) publications followed by Liu, Y with 31 (0.36%) publications, Wang, L with 28 (0.33%) publications, Wang, J with 25 (0.29%) publications, Zhang, J with 22 (0.20%) publications, Wang, Y with 21 (0.24%) publications, Zhang, L with 42 (0.18%) publications and Anonymous with 19 (0.22%) publications respectively. And a total of 28,528 authors are contributed entire research output of the period under study. Table 3 provides the most prolific authors who have contributed 15 or more publications.

Figure 3 Most prolific authors



9.4 Highly productive institutions

Table 4 Highly productive institutions

Rank	Institutions	Country	No. of Publications
1	Chinese Academy of Science	China	182 (2.11%)
2	Zhejiang University	China	60 (0.70%)
3	Consejo Superior de Investigaciones Científicas (CSIC)	Spain	51 (0.59%)
4	Harvard University	USA	50 (0.58%)
5	Tsinghua University	China	47 (0.55%)
6	University of Tokyo	Japan	46 (0.53%)
7	National University of Singapore	Singapore	45 (0.52%)
8	University of Florida	USA	43 (0.50%)
9	University of Maryland	USA	42 (0.49%)
10	University of Toronto	Canada	42 (0.49%)
11	University of California, Berkeley	USA	41 (0.48%)

In all there were 6524 institutions involved in research activity on green technology. Table 4 presents the top 11 institutes that have contributed 40 or more publications on during 2006-2015. Chinese Academy of Science, China topped the list with 182 publications followed by Zhejiang University, China with 60 publications, Consejo Superior de

Investigaciones Científicas (CSIC), Spain with 51 publications, Harvard University, USA with 50 publications, Tsinghua University, China with 47 publications, University of Tokyo, Japan with 46 publications, National University of Singapore, Singapore with 45 publications and University of Florida, USA with 43 publications.

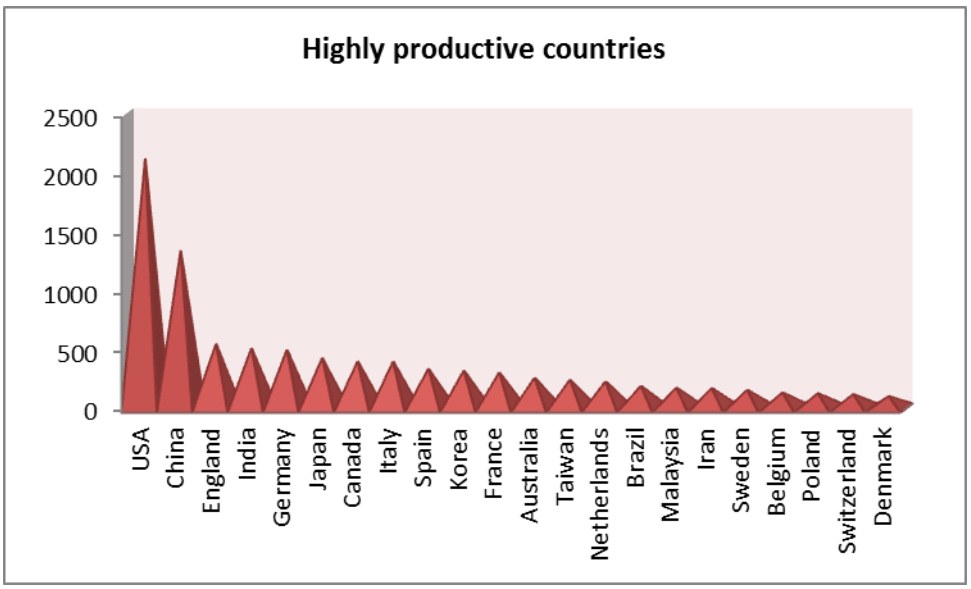
9.5 Geographical distributions of research output

Table 5 Geographical distribution of publications

Rank	Country	Total Publications (%)	Rank	Country	Total Publications (%)
1	USA	2116 (24.58%)	12	Australia	257 (2.99%)
2	China	1336 (15.52%)	13	Taiwan	242 (2.81%)
3	England	546 (6.34%)	14	Netherlands	226 (2.63%)
4	India	508 (5.90%)	15	Brazil	188 (2.18%)
5	Germany	496 (5.76%)	16	Malaysia	174 (2.02%)
6	Japan	426 (4.95%)	17	Iran	170 (1.97%)
7	Canada	397 (4.61%)	18	Sweden	155 (1.80%)
8	Italy	397 (4.61%)	19	Belgium	132 (1.53%)
9	Spain	335 (3.89%)	20	Poland	126 (1.46%)
10	Korea	320 (3.72%)	21	Switzerland	118 (1.37%)
11	France	303 (3.52%)	22	Denmark	100 (1.16%)

There were as many as 104 countries involved in carrying out research in the field of green technology and produced 8610 publications. Table 5 list of countries whose share in the research output is more than 1% of the total output. USA topped the list among all the countries with 2116 publications followed by China with 1336 publications, England with 546 publications, India with 508 publications, Germany with 496 publications, Japan with 426 publications, Canada with 397 publications, Italy with 397 publications, Spain with 335 publications, Korea with 320 publications, France with 303 publications and the remaining countries are publishing less than 3% of the research output in this study period. However, USA and China together accounts for 40% of world green technology research publications. India ranks 4th among the countries publishing green technology publications

Figure 4 Highly productive countries



9.6 Language wise distributions

Table 6 Language wise distribution of publications

Rank	Language	No. of Publications
1	English	8367 (97.18%)
2	Chinese	86 (1.00%)
3	Portuguese	36 (0.42%)
4	German	28 (0.33%)
5	Spanish	25 (0.29%)
6	Polish	17 (0.20%)
7	Japanese	12 (0.14%)
8	French	10 (0.12%)
9	Russian	7 (0.08%)
10	Croatian	4 (0.05%)

Publications on green technology are spread over 20 languages. The study reveals that the maximum number of publications have been published in English language with 8367 (97.18%) publications, followed by Chinese language with 86 (1%) publications, Portuguese language ranks third position with 36 (0.42%) publications, German language with 28 (0.33%) publications, Spanish language with 25 (0.29%) publications, Polish language with 17 (0.20%) publications and Japanese language with 12 (0.14%) publications. The most

predominant language used for communication was English in every year in total productivity on the subject during the study period.

9.7 Most preferred source titles

Table 7 Source Title of Publications

Rank	Source Title	No. of Publications	Percentage	Impact Factor
1	Renewable sustainable energy reviews	158	1.84	6.798
2	Energy policy	121	1.41	2.696
3	Journal of cleaner production	101	1.17	4.959
4	PLOS One	73	0.85	3.234
5	Green chemistry	70	0.81	8.02
6	RSC advances	54	0.63	3.289
7	Journal of green building	52	0.60	0.90
8	Bioresource technology	44	0.51	4.494
9	LWT food science and technology	43	0.50	2.292
10	Applied energy	41	0.48	5.746

Table 7 provides the leading journals each with number of publications and impact factor. The scientific literature on green technology is spread over 2882 different web of science source journals. It reveals that Renewable sustainable energy reviews the list with the highest number of publications 158 (1.84%) and the impact factor is 6.80, followed by Energy policy with a share of 121 (1.41%) publications and the impact factor is 2.70. Journal of cleaner production occupies the third position with 101 (1.17%) publications and the impact factor is 4.96. The fourth highest source title is PLOS One with 73 (0.85%) publications and the impact factor is 3.23, Green chemistry with 70 (0.81%) publications and the impact factor is 8.02 and RSC advances with 54 (0.63%) publications and the impact factor is 3.29.

9.8 High productivity subject areas

Table 8 High productivity subject areas

Rank	Subject	No. of Articles	Percentage
1	Engineering	1866	21.67
2	Chemistry	1414	16.42
3	Environmental sciences ecology	1079	12.53
4	Science technology	1071	12.44
5	Materials science	829	9.63
6	Energy fuels	809	9.40
7	Biotechnology applied microbiology	555	6.45
8	Physics	519	6.03
9	Biochemistry molecular biology	505	5.87
10	Agriculture	502	5.83

The scientific literature on green technology is spread over 90 different subjects. Table 8 shows high productivity subjects which are contributing more than 500 articles. It is found that Engineering has highest number of articles with 1866 (21.67%) followed by Chemistry contributing 1414 (16.42%) articles. Environmental sciences ecology occupies the third position with 1079 (12.53%) articles. The fourth highest articles belonged to the subject Science technology with 1071 (12.44%), Materials science with 829 (9.63%) and Energy fuels with 809 (9.40%) articles respectively.

10. Conclusions

The present study attempted to highlight the growth and development of research publication on green technology. A total of 8610 publications were published during 2006-2015 and the average number of publication per year was 861. There was a steady growth of publication during the study period. USA topped the list with highest share (33.89%) of publications followed by China with 12.59% share of publications, England with 10.21% share of publications and Germany with 9.14% share of publications. Chinese Academy of Science, China topped the list with 1298 (5.56%) publications followed by National Oceanic and Atmospheric Administration, USA with 424 (1.82%) publications, National Centre for

Atmospheric Research, USA with 350 (1.50%) publications, and Columbia University, USA with 337 (1.44%) publications. The most prolific authors, high productive subjects and also the most preferred journals with impact factor which they publish have also been identified. The single most prevalent type of publications is the journal article, in which 79.33% of the total publication is published. This shows that green technology scientists preferred medium of communications is journal article. A large number of researchers are pursuing their research in the field of green technology, giving hope that more publications would be published on the subject from all over the world in upcoming years.

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