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ABSTRACT

Web of Science (WoS) is a major citation database for scholarly literature. Green Technology is a dynamic area of research in which majority of research work takes place and includes the subjects like Renewable Energy, Green Chemistry, Ecology, etc. The citation data on Green Technology has been retrieved for a period from 2000 to 2015 from WoS, and aims to analyse the Indian contribution in the subject. A total of 16652 papers were downloaded and analyzed by using Hiscite™. This paper discusses on document type, year-wise, RGR & DT, country-wise, institution-wise, and also verifies the fitness of Bradford's law of scattering. The result shows that the research productivity of the educational and research institutions is much recognized in this subject.

Keywords: Scientometrics, Web of Science, Green Technology, Bradford's Law

1. INTRODUCTION

Humankind is in a perilous state which alarms for the techniques and technologies that will retain the earth green. Techniques for generating energy to non-toxic cleaning products are named as "green technology" and current anticipation is that this field will bring innovation and changes in daily life of similar magnitude to the "information technology" explosion over the last two decades. The idea of green technology evolved from the social ecological movement of western industrialized countries during 1960s and 1970s and refers to the generic terms of technology, industrial art or products which can reduce environmental pollution and diminish employment of raw materials, natural resources and energy. The measure of research on green technology all over the world indicates towards the wide acceptance. The majority researches

focus on specific fields, such as green technology innovation, green technology development and green technology expansion, while philosophical reflections upon and inquiry into green technology become fewer. Exact understanding in green technology mainly includes the following four aspects; like Limitation of green technology, Green technology is a dynamic concept, Complexity of green technology and Practical industrial production.

2. SCOPE, METHODOLOGY AND LIMITATION

Web of Science is an online citation database hosted by Thomson Reuters which is designed for providing access to multiple databases, cross-disciplinary research, and in-depth exploration of specialized subfields within an academic or scientific discipline. It is part of the Web of Knowledge, which includes Web of Science, Journal Citation Reports, Essential Science Indicators, Current Contents, ISI Proceedings, BIOSIS previews. The Science Citation Index (SCI), now Science Citation Index Expanded was first promulgated in Science in 1955, as an up-to-date tool to facilitate the dissemination and retrieval of scientific literature. By using a citation index one determines what subsequent papers have cited a particular source documents which is the major advantage of citation indexes over conventional subject indexes and using SCI a user can find high-impact articles from peer-reviewed, influential journals, uncover relevant results in related fields, discover emerging trends that help you to pursue successful research and grant acquisition, identify potential collaborators with significant citation records and integrate searching, writing, and bibliography creation into one streamlined process.

The bibliographic details of the published literature were collected using the following search formulation:

Topic = ((Green* Tech*) OR (Green* Ener*) OR (Green* Chem*) OR (Green* Nanotech*) OR (Environ* Tech*) OR (Clean* Tech*) OR (Eco* Friend*) OR (Sustain* Ener*)) AND Address = (India), Timespan = 2000-2015 and database = SCI-Expanded.

The search was limited for a period from 2000 to 2015 and 16652 papers was retrieved. Once a marked list of papers was created, the resulting export file was processed by HistCite™ (Bibliometric Analysis and Visualization Software developed by Garfield et al., 2006). Even though all the publications emanating in the subject Green Technology are not covered in Web

of Science, the study is confined to Web of Science only. And another limitation is that the publications of science departments alone are considered for the study period.

3. REVIEW OF LITERATURE

Aswathy and Saravanan (2016) conducted a study on authorship and collaboration pattern in Green technology literature with reference to India from 2000 to 2012. Authorship analysis shows that mega authored contributions are more. Analysis confirms Lotka's Law of author productivity.

Aswathy and Gopikuttan (2014) presented a study on spacecraft propulsion research which is a dynamic area of research in which majority of research work is being done based on Web of Science which is a premier research platform, helping to find, analyze, and share information in the sciences, social sciences, arts, and humanities from 1999 to 2012. This study analyzed the Indian contribution in the subject area. The study also analyses year-wise, language-wise, document type-wise distribution and also the country-wise analysis which provides the percentage of Indian share to this subject. The analysis also includes institution-wise categorization; Degree of Collaboration and also verifies the fitness of Bradford's Law of Scattering.

Sudhier (2013) analyzed the research productivity of physicists at the Indian Institute of Science (IISc) as well as the University of Kerala (KU) during 2004-2008 and summarizes and reviews the various research evaluation studies of institutions and disciplines. The study concludes that multi-authorship is prevalent in IISc while in KU solo research is predominant since the degree of collaboration of publication was calculated to be 0.94 in IISc researchers and 0.40 in the case of the KU. Journals are the most preferred channel of publication of IISc researchers while KU researchers prefer to publish their research findings mostly in national seminars.

Gupta *et al*. (2013) studied India's performance in science and technology (S&T), using publications data and different quantitative and qualitative measures and focused 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 velocity of Indian scientific research and also improve its excellence compared with other developed and developing countries and also suggests the need for India to build up its scientific capability, competence and knowledge base to help bridging the scientific and technological gap with leading countries.

4. OBJECTIVES

The main objectives of the study are to do analysis on:

1. Document types and the year-wise analysis
2. Pattern of growth of literature during 2000 - 2015
3. Core journals in Green Technology
4. Collaborating countries and their share of contribution
5. Institutional affiliation of authors contributing articles
6. To find the fitness of Bradford's law of journal distribution

5. DATA ANALYSIS, RESULT AND INTERPRETATION

5.1. Document types and the year-wise analysis

Table 1 provides details regarding various document types published on Green technology included in WoS which shows research papers 89.60% (14921) are journal articles followed by 1653 (9.93%) reviews and 45 (0.27%) conference papers.

Table 1: Type of Documents published in Green Technology

DOCUMENT TYPE	# PAPERS	%	LCS	GCS
Article	14921	89.60	4280	72609
Review	1653	9.93	538	24920
Article; Proceedings Paper	45	0.27	177	4473
Editorial Material	20	0.12	6	117
Review; Book Chapter	8	0.05	11	408
Others	5	0.03	3	158
Total	16652	100		

% - Percentage; LCS – Local Cite Score; GCS – Global Cite Score

The year-wise distribution of the literature published on Green technology is given below. From the Table 2, it is evident that in year 2000 the number of published documents is 218 while in 2015 the papers has increased to 2780 and it is clear that there is an increase in the literature productivity in Green technology every year. Also the Local Citation Score (**LCS** - Local Citation Score, *i.e*. Citations in the collection to the articles published in that year) and Global Citation Score (**GCS** - Global Citation Score. *i.e.* Citations in Web of Science to papers published that year in the collection) from WoS is provided here.

Table 2: Year-wise distribution of Green Technology publications

YEAR	# PAPERS	%	LCS	GCS
2000	218	1.31	204	3784
2001	292	1.75	367	5736
2002	303	1.82	309	5304
2003	374	2.25	661	6989
2004	427	2.56	394	7257
2005	490	2.94	614	8204
2006	600	3.60	727	10375
2007	776	4.66	917	12170
2008	871	5.23	973	11772
2009	1013	6.08	1528	11747
2010	1088	6.53	1397	8743
2011	1399	8.40	1576	7079
2012	1603	9.63	1443	3525
2013	1988	11.94	1212	18527
2014	2430	14.59	834	14893
2015	2780	16.69	301	7011
	16652	100		

% - Percentage; LCS – Local Cite Score; GCS – Global Cite Score

Figure 1 represents the graphical representation of growth of Green technology for the study period.

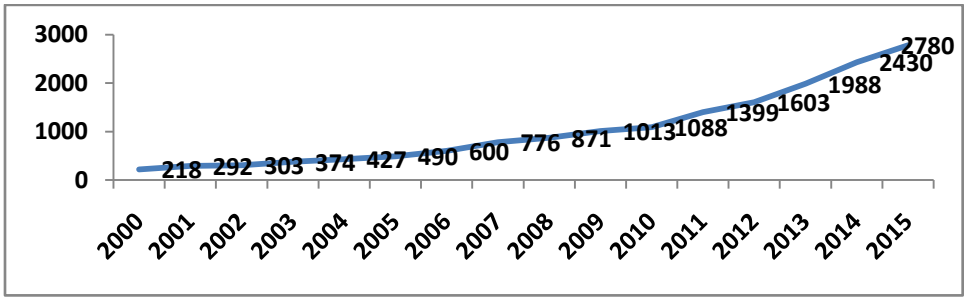

Fig. 1 Year vs. No. of articles

5.2. Relative Growth Rate and Doubling Time of Green Technology literature during 2000-2015

The definition of Relative Growth Rates (RGR) has been derived from the study of growth analysis of individual plants and effectively applied in the field of Botany (Hunt, 1978), which in turn had its origin from the study of rate of interest in the financial investment (Blackman, 1919), which is a measure to study the growth or increase in number of articles, pages per unit of articles and pages per unit of time (Mahapatra, 1985). Mathematical representation of the mean RGR of articles over a specific period of interval is:

$$R(P) = \frac{\text{Log}_e 2P - \text{Log}_e 1P}{2^T - 1^T}$$

Doubling Time (DT) is the time required for articles or citations to grow double from the exiting number, which is directly related to RGR. DT can be determined using the mathematical formula

$$DT = \frac{\text{Log}_e 2}{R(P)} = \frac{0.693}{R(P)}$$

Table 3 provides the calculated RGR and DT of Green technology literature during 2000 to 2015. It is observed from the table that the RGR is not steady with various ups and downs. The mean RGR has declined from 0.35 to 0.20 and further in 2010 and 2015 declined to 0.18. But the DT has been increased from 0.82 to 3.79 and the steady growth is visible with increase in mean DT from 1.81 to 3.56.

Table 3: Relative Growth Time and Doubling Time of Green Technology

YEAR	# PAPERS	CUMULATIVE	w1	w2	R(a)	Mean (a) 1-2	DOUBLING TIME	Mean pt (a) 1-2
2000	218	218		5.38				
2001	292	510	5.38	6.23	0.85		0.82	
2002	303	813	6.23	6.70	0.47		1.49	
2003	374	1187	6.70	7.08	0.38		1.83	
2004	427	1614	7.08	7.39	0.31		2.26	
2005	490	2104	7.39	7.65	0.27		2.61	
2006	600	2704	7.65	7.90	0.25		2.76	
2007	776	3480	7.90	8.15	0.25	0.35	2.75	1.81
2008	871	4351	8.15	8.38	0.22		3.10	
2009	1013	5364	8.38	8.59	0.21		3.31	
2010	1088	6452	8.59	8.77	0.18		3.75	

2011	1399	7851	8.77	8.97	0.20		3.53	
2012	1603	9454	8.97	9.15	0.19		3.73	
2013	1988	11442	9.15	9.35	0.19		3.63	
2014	2430	13872	9.35	9.54	0.19		3.60	
2015	2780	16652	9.54	9.72	0.18	0.20	3.79	3.56
	16652							

5.3. Core journals contributing literature in Green Technology

The top ten journals contributing to Green technology are provided in Table 4. Among these journals, *RSC Advance*s is in the top with 442 papers followed by *Renewable & Sustainable Energy Reviews* with 254 papers. *Current Science* possesses third position with 222 articles. The citations including Local Citation Score and the Global Citation Score of the journals are also provided here.

Table 4: Top Journals vs. Citations received in Green Technology

JOURNAL NAME	# PAPERS	%	LCS	GCS
RSC Advances	442	2.65	202	2434
Renewable & Sustainable Energy Reviews	254	1.53	353	4121
Current Science	222	1.33	194	1733
Spectrochimica Acta Part A-Molecular And Biomolecular Spectroscopy	192	1.15	532	1602
Tetrahedron Letters	155	0.93	244	1919
Journal Of Scientific & Industrial Research	112	0.67	56	350
Ceramics International	105	0.63	38	711
Asian Journal Of Chemistry	103	0.62	14	58
Journal Of The Indian Chemical Society	101	0.61	40	129
Green Chemistry	100	0.60	282	1600

% - Percentage; LCS – Local Cite Score; GCS – Global Cite Score

5.4. Top Collaborating countries in Green technology

Table 5 provides the countries that collaborated with India to produce Green technology literature. It is clear that India is the country collaborated more with 16650 articles which is followed by USA with 926 articles. South Korea, UK and Japan are in the 3rd, 4th and 5th position with 432, 287 and 271 articles respectively.

Table 5: Top collaborating countries contributing Green Technology

COUNTRY	# PAPERS	%	LCS	GCS
India	16650	99.988	13360	141121
USA	926	5.561	470	13674
South Korea	432	2.594	273	3481
UK	287	1.724	152	5727
Japan	271	1.627	167	4083
Germany	267	1.603	163	4925
Australia	177	1.063	105	2388
Canada	173	1.033	119	2987
France	172	0.865	73	2198
Peoples R China	167	0.811	68	3173
Saudi Arabia	144	0.739	115	1230
Italy	135	0.811	100	2391

% - Percentage; LCS – Local Cite Score; GCS – Global Cite Score

5.5. Institutional affiliation of authors contributing articles

Table 6 provides top ten affiliating institutions which contributed literature on Green technology. It is found that IIT contributed 1651 articles and is in the first position which is followed by CSIR with *516* articles. Among top contributing institutions, there are 4 universities which include University of Delhi, Banaras Hindu University, Jadavpur University and Anna University. It is clear from the table that Educational institutions and Research institutions are the major contributor to the subject Green technology.

Table 6: Institution vs. No. of contribution in Green Technology

INSTITUTION	# PAPER	%	LCS	GCS
Indian Institute Technology	1651	9.915	1476	18217
CSIR	516	3.099	375	5411
National Institute Technology	439	2.636	315	2678
Bhabha Atomic Research Centre	369	2.216	154	2492
Indian Institute Science	364	2.186	362	4843
University of Delhi	358	2.15	341	4213
Banaras Hindu University	325	1.952	298	3077
Jadavpur University	309	1.856	209	2209
Anna University	306	1.838	126	2516

% - Percentage; LCS – Local Cite Score; GCS – Global Cite Score

6. FITNESS OF BRADFORD'S LAW OF JOURNAL DISTRIBUTION

Bradford, studied and observed the allocation and scatter of papers through the scientific journals which resulted in Bradford's law of Scattering, which describes a quantitative relation between journals and the papers they bring out. Bradford (1934) made a statistical analysis of two geophysics bibliographies, the Current Bibliography of Applied Geophysics (1928-1931) and the Quarterly Bibliography of Lubrication (1931-1933). Bradford's law (Bradford, 1948) states that "if scientific journals are arranged in order of their decreasing productivity of articles on a given subject, they may be divided into a nucleus of periodicals more particularly devoted to the subject, and several 'group' or 'zones' containing the same number of articles as the nucleus, where the number of periodicals in the nucleus and succeeding zones will be 1: n: n2, 'n' is a multiplier".

Table 7 provides the rank list of Journals in which the authors contributed more number of articles. The top 10 journals which come within 10th rank are listed below with number of articles. Among these journals, "*RSC Advances*" possesses first rank with 442 articles followed by "*Renewable & Sustainable Energy Reviews*" and "*Current Science*" which possess second and third position with 254 and 222 articles respectively.

Table 7: Core Journals vs. Rank

RANK	JOURNAL NAME	# PAPER
1	RSC Advances	442
2	Renewable & Sustainable Energy Reviews	254
3	Current Science	222
4	Spectrochimica Acta Part A-Molecular And Biomolecular Spectroscopy	192
5	Tetrahedron Letters	155
6	Journal of Scientific & Industrial Research	112
7	Ceramics International	105
8	Asian Journal Of Chemistry	103
9	Journal of The Indian Chemical Society	101
10	Green Chemistry	100

Number of journals with articles and the cumulative frequency and log are provided in Table 8. The highest number of articles i.e. 442 is published through a single journal.

Table 8: Distribution of Journals

RANK	COUNT JOURNALS	CUM. # JOURNALS	# PAPER	CUM. # PAPER	log N
1	1	1	442	442	0.0000
2	1	2	254	696	0.3010
3	1	3	222	918	0.4771
4	1	4	192	1110	0.6021
5	1	5	155	1265	0.6990
6	1	6	112	1377	0.7782
7	1	7	105	1482	0.8451
8	1	8	103	1585	0.9031
9	1	9	101	1686	0.9542
10	1	10	100	1786	1.0000
11	1	11	98	1884	1.0414
12	1	12	95	1979	1.0792
13	1	13	93	2072	1.1139
14	1	14	92	2164	1.1461
15	1	15	89	2253	1.1761
16	1	16	83	2336	1.2041
17	1	17	80	2416	1.2304
18	1	18	72	2488	1.2553
19	1	21	70	2558	1.3222
20	3	22	70	2628	1.3424
21	1	23	70	2698	1.3617
22	1	24	69	2767	1.3802
23	1	27	66	2833	1.4314
24	3	28	65	2898	1.4472
25	1	29	64	2962	1.4624
26	1	30	64	3026	1.4771

The journals are grouped in three major zones as 29:271:2495. The number of articles covered by first 1/3rd i.e.29 journals in the zone 1 is 3214 and the other 1/3rd of journals i.e. 271 and 2495 covers next 6300 and 6856 articles respectively. Thus the first or nucleus zone contains 29 journals, and the second or outer zone and the third or peripheral zone contains 271 and 2495 journals respectively. Here k is 9.28. Therefore 29:29×9.28:29×(9.28)2 and 29:271:2495. This shows the approximate fitness of Bradford's law to the present data.

The Table 9 provides the value of 'k' i.e. the Bradford Multiplier and the number of journals in zone up to third level and also the number of articles published through these journals. The value of the calculated Bradford Multiplier value is 9.28.

Table 9: Scatter of journals over Bradford's zone

ZONES	# JOURNALS	% of JOURNALS	# PAPERS	% of PAPERS	k
Core zone	29	1.037	3214	19.63	-
Zone 1	271	9.69	6300	38.49	9.34
Zone 2	2496	89.27	6856	41.88	9.21
Total	2796	100	16370	100	9.28

The Table 9 provides list of core journals up to level 3 along with number of articles and rank, which consists of 55 journals. Among the 2796 journals and 16370 articles 29 journals are in the core zone with 3214 articles. The rest of the journals are scattered in second and third zones respectively. In the second zone there are 271 journals with 6300 articles and the third zone consists of 2496 journals with 6856 articles.

7. MAJOR FINDINGS

The analysis reveals that articles forms the majority in Green technology literature followed by reviews and conference proceedings (papers). Year-wise distribution indicates that there is an increase in the literature productivity in Green Technology every year and the RGR is decreased year to year and the corresponding DT increases in the case of Green Technology literature production. The Bradford's journal distribution is also approximately fits to the present data set. *RSC Advances* is in the top followed by '*Renewable & Sustainable Energy Reviews'*. India is the country collaborated more with 16650 articles which is followed by USA with 926 articles. Educational institutions and Research institutions are the major contributor to the subject Green technology.

8. CONCLUSION

This study has explored the representation of India in the research productivity in the area of Green technology. Reducing waste and pollution by changing patterns of production and consumption is the need of the hour and it has to be implemented by "cradle to cradle" design -

ending the "cradle to grave" cycle of manufactured products, by creating products that can be fully reclaimed or re-used. To realize this research has to be conducted for developing alternatives to technologies like whether fossil fuel or chemical intensive agriculture - that have been demonstrated to damage health and the environment. The study concludes that there is a good representation of literature on Green technology which indicates towards the quantity of research organized in India and the quantum of research from the educational and research institutions from India. The transformation should arrive through policy, research, education, incentives and forward-looking relationships with industry, government can play a central role in building a green future, community by community.

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