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Authorship productivity in “Green Propulsion” research

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Abstract

Spacecraft research is a significant research field in Science and Technology development and “Green Propulsion” has its importance as a sub domain which directs the Spacecraft Propulsion field to non-hazardous and tries to keep the environment clean. The data were downloaded from Web of Science from 2000 to 2014 (15 years). Through bibliometric techniques attempt has been made to analyse the characteristics of the research output in Green Propulsion. This study investigates the growth pattern, year-wise, institution-wise, country-wise distribution of articles. The prolific authors along with the H-index and the obtained citations have been tabulated. The fitness of Lotka’s law has been tested using K-S test.

Keywords: *Bibliometrics; Scientometrics; Green Propulsion; Authorship pattern; H-Index; Lotka’s Law*

Introduction

Scientometrics is a widely accepted method for supervising and assessment purposes. Regardless of its limitations, this method provides the status about the position of a country’s national innovation system and monitoring and evaluating the various facets of the scientific enterprise and is a necessary and integral part of science policy. Scientometric approach measures the availability of research with the necessity and impact thereof. According to Pouris (1988), they are repeatable and verifiable exercises and are not dependent on the choice of experts and their opinions which may vary depending on the choice of the participant’s in peer reviews. Probably their most important advantage is that they allow for comparisons among different scientific disciplines and different countries. Both types of comparisons are not possible through peer review approaches as it is almost impossible to find peers with expertise in different scientific fields and knowledge of the research systems in different countries.

Space industry has forced the imagination of people throughout history. Since historic times, the progress of rocket propulsion and the space exploration have seized the enthusiastic human minds. A huge quantity of rocket fuel is needed to propel a rocket into space. Although the exhaust velocity of burnt gasses is high, the gases themselves are light, so a lot of propellant is needed to overcome Earth’s gravity and lift a small payload into space. The propellants used in space programs pose environmental concerns in four main areas such as ground-based impacts, atmospheric impacts, space-based impacts, and biological impacts. Ground-based impacts range from groundwater contamination to explosions caused by mishandling of propellants. Atmospheric impacts generally come from the interaction of propellant exhaust with the atmosphere. Space-based impacts generally focus on debris and effects on spacecraft. Biological impacts tend to focus on the toxicology and corrosiveness of propellants (Aerospace, 2011).

During recent years, low toxicity (or “green”) liquid rocket propellants have become attractive as possible substitutes for hydrazine and nitrogen oxides in low or medium thrust engines because of the reduced environmental impact and, also because, the cost savings associated with the drastic simplification of the required health and safety precautions (ALTA, 2012). All propellants affect the environment in some way. For instance, all launch vehicles produce exhaust. The components of this exhaust can include soot, carbon dioxide, alumina, inorganic chlorine, water vapor, sulfates, and nitrogen oxides. All of these have an environmental impact, and may contribute to climate change, ozone destruction, or upper atmospheric contrails, depending on the atmospheric layer in which they are deposited; however, the severity and duration of the impact can vary

greatly. A green propellant is more correctly viewed as one that seeks to minimize or eliminate a critical environmental impact in one or more of the four main areas. A green propellant is likely to have its own environmental impacts, which may be equal to the current technology in certain areas. For example, many green propellants seek to eliminate hydrazine because of its biologic impact, but they still present atmospheric or space-based effects.

Review of literature

Eutrophication has become a top environmental issue for most lake ecosystems in the world and enhanced phosphorus (P) input is usually considered the primary stressor, Gao, Wei...[et al.] (2015) focused through a bibliometric study on the role of phosphorus in eutrophic lakes, to quantitatively evaluate the main interests of research and trends in this area using data from the Science Citation Index Expanded database between 1900 and 2013, a total of 3,875 publications. Result shows that the annual publications on 'P' in eutrophic lakes keep an exponential over the last two decades, reflecting an increasing attraction in this area. However, publications of phosphorus research make up only 40 % of total records in eutrophic lakes, indicating that there are other significant topics in eutrophication problems of lakes. The USA is the largest output country in this area, contributing 23 % of the total articles, followed by China with a proportion of 15 %. Hu, Yue...[et al.] (2014) applied a scientometric analysis in this work to evaluate the status and trends of electric vehicle papers published between 1993 and 2012 in any journal of all the subject categories of the Web of Science. Electric vehicle was used as a keyword to search parts of titles, abstracts, or keywords. Publication trends were analyzed by the retrieved results in publication outputs, subject categories and publication pattern, international productivity. The paper found that 11 document types were found in all electric vehicle-related papers and proceedings paper was the most frequently used document type. The USA, China and Japan were the most productive countries. University of Michigan, Harbin Institute of Technology and Ohio State University were the most productive countries. Aswathy, S.andGopikuttan, (2014) studied the research productivity in spacecraft propulsion research which is a dynamic area of interest in which majority of work is being done through WoS, a premier research platform, helping to find, analyze, and share information in the sciences, social sciences, arts, and humanities. The data for the present analysis has been retrieved for a period of 14 years during 1999 to 2012 from this database. This study aims to analyse 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.

Methodology

Thomson Reuters (formerly the Institute for Scientific Information (ISI)) Web of Science (WoS) databases (Science Citation Index Expanded, Social Sciences Citation Index and Arts and Humanities Citation Index) is the most often used for these types of investigations. The data for the present study were collected from SCI Expanded, Web of Science Core Collection. The Search was conducted as follows:

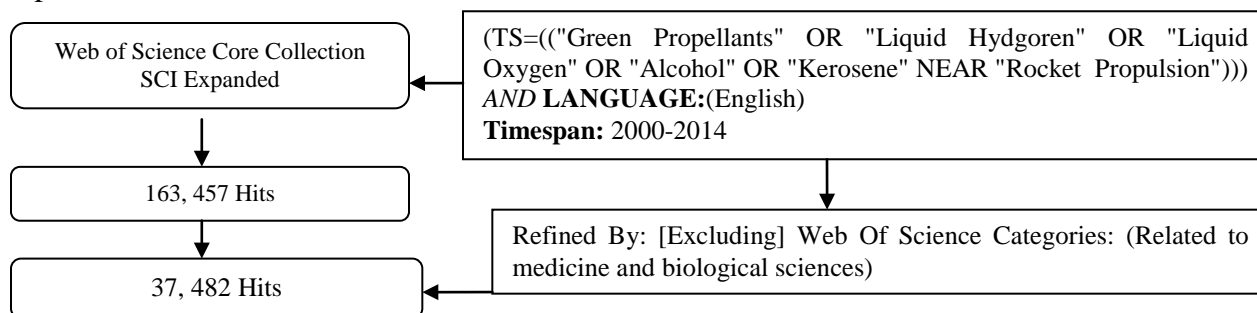


Figure 1 Schematic representation of formulated search strategy

Objectives

The main objective of this study is to make an analysis to know the status of research productivity in the area of “Green propulsion”. This is realized through the following specific objectives such as: Find out the year-wise distribution of authorship, to find the highly productive authors and verify the fitness of Lotka’s law of author productivity, to analyze the collaboration pattern of authors by Degree of collaboration and Collaborative Coefficient in “Green propulsion” research; to establish the co-authorship network, to find out India’s contribution to this research area & to determine influential individuals, papers, institutions etc through Essential Science Indicator

Analysis& Discussion

Authorship pattern

Authorship pattern denotes the number of authors who collaborated to write a research article. Table-1 indicates that multi-authorship is prevalent in this area of research and also the joint authorship is increasing year to year. The total single authorship is 1453 while mega authored (5 and more than that) are 22999 in number.

Table -1 Authorship pattern of publications

Year	Single	Two	Three	Multi	Mega	DC	CC
2000	68	311	383	284	3046	0.983	0.180
2001	89	304	386	277	3057	0.978	0.182
2002	71	329	370	308	3080	0.983	0.175
2003	83	347	405	347	3185	0.981	0.176
2004	81	314	414	368	3181	0.981	0.186
2005	99	350	456	414	3324	0.979	0.183
2006	103	379	498	458	3444	0.979	0.181
2007	104	397	494	482	3484	0.979	0.178
2008	124	403	559	493	3587	0.976	0.182
2009	101	426	627	566	3729	0.981	0.185
2010	120	435	638	573	3776	0.978	0.184
2011	107	479	650	618	3865	0.981	0.178
2012	114	490	688	646	3950	0.981	0.180
2013	98	499	752	779	4141	0.984	0.187
2014	91	517	775	858	4255	0.986	0.188
Total	1453	5980	8095	7471	22999	0.968	0.137

DC=Degree of Collaboration, CC= Collaborative Coefficient

Author collaboration is the act whereby two or more people agree to execute a certain project, be it intellectual or non-intellectual (Harande, 2001). Subramanyam, K (1983) proposed the Degree of Collaboration as a measure of the strength of collaboration in a discipline. The Degree of Collaboration among authors is the ratio of the number of collaborative publications to the total number of publications published in a discipline during certain period of time, which can be calculated for both publications and citations (Subramanyam, 1983).

The mathematical expression of the formula is $C = \frac{Nm}{Nm + Ns}$, (1)

where C = Degree of collaboration, Nm = Number of multi-authored papers and Ns = Number of single authored papers. It is found that the year wise DC is almost constant and does not vary year to year and the value of DC is 0.968 for the present data set which provides the hint towards the high collaborative pattern amongst the authors in Green Propulsion research.

The mathematical formula to calculate Collaborative Coefficient (Ajiferuke, B. and Tague, 1988) is

$$CC = 1 - \frac{\sum_{j=1}^A \left(\frac{1}{j} \right) f_j}{N}, \quad (2)$$

Where f_j is the number of “j”- authors papers published in a discipline during a certain period of time; N is the total number of papers published in a discipline during a certain period of time; and “j” is the greatest number of authors per paper in a discipline. Here the value of CC has come variation during the study period. CC was observed to be 0.180 during 2000 and 0.137 during 2014.

Lotka's law of author productivity

While examining the distribution frequencies of scientific productivity of chemistry and physics from the publications covered by Chemical Abstracts and Auerbach's *Geschichtstafln der Physik*, Alfred J Lotka (1926) observed a quantitative relation among the authors and their scientific production.

It states that, “... the number (of authors) making n contributions is about $1/n^2$ of those making one; and the proportion of all contributors, that make a single contribution, is about 60 percent”, which means that out of all the authors in a given field, 60% will have only one publication, 15% will have two publications and 7% of authors will have 3 publication and so on. In other words, in a particular topic, for every 100 authors whose contribution is single article, there will be 25 authors with two articles, 11 authors with three articles etc. General expression of Lotka's law is $x^n y = k$, (3)

Where, y is the frequency of authors making n contributions each and k is a constant.

The productivity of the papers in AIAA Journals is verified to find the conformity with the Lotka's inverse square law using Pao's (1985) method and it is tested by K-S goodness-of-fit test (table-2). The ‘n’ is determined using Linear Least Square (LLS) regression method.

$$n = \frac{\left[N \sum (\ln x \cdot \ln g(x)) - \sum \ln g(x) \sum \ln x \right]}{\left[N \sum (\ln x^2) - (\sum \ln x^2) \right]}, \text{ where } N=10 \quad (4)$$

Here “n” is obtained as 0.71

By substituting the values in the following equation, the value of ‘c’ is determined. For this purpose, ‘n’ value is provided as 1.62 and ‘p’ is assumed to be 20.

$$c = \frac{1}{\sum_{x=1}^{p-1} \frac{1}{x^2} + \frac{1}{(n-1)(p^{n-1})} + \frac{1}{2} p^n + \frac{n}{24 \times (p-1)^{n+1}}} = 0.35 \quad (5)$$

Here, p is assumed to be 20 and n is the experimentally computed value of the exponent from the observed distribution. Once the value of n and k is determined, then using Eqn. 5, determine the number of authors writing 1, 2, 3,...x articles. By replacing the values of ‘n’ and ‘c’ in Lotka's model $g(x)=kx^{-n}$, the fitness of Lotka's law to the present data set is determined by K-S statistical test. The difference between fractional values of observed and expected frequencies has been calculated and provided in the table-2. From the table - 2 it is clear that the maximum absolute difference value Dmax which represents the maximum deviation is identified as 0.0. The table value or critical value of D in K-S test at 0.05, level of significance is 0.00045 and at 0.01 level the critical value of D is 0.0054. When the calculated value of D = 2.361 falls within the critical

value D, it can be said that the present data set conforms to lotka's law. The graphical representation also proves the conformity of Lotka's law to the present data set.

Table-2 Lotka's distribution

x	y	X	Y	xX	XY	yx/sigmayx	C Obs	Expect	Cum Exp	D
1	62865	0	4.80	0.00	0.00	0.71	0.71	-0.35	-0.35	1.06
2	12986	0.30	4.11	0.09	1.24	0.15	0.86	-0.21	-0.56	1.42
3	4963	0.48	3.70	0.23	1.76	0.06	0.91	-0.16	-0.72	1.64
4	2619	0.60	3.42	0.36	2.06	0.03	0.94	-0.13	-0.86	1.80
5	1483	0.70	3.17	0.49	2.22	0.02	0.96	-0.11	-0.97	1.93
6	909	0.78	2.96	0.61	2.30	0.01	0.97	-0.10	-1.06	2.03
7	571	0.85	2.76	0.71	2.33	0.01	0.98	-0.09	-1.15	2.13
8	426	0.90	2.63	0.82	2.37	0.00	0.98	-0.08	-1.23	2.21
9	295	0.95	2.47	0.91	2.36	0.00	0.98	-0.07	-1.31	2.29
10	261	1	2.42	1.00	2.42	0.00	0.99	-0.07	-1.37	2.36
11	186	1.04	2.27	1.08	2.36	0.00	0.99	-0.06	-1.44	2.43
12	152	1.08	2.18	1.16	2.35	0.00	0.99	-0.06	-1.50	2.49
13	126	1.11	2.10	1.24	2.34	0.00	0.99	-0.06	-1.55	2.55
15	97	1.18	1.99	1.38	2.34	0.00	0.99	-0.05	-1.61	2.60
14	89	1.15	1.95	1.31	2.23	0.00	0.99	-0.05	-1.66	2.65
17	69	1.23	1.84	1.51	2.26	0.00	0.99	-0.05	-1.71	2.70
16	67	1.20	1.83	1.45	2.20	0.00	1.00	-0.05	-1.76	2.75
20	41	1.30	1.61	1.69	2.10	0.00	1.00	-0.04	-1.80	2.79
18	40	1.26	1.60	1.58	2.01	0.00	1.00	-0.04	-1.84	2.84
19	39	1.28	1.59	1.64	2.03	0.00	1.00	-0.04	-1.89	2.88
21	31	1.32	1.49	1.75	1.97	0.00	1.00	-0.04	-1.93	2.92
23	29	1.36	1.46	1.85	1.99	0.00	1.00	-0.04	-1.96	2.96
22	21	1.34	1.32	1.80	1.77	0.00	1.00	-0.04	-2.00	3.00
24	17	1.38	1.23	1.90	1.70	0.00	1.00	-0.04	-2.04	3.04
27	16	1.43	1.20	2.05	1.72	0.00	1.00	-0.03	-2.07	3.07
29	14	1.46	1.15	2.14	1.68	0.00	1.00	-0.03	-2.11	3.10
26	13	1.41	1.11	2.00	1.58	0.00	1.00	-0.03	-2.14	3.14
34	10	1.53	1.00	2.35	1.53	0.00	1.00	-0.03	-2.17	3.17
30	10	1.48	1.00	2.18	1.48	0.00	1.00	-0.03	-2.20	3.20
3143	88562	110.70	74.65	176.44	76.38				Max D	2.361

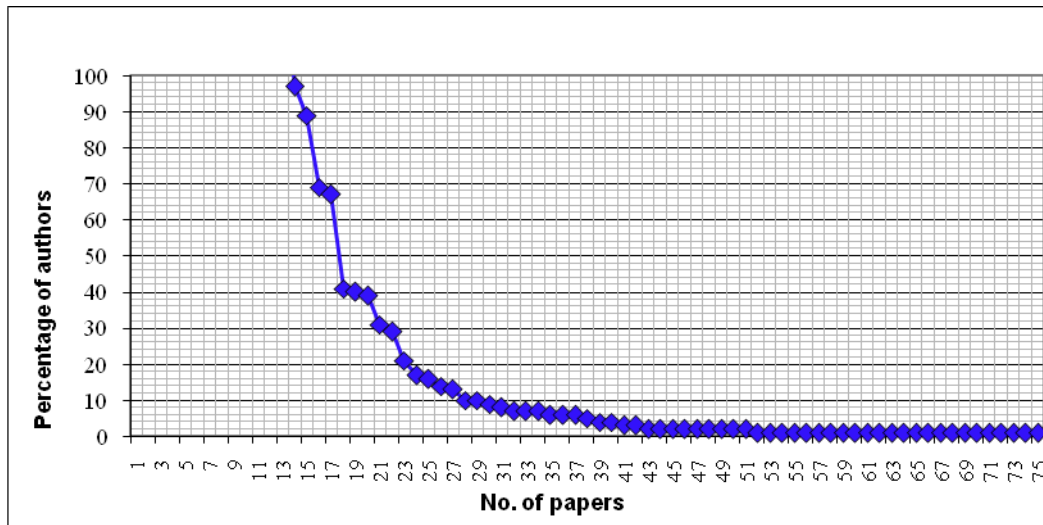


Figure-2- Lotka's distribution

Table- 3 Prolific authors contributing to Green Propulsion research

Author	No. of articles	H index	Country	Citation sum (h-core)	LCS	GCS
Wang Y	150	26	China	1675	417	2516
Li Y	122	21	China	1051	142	1505
Liu Y	121	19	China	698	169	1194
Zhang Y	117	20	China	1025	169	1487
Li J	114	20	China	590	120	1085
Zhang L	114	20	China	1282	181	1751
Wang J	89	19	China	4133	159	4528
Zhang J	87	19	China	704	108	986
Liu J	84	19	China	836	160	1118
Wang X	79	16	China	1677	105	1971
Wang L	78	19	China	796	100	1071
Domanska U	73	26	Poland	1106	366	1632
Chen Y	71	17	China	793	66	1062
Wang H	70	16	China	657	186	911
Zhang H	70	19	China	745	102	1037

The h-index is an index that attempts to measure both the productivity and citation impact of the published body of work of a scientist or scholar. Table-3 provides list of most productive authors along with their h-index and Local Citation Score and Global Citation Scores. It is observed that China is in the forefront maximum number of authors in Green Propulsion research. Wang Y with 150 articles is at the top with the h index 26. It is clear from table-3 that Domanska U with 73 articles also possesses h – index 26. Hirsch proposed h-index in 2005 to measure the productivities and impacts of the published works of not only scientists and scholarsbut also research organizations, countries, and journals(Huibin Du...[et al.], 2013). It is defined simply as: “A scientist has index h if h of his/her N_p papers have at least h citations each, and the other (N_p-h) papers have no more than h citations each,” where N_p is the number of papers published over n years (Hirsch 2005). And therefore, the h-index combines a measure of quantity (number of publications) and impact (number of citations) in a single indicator (Vieira and Gomes 2011).It has the advantage of being objective and hence is a good indicator of the impact of a scientist or journal (Kinney,2007).

The h-index of the top productive authors varies from 26 to 19. The Global Citation Score of top productive author is high i.e. 2516 while that of the author with 70 papers is less i.e. 1037.

Indian Contribution to Green Propulsion Research

Number of contributions in green propulsion research from India is 3191 articles during 2000 to 2014. The contribution shows an increasing trend from 88 in 2000 to 397 in 2014 with 2580 LCS and 34927 GCS. Indian Institute of Technologies and National Chemical Lab is in forefront in research in this area with 303 and 114 records respectively. Among 1452 contributing institutions there were 493 universities. It is found that 527 journals contributed literature in Green Propulsion. Table – 4 provides top productive journals with Indian contributions along with the LCS and GCS. Impact Factor, Eigen Score and Article Influence Score is also provided.

According to Carl Bergstrom (2007), Eigen factor, accounts for the fact that a single citation from a high quality journal may be more valuable than multiple citations from peripheral publications. It measures the importance of a citation by the influence of the citing journal divided by the total number of citations appearing in that journal. Conceptualized by Eugene Garfield in 1955, the journal Impact Factor is the average number of times articles from the journal published in the past two years have been cited in the Journal Citation Reports (JCR) year using Thomson Reuter's citation data. Article Influence Score is the journal's Eigenfactor Score divided by the fraction of articles published by the journal. That fraction is normalized so that the sum total of articles from all journals is 1.

Table- 4 Top Indian Journals contributing articles

Name of Journal	Articles	LCS	GCS	Impact Factor	Eigen Score	Article Influence Score
Asian Journal of Chemistry	122	6	113	0.355	0.00334	0.033
Journal of Molecular Catalysis A-Chemical	104	196	2188	3.679	0.01844	0.691
Industrial & Engineering Chemistry Research	79	87	1028	2.235	0.07186	0.600
Journal of The Indian Chemical Society	78	24	137	0.251*	0.00095	0.049
Rsc Advances	71	16	182	3.708	0.02401	0.734
Indian Journal of Chemistry Section A-Inorganic Bio-Inorganic Physical Theoretical & Analytical Chemistry	69	41	322	0.628	0.00126	0.139
Journal of Molecular Liquids	54	96	440	2.083	0.00637	0.399
Applied Catalysis A-General	51	102	1335	3.674	0.03925	0.873
Oxidation Communications	50	21	130	0.507	0.00023	0.028
Catalysis Communications	46	72	645	3.320	0.02412	0.698

*2012 Impact Factor

Essential Science Indicators (ESI)

ESI determines the influential individuals, institutions, papers, publications, and countries in their field of study — as well as emerging research areas that could impact their work. This unique and comprehensive compilation of science performance statistics and science trends data is based on journal article publication counts and citation data from Thomson Scientific databases.

Table-5 Top ESI papers

Journal	Country	Articles	LCS	GCS	Impact Factor	Eigen Score	Article Influence Score
Journal of the American Chemical	USA	39	56	5617	11.444	0.81839	3.072

Society							
Journal of Power Sources	Netherlands	24	56	2385	5.211	0.10803	1.046
Advanced Materials	Germany	17	21	4847	15.409	0.27506	4.266
Chemical Society Reviews	UK	16	19	3081	24.892	0.17914	8.927
Fuel	Netherlands	16	26	1759	3.406	0.04013	0.987
International Journal of Hydrogen Energy	UK	14	13	684	2.930	0.07629	0.613
Chemical Reviews	USA	13	18	4195	45.661	0.21741	14.261
Angewandte Chemie-International Edition	UK	12	17	3520	11.336	0.50348	3.242
Chemical Communications	UK	11	7	1262	6.718	0.31620	1.522
Green Chemistry	UK	10	3	859	6.852	0.03989	1.418
Nature	UK	10	21	3120	42.351	1.60305	22.184
Science	USA	10	14	3704	31.477	1.27503	17.698

It is an ideal analytical resource for policymakers, administrators, analysts and information specialists in government agencies, universities, and corporations. In table-5 top journals along with the Impact Factor, Eigen Score and Article Influence Score is provided from this category. There were 109 journals in this category. It is clear that Journals from UK are more in number with influential papers along with Germany and Netherlands. Two journals from India i.e. “Journal of Scientific and Industrial Research” by NISCAIR and “Chemistry: an Asian Journal” also comes under this category. Fourteen articles from India are counted in ESI articles.

Conclusion

It is found that multi-authorship dominates in Green propulsion research. Hence it is to be stressed that collaborative research is more prevalent in this research area. There is a perfect fitness of Lotka’s law of author productivity. The h-index of the top productive authors varies from 26 to 19. There were 15 leading authors with more than 70 articles. Indian is also having its contribution in this research area and “Asian Journal of Chemistry” is in the most productive journal and there are 527 journals and 3191 articles at the credit. Two Indian journals are categorized under Essential Science Indicators among other 109 journals. Among the top ESI category, “Journal of the American Chemical Society” of USA ranks first. Nature (UK) and Science (USA) also comes in this category. Space research and activities has a major role in all the technological progress available at present. At this juncture the research in green propulsion has its importance. The analysis indicates that the research productivity in Green propulsion research is constantly increasing which is a hint towards the increasing trend and positive attitude and responsibility to protect the environment.

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