Application of Lotka's Law and Author Productivity in the Journal of Energy and Environmental Science

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Abstract- Journal of Energy and Environmental Science is one of the leading journals in the field of chemistry and is published by the Royal Society of Chemistry. The main objective of this study is to cover various aspects of the journal through bibliometric law. This paper presents an application of Lotka's Law and writer productivity of JEES during 2018-2022. During the period 2018-2022, a total of 1753 full-length articles were published in a particular journal. The study includes various aspects such as the distribution of full-length articles on an annual basis, classification of articles by category, authorship pattern of articles, ranking of authors, degree of author collaboration, use of Lotka's law, K-S statistics, etc. As a result, the degree of collaboration in the Journal of Energy and Environmental Science is 0.65, which clearly shows the dominance of multiple authors in their contributions. Writer productivity follows a logarithmic distribution. Here, it is clear that the value of D i.e. 0.0356 is less than the value of K-S statistic i.e. 0.0389; Therefore, it is important that the given data fits Lotka's law.

I. INTRODUCTION

The history of Bibliometric studies is about 2 centuries old now. The first documented Bibliometric study was done by Cole and Eales' which appeared in Science Progress (Cole & Eales,1917). Hulme' presented the second work on bibliometrics and introduced the term 'Statistical Bibliography'. Since then, a number of studies discussed the theoretical aspects of bibliometrics. Three laws of bibliometrics provide theoretical foundations for Bibliometrics 'studies (Hulme,1923). Lotka proposed the Law of scientific productivity, which describes the frequency of publications by authors in a given field. Bradford's Law of Scatter appeared in 1934, which _ reported that a major portion of the literature of any discipline is concentrated in a small number of core journals. Zipf proposed his Law of Least Resistance in 1949, based on the frequency of word distribution in a document. Garfield joined the field in 1955 and greatly contributed to citation analysis (Lotka,1926). Pritchard* introduced the term bibliometrics for the first time, which replaced the earlier term 'Statistical Bibliography' that was used for the same concept (Pritchard,1969).

Bibliometric laws have many strengths and weaknesses, and a number of researchers have tested the same. Lotka's law, also known as the "Inverse square law of scientific productivity", states that the number of authors who make x contributions is 1/x" of those making one contribution, where n is always nearly equal to two. Lotka expressed the relationship by the equation $x"y = const$ and calculated the value of the constant (c) for n = 2, which was equal to 60.79 percent (Lotka,1926). Some studies confirmed Lotka's law but some other studies did not support it|'. Some studies suggested that it was not acceptable for all types of data 7° and parameters of Lotka's law show varying behavior for different sets of data. In a recently conducted study, which examined the characteristics influencing the parameters of Lotka's law, Pulgarin used a quasi-experimental method to estimate the parameters of Lotka's law in different scientific areas. He found that both Lotka's exponent and constants are dependent on the development state of the scientific area, the productivity of the scientific area, the country, and the time period under study (Nazim & Ahmad, 2007). The study found that parameters of Lotka's law showed different behavior when estimated for the data having diverse characteristics. Askew '° examined Lotka's law in the field of library and information studies and found that library and information studies literature did conform to Lotka's law with reliable results and concluded that Lotka's law can be used as a standard tool to measure the author productivity(Clausen,2001 & Pulgarin,2012).

II. OBJECTIVE OF STUDY

- To investigate year wise and document wise publication patterns.
- To Find out the Most Author Productivity:
- Know the geographical distribution of authors
- To apply the non-parametric Kolmogorov – Smirnov (K-S) test of 'Goodness-of-fit' for conformity of the Lotka's law.
- Evaluate the implementation of Lotka's law productivity

III. METHODOLOGY

The present study investigates the research contributions of authors in Energy and Environmental Science journals through bibliometric analysis from 2018 to 2022 (five years). The journal is retrieved from its website, i.e. https://journals.aps.org/prab/. A total of 71753 full-text research articles were published between 2018-2022. Bibliographic details obtained from the publications were tabulated, organized, and analyzed using MS Excel. Data were arranged and organized to consider different perspectives related to growth rate, degree of collaboration (DC), and Lotka's law of productivity.

IV. SCOPE OF THE STUDY

The scope of the study is limited to evaluating the research contributions of scientific professionals published as full-text papers in Energy and Environmental Science journals. Publications of Physical Review Accelerators and BEMS for the five years 2018 to 2022 are taken up for the present study. A total of 1753 articles were published over five years totaling Five volumes.

V. DATA ANALYSIS AND INTERPRETATION

5.1.Year-wise distribution of articles

Table 1: Year-wise distribution of articles

Sr. No	Year	Number of Articles	%	Number of Citations	Average no. of Citation
1	2018	311	17.74	1162	3.74
2	2019	282	16.09	9230	32.73
3	2020	344	19.62	12751	37.07
4	2021	396	22.59	13077	33.02
5	2022	420	23.96	14577	34.71
Total		1753	100.00	50797	28.98

Table 1 indicates that there are 1753 articles and 50797 references in the Journal of Documentation published during 2018-2022. Maximum number of references per article appeared in 2020 and minimum in 2018. The present study reveals that the average number of references per article has been increasing from 2003 to 2015. The average number of references per year is 10159.4

5.2 Relative Growth Rate and Doubling Time of Publication

Growth rate analysis The growth rate analysis is done with respect to the relative growth rate and doubling time.

Relative growth rate per unit of publications per unit of time, ie, R(a) =

W1 = log w1 (Natural log of initial number of publications);
W2 = log w2 (Natural log of initial number of publications);
T2-T1=The unit difference between the initial time and final time.

Table No. 2: Relative Growth Rate and Doubling Time of Publication

Sr. No	Year	Number of Articles	Cumulative Frequency	W1	W2	RGR	Mean[R(P)]	[Dt(p)]	Mean Dt (p)
1	2018	311	311		5.74				
2	2019	282	593	5.74	6.38	0.64		1.08	
3	2020	344	937	6.38	6.84	0.46	0.43	1.51	1.784
4	2021	396	1333	6.84	7.19	0.35		1.98	
5	2022	420	1753	7.19	7.46	0.27		2.57	

Table 2 shows that the relative growth rate of articles is decreased from 0.64 in 2018 to 0.0.27 in 202022. The mean relative growth rate for the entire period is 0.43. The whole study period has witnessed a mean doubling time of 1.784. The analysis clearly indicates that relative growth rate of articles has shown a declining trend, whereas a doubling time for publication has shown increasing.

5.3 Authorship and Collaboration Trend

Table No. 1.5.1: Authorship Pattern year wise

Year	2018	2019	2020	2021	2022	Total	%
First Author	141	108	112	119	129	609	34.74
Second Author	72	69	109	103	113	466	26.58
Third Author	41	38	43	86	83	291	16.6
Fourth Author	27	34	31	49	53	194	11.07
Fifth Author	14	21	29	19	22	105	5.99
Sixth Author	8	6	11	9	12	46	2.62
Seven Author	5	4	6	7	6	28	1.6
Eight Author	3	2	3	4	2	14	0.8
Total	311	282	344	396	420	1753	100

5.4 Degree of Collaboration

Degree of collaboration (DC) among different authors presented in Table No. 5.2 in order to calculate the Degree of Collaboration (DC) the formula given by Subramanyam (1983) have been employed which is expressed mathematical as;

$$DC = \frac{Nm}{Nm + Ns}$$

Whereas-
DC= Degree of Collaboration
Nm= No. of multi authors papers
Ns= No. of Single authored Papers.

Table no.3: Degree of Collaboration

Sr. No	Year	Single Author	Multi Author	Total	DC
1	2018	141	170	311	0.55
2	2019	108	174	282	0.62
3	2020	112	232	344	0.67
4	2021	119	277	396	0.70
5	2022	129	291	420	0.69
Total		609	1144	1753	0.65

The above table reveals that, DC was lowest at 0.55 in 2018 and highest at 0.70 in 2021. There is a steady increase in multi-authored papers in all years, but it is the lowest in 2022 and hence shows a study duration of 0.69 during the average DC.

5 .5 Authors Productivity

Table no. 4: Year-wise Authors Productivity

Sr. No	Total Articles	Total Author	AAPP	APP
1	311	693	2.23	0.45
2	282	681	2.41	0.41
3	344	860	2.50	0.40
4	396	1009	2.55	0.39
5	420	1056	2.51	0.40
Total	1753	4299	12.21	2.05

Table No. 4. illustrates the average author per paper for the period 2018-2022 is 12.21 and productivity per author mentioned as 2.05. The above table shows that the data pertaining to author productivity and average author per year. The highest no. of productivity per author is 0.45 and lowest no of author is found 0.39. In the case of Average Author Per Paper the highest no. was found that 2.55 and lowest number was found 2.23.

5.6 Geographical distribution

Table No.5: Country-wise distribution of publications- Top 20

Sr. No	Keyword	Frequency	%
1	China	823	7.80
2	United States	594	5.63
3	South Korea	193	1.83
4	Germany	187	1.77
5	United Kingdom	169	1.60
6	Australia	124	1.17
7	Hong Kong	96	0.91
8	Switzerland	83	0.79
9	Canada	73	0.69
10	Japan	65	0.62
11	Singapore	60	0.57
12	Spain	48	0.45
13	France	45	0.43
14	Italy	43	0.41
15	Sweden	37	0.35
16	Netherlands	36	0.34
17	Denmark	32	0.30
18	Saudi Arabia	31	0.29
19	India	27	0.26
20	Taiwan	25	0.24
Truncated			
Total		10558	100

Table 5 top - 20gives the geographical distribution of the articles under study. Out of 10558 contributions, the highest number, i.e., 823 (7.80 %), has been contributed by China followed by United States with 594 (5.63%), South Korea with 193 (1.83%), Germany with 187 (1.77%) and United Kingdom 169 (1.60%) . It is found that there were only Five contributions from Asian countries.

5.7 Document Types

Types of documents Table 2 below shows the types of publications retrieved in Journal of Energy and Environmental Science during 2018-2022**.**

Table 6: Document -wise distribution of articles

.Sr. No	Type of Documents	Frequency	%
1	Article	1392	79.41
2	Review	296	16.89
3	Erratum	51	2.91
4	Note	10	0.57
5	Editorial	4	0.23
Total		**1753**	**100.00**

The findings showed that most of the publications retrieved were in the form of articles with 1392 (79.41%), followed by Review with 296 (19.89%), Erratum with 51 (2.91%), Note with 10 (0.57) and a Editorial with 4 (0.23%) publication, indicating that most scholarly publications are published as articles and the least publication is the Editorial.

5.8 Productivity Trends and Application of Lotka's Law

Table No.7: Frequency of observed and expected authors

X (No of articles)	No. of Authors				
	Y(no. of publication)	Percentage	Expected	Percentage	
1	609	0.35	609	0.78	
2	466	0.27	117	0.15	
3	291	0.17	32	0.04	
4	194	0.11	12	0.02	
5	105	0.06	4	0.01	
6	46	0.03	1	0.00	
7	28	0.02	1	0.00	
8	14	0.01	0	0.00	
	1753		776		

Table No. 8: Cumulative frequency of observed and expected authors

No. of articles	Frequency of authors		Cumulative Frequency		D=Fo(x)-Sn(x)
	Observed	Expected	Sn(x)	Fo(x)	
1	0.3474	0.7848	0.000198	0.7846	0.78437
2	0.2658	0.1501	0.000152	0.9347	0.93454
3	0.1660	0.0417	0.000095	0.9764	0.97627
4	0.1107	0.0156	0.000063	0.9920	0.99192
5	0.0599	0.0054	0.000034	0.9974	0.99736
6	0.0262	0.0016	0.000015	0.9990	0.99903
7	0.0160	0.0007	0.000009	0.9998	0.99977
8	0.0080	0.0003	0.000005	1.0001	1.00006

From Table 3, it is observed that D= Max | Fo(X) –Sn (X) | = 0.0356 At the 0.01 level of significance,
K-S Statistics = n 1.63

Here n is number of authors observed during the study which is 1753 (from Table 1)

$$K - S\ Statistics\ = \frac{1.63}{\sqrt{1753}}$$

$$= \frac{1.63}{41.87} = 0.0389$$

Here, it is clear that the value of D i.e. 0.0356 is less than the value of K-S statistic i.e. 0.0389; Therefore, it is crucial that the given data fits Lotka's law.

VI. CONCLUSION

The study quantitatively identified the research productivity in the "Journal of Energy and Environmental Science" search from the Scopus database period of Five years (2018-2022). A total number of 1753 documents were retrieved following the Journal of Energy and Environmental Science. It was revealed that 2022 had the highest publication of 420 articles with a percentage of (23.96%), and the lowest number of publications were produced in 2019 with 282 (16.09%) publications. While the country-wise distribution of publications was also considered. It was indicated that China was the most productive country with 823 documents (7.80%) followed by the United States with 594 (5.63%) publications. It was further noted from the study that Snyder, G.J. & Wang, Z.L. was the most productive authors with 18 (0.42%) publications followed by Li, Y. with 16 (0.37%) publication. It was further revealed that Snyder, G.J. & Wang, Z.L. the most productive author and also the most prolific author with an H-Index of 65 as well as an i10-Index of 135. In relation to publication types, it was revealed that the article category had the most number of publications 79.41% followed by Review 16.89%, and Erratum 2.91%, etc.

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