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Scientometric Mapping and Visualization of Environmental Science Research: a case study

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Abstract:

The present study attempts to emphasize quantitatively the development of environmental science literature in terms of publication output as per Scopus database for thirty years (1989-2018). The focus of this paper is to analysis the literature published by the researchers of the University of Calcutta during the period under study. Total 1093 records have been retrieved for this study. An exponential growth rate has been identified. *Authorship trend was towards multi-authored papers. Most prolific authors and most productive journals have been traced.* The most productive journal is Environmental Monitoring and Assessment. *Co-authorship pattern and Co-occurrence of keywords have also been conducted through cluster analysis method with the aid of VoS viewer software.* Country wise Co-authorship pattern shows that India, UK, USA, and China evolved as the leading countries in environmental science research.

Keywords: *Environmental science, Co-authorship network, Co-occurrence analysis, University of Calcutta*

Introduction

The physical, chemical and biological presence of living and non-living things outside an individual species is called as its environment (Anjaneyulu, 2004). Since the Industrial Revolution, the environmental impact has grown rapidly and steadily to a point where our economic activities have far exceeded the regenerative capacities of Earth's eco-systems, resulting in degradation of environment. A study of the Environmental science is indispensable for all citizens of the world. It informs everyone about the natural knowledge about saving conservation and efforts towards their sustainability (Anandan, & Kumaravelan, 2006).

Environmental science is the study of how various species interact with one another and with the non-living environment (matter and energy). It is the study of how all the components of nature

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and human societies adapt and interact. In this connection Hon'ble Supreme Court has rightly taken proactive role by giving directions to all state Governments and Institutions of higher education to make environmental education is a compulsory subject. This general study of this subject will bring in environmental literacy and emphasizes the value of environmental education. Environmental education generates concepts of prediction, prospecting, promotion, preservation and vision about restoration and resuscitation of dwindling natural resources. In the 21st century, environment related issues become a topic of discussion over a cup of tea. Every sections of our society have more or less aware of the environment related issues.

Scientometric is the quantitative study of science. Scientometrics can be defined as the "quantitative study of science, communication in science, and science policy" (Hess, 1997).

In recent time, several authors like, Rethlefsen and Aldrich (2013), Mamtora, Wolstenholme, and Haddow (2014), Sarvanan et al (2014), Sethi, Sahoo and Mohanty (2014), Kolle and Thyavanahalli (2016), Li et al (2017), Amsaveni and Krishnan (2018), Zhang, Xue, and Tang (2018) have explained their experiences on environmental science research using various online databases like Web of Science, Scopus, Science Direct, etc. All these authors used several bibliometric indicators for analysis of the collected data. The facets like growth of literature, authorship pattern, degree of collaboration, geographical distribution of publications, distribution by journal, citation pattern, and ranking pattern etc. have been enumerated through their noteworthy writings.

This study is confined into research activity of the University of Calcutta (CU) on environmental related issues. The legacy of this university in science research is noteworthy. In this study, an overall scenario of research activity on environment over thirty years with the aid of quantitative indicators has been enumerated.

Objectives

The major objectives of the study are:

- To examine year-wise distribution of publication during the period under study;
- To identify most prolific researchers;
- To visualize academic output of University of Calcutta in Environmental Science research;
- To find out the Country wise Co-authorship pattern;

- To study Co-occurrence of keywords and its link strength.

Methodology

The data for this study was downloaded from the SCOPUS database for thirty years period (1989-2018). A total of 1093 publications fulfilled the desired search query. In this study, we used Visualization of Similarity (VOS) Viewer software to visualize scientific landscape specially, complex scientometric relations such as Co-authorship analysis and Co-word occurrence analysis in environmental science research. MS-Excel Software program is used as analysis tool to analyze different scientific structure based on different scientometric indicators.

Results and Discussion

Category of Document

A total 1093 papers have been published on environmental science research by researchers of CU during the last 30 years from 1989 to 2018. Of the total publications, about 90% (990) came out as articles, 3.47% (38) as book chapter, 1.82% (20 each) as conference papers and reviews, 1.06% (11) as book, and rest part belongs to notes, editorial, short surveys, etc (Fig. 1).
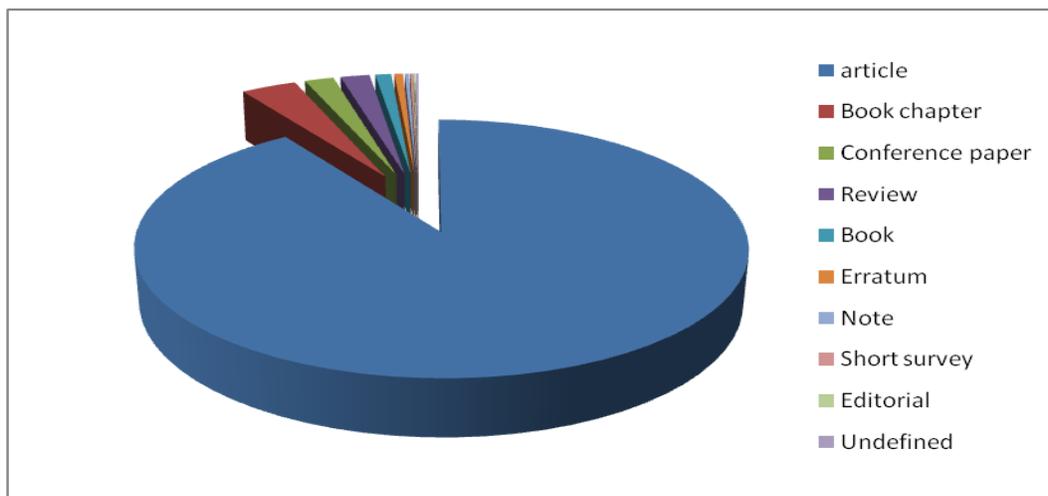

Figure 1: Document category wise distribution

Pattern of output during 1989-2018

Table 1 indicates the quinquennial distribution of output made by environmental science researchers of CU during 1989-2018.

Table 1: Quinquennial distribution of publications

Period	Paper	% of contribution
1989-1993	40	3.65
1994-1998	50	4.57
1999-2003	77	7.04
2004-2008	145	13.26
2009-2013	303	27.72
2014-2018	478	43.73

Figure 1 shows that in the initial years the output is low, but it started increasing after 2003 and reached a peak in 2018. The growth pattern of literature represents slow development from 1989 to 2003. One possible reason for low output in the initial years may be that Scopus database started publishing only in 2004 and before that period it might be having a lower coverage of journals published from India, which might have increased in later years (Tripathi & Garg, 2016).
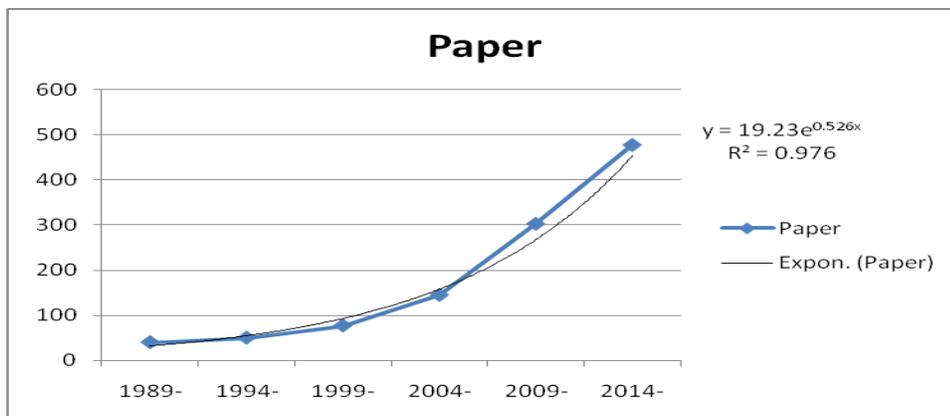
Figure 2: Period wise distribution of publications

The above figure (Fig. 2) also reveals significant growth, with an exponential adjustment containing the equation: $y = 19.23e^{0.526x}$; where $R^2 = 0.976$. From the analysis it also found that year 2017 and 2018 have the maximum publications while 1993 and 1995 have minimum output during the period under study.

Authorship pattern

Table 2 presents data about the authorship pattern in environmental science research during the period under study. It shows that the share of papers written by single authors is the lowest. Also, more than half (54%) of the papers were published as multi-authored and mega-authored papers. As environmental science is multidisciplinary subject that's why several researchers from different disciplines were made contribution to it. It should be noted that if two authors co-author a publication, the publication will be counted for both authors.

Table 2: Authorship pattern

Authorship	Paper	% of contribution
Single	42	3.842635
Two	221	20.21958
Three	238	21.77493
Multi-authored (4 &5)	354	32.38792
Mega-authored (> 5 authors)	238	21.77

Most Active Researchers

The list of most active researchers in the field of environmental science research on the basis of number of publications is shown in Table 3.

**Table 3: Most Active researchers**

Author	Paper	H-index	Affiliation	Citations	Total link strength
S K Sarkar	102	27	CU	2266	273
A Mukherjee	51	25	CU	1239	110
S Ghosh	46	18	CU	1252	130
T K Jana	40	17	CU	624	147
S Ray	37	17	CU	676	83
S Sen	35	17	CU	750	78
K K Satpathy	33	22	Indira Gandhi Centre for Atomic Research, Kalpakkam	909	138
A Bandyopadhyay	31	11	CU	307	17
S K Das	29	21	CU	1476	33

B D Bhattacharya	25	16	CU	830	106
M Chatterjee	24	16	Basanti Devi College, Kolkata	868	102
P Chaudhuri	24	11	CU	282	70
S Lahiri	23	21	Homi Bhabha National Institute, Mumbai	239	56
G Aditya	22	16	CU	133	39
K Chakrabarti	22	19	Scottish Church College, Kolkata	657	81

The most prolific researcher is S K Sarkar with 102 publications, 2266 citations, and h-index of 27. It is significant to note that from top 15 researchers, 11 are from University of Calcutta, 1 each from Indira Gandhi Centre for Atomic research, Kalpakkam, Basanti Devi College, Kolkata, Homi Bhabha National Institute, Mumbai and Scottish Church College, Kolkata. The overall share of the productive authors to the total publications is about 50%.

Co-authorship network

From the result we see that 1093 papers were published by 1741 authors. We consider only those authors who contributed at least 5 papers. It shows that only 236 authors have met the threshold. For each of the 236 authors, the total strength of the co-authorship links with other author is shown in figure 3. Cluster analysis of researchers' co-authorship network indicates that this network includes 16 clusters in different colors. The size of the nodes denotes the number of publications resulting from collaboration for each author.
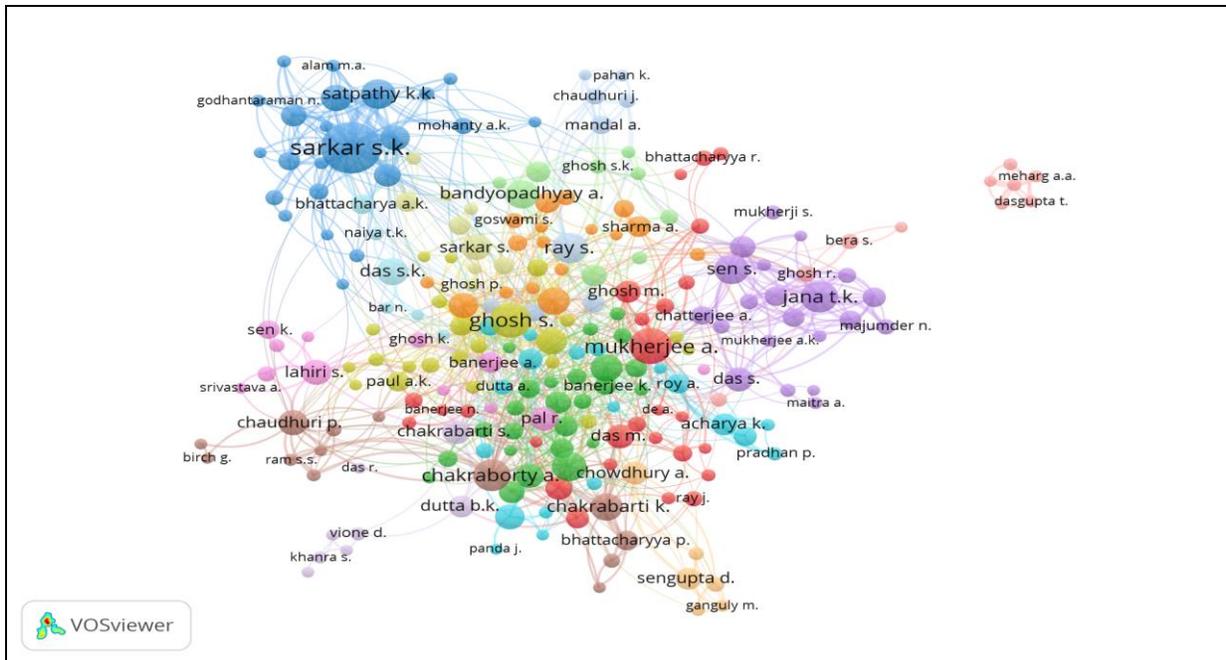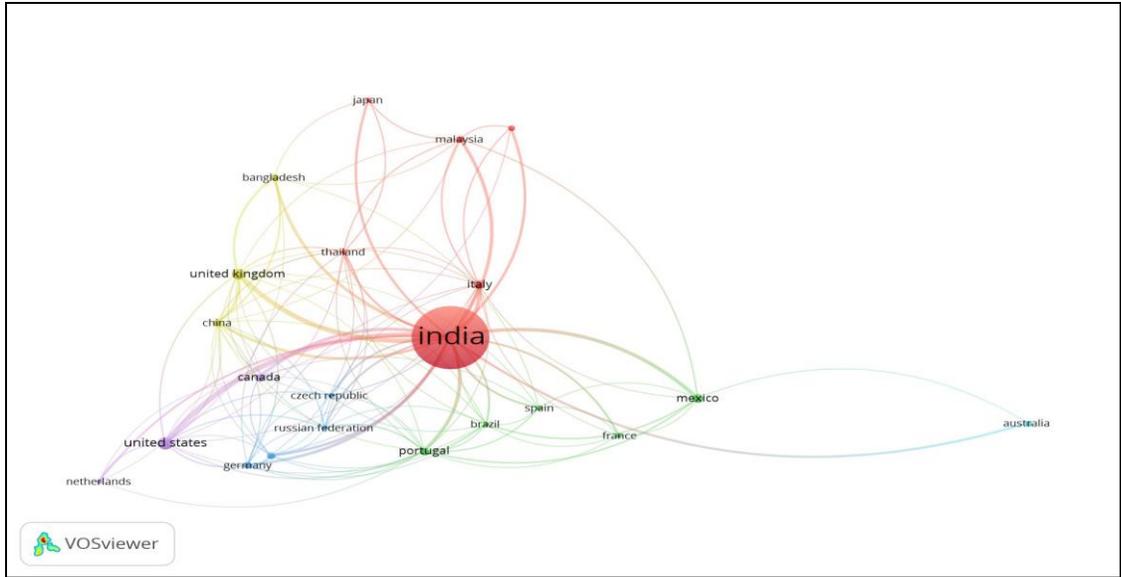
Figure 3: Co-authorship network

The main and important clusters in the co-authorship network of authors are appearing in bright blue color by presence of "Sarkar, S. K.", "Ray, S" and "K K Satpathy"; bright red color by presence of "Mukherjee, A"; bright yellow color by presence of "Ghosh, S"; bright purple color by presence of "Jana, T K" and "Sen, S" and finally bright green color by presence of "Bandyopadhyay, A".

Country wise Co-authorship pattern

Collaboration is vital to scientific innovation, as it facilitates the exchange of ideas and expands the range of perspectives on a given subject (Beaver, 2013). In this analysis, whole rather than fractional counting is applied. From the result we see that 1093 papers were published by authors who are from 63 countries. In the output figure a node symbolizes a country while the size of the node represents the volume of activity of the country. The thickness of the curve shows the extent of collaboration between the respective countries. In the present case, the defined criterion was set up. Only those countries have been taken for consideration which having at least 5 publications. It shows that out of 63 such countries only 22 countries have published 5 or more than 5 paper. For each of the 22 countries, the total strength of the co-authorship links with other countries is shown in figure 4.

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Figure 4: Country-wise co-authorship network

The software separates these 22 countries into 6 clusters which forms 115 links with total link strength of 434. India has the total links strength of 285 with the other countries, followed by United Kingdom (UK) (67), United States (USA) (65), China (44) and Italy (39) respectively. It can be also shows that the link strength between India and UK is 35, between the India and USA being 42, between India and China being 14 and between India and Italy being 21.

Therefore this kind of analysis has identified the scenario of global cooperation in scholarly communication.

Distribution of Output in Journals

The source of publications plays an important role in the research result dissemination and its impact on society.

Table 4 shows the most productive 10 journals and their published papers in environmental science research. The researchers have published about 21% papers related with environmental science in these journals. The most productive journals are Environmental monitoring and assessment with 35 publications, Bulletin of environmental contamination and toxicology with 34 publications, Journal of radio analytical and nuclear chemistry and Marine pollution bulletin with 25 publications respectively.

Table 4: Journal wise distribution of publications

SR.	Journal	No. of output	Citscore

| No.			
1	Environmental monitoring and assessment	35	2.23
2	Bulletin of environmental contamination and toxicology	34	1.78
3	Journal of radio analytical and nuclear chemistry	25	1.18
4	Marine pollution bulletin	25	4.01
5	Chemosphere	22	5.34
6	Environmental science and pollution research	22	3.14
7	Ecotoxicology and environmental safety	21	4.88
8	Indian journal of fibre and textile research	18	0.79
9	Journal of environmental biology	16	0.66
10	Proceedings of the National Academy of Sciences, India-section B	16	0.62

The publishing houses of these journals originate from three countries including Germany, Netherlands and India.

Analysis of Keywords

Liu et al. (2015) stated that "Co-occurrence analysis is based on the assumption that when two items appear in the same context, they are related to some degree".

Co-occurrence of Keyword

Figure 5 shows co-occurrence of keywords with greatest total links strength based on full counting method given in the VOS viewer. The criteria of the keywords having appeared five times or more than five times have been selected. Out of 3226 keywords, 86 met the threshold. Out of 86, the leading 50 keywords with the greatest total link strength were selected.
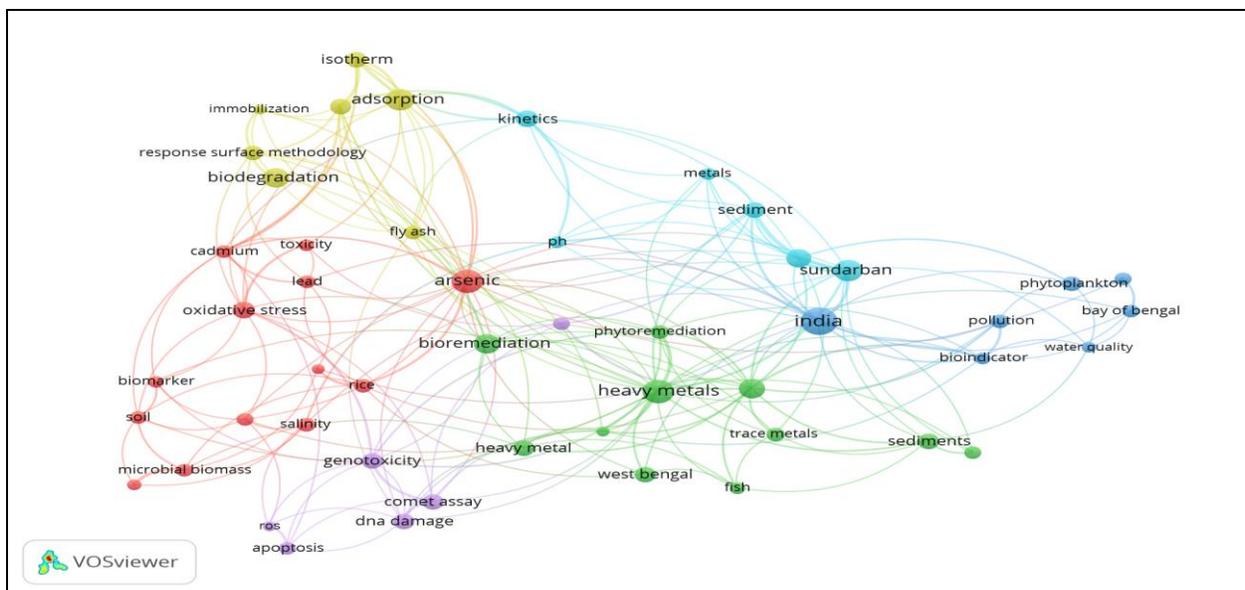
Figure 5: Co-occurrence of Keywords

The keywords are Heavy metals (occurrence-28, link strength -37), Sundarban ((occurrence-23, link strength -33), Bioaccumulation (occurrence-19, link strength -31), Arsenic (occurrence-28, link strength -25), India (occurrence-37, link strength -25), Sediment (occurrence-13, link strength -22), Mangrove (occurrence-17, link strength -20), etc. These keywords throws light on the research areas in which faculty members are engaged with. Here, we see that only 6 cluster were created with 206 links as a whole having 319 links strength.

Conclusion

A comprehensive scientometric study on environmental science research conducted by researchers of the University of Calcutta has been performed through Scopus database based data with a time span of thirty years. Following results can be drawn from the above study:

The University of Calcutta has observed a significant increase in research publications in environmental science in recent years. An exponential growth rate has found. More than half (54%) of the papers were published as multi-authored and mega-authored papers. S. K Sarkar of CU is the most prolific researcher. Cluster analysis of researchers' co-authorship network indicates that this network includes 16 clusters in different colors. The strongest collaboration highlighted through blue color by presence of Sarkar, S K, Ray, S and Satpathy, K K. The most productive journal is Environmental Monitoring and Assessment. The Country wise Co-

authorship pattern shows that India, UK, USA, and China evolved as the leading countries in environmental science research. Through the analysis of keywords it may be observed that the research topics such as Heavy metal, Sundarban, Bioaccumulation, Arsenic and Mangrove have been elevated. This kind of study may have some impact on the researchers' who deals with environment and its allied area in anticipating future.

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