11-21-2020

Mapping of Microbial Technology Research Output at the Global Level: A Scientometric Study

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Abstract

Using the Web of Science Bibliographic database, the present study tries to give a complete view of the evolution of the field of Microbial technology research output during the period from 1990 to 2018. The study presents the growth tendency and literature output in the field of Microbial Technology. The study shows that a total of 2968 articles were published during the period by the top authorship pattern, collaborative coefficient, doubling time key word co-occurrence, co-authorship pattern etc.,. some of those research articles have been produced by single authors while multiple authors have contributed articles in most other instances.

Keywords: Scientometrics, Microbial Technology, Co-Authorship, Collaborative Coefficient

Introduction

Microorganisms form one of the omnipresent living particles in and around the surface of the earth. Microorganisms are found in abundant numbers in the air, water and soil. Certainly, microorganisms are the gift of nature to the human society at large. They are used for a wide range of productive

purposes primarily through the method of fermentation. Microorganisms contribute to the production of organic acids, amino acids, enzymes, and vitamins etc., which are most essential to fulfil the food and healthcare needs of humans as well as other living beings. In addition, microorganisms are essential for the production of insulin, vaccines, gene therapy, bioenergy and so on. It is a well-known fact that insulin is the necessary component for treating diabetics patients. Likewise, vaccines are the primary precautionary measures for protecting human beings from lethal deceases. Gene therapy is commonly used for inventing efficient antibiotics and other antimicrobial agents. Bio fuels and bio mass conversion are quite potential sources of renewable energy which is an invariable use of microorganisms. Undertaking a study about the scholarly articles and journal publications about the microorganisms will be a fruitful endeavour, which is attempted in this paper.

Scientometrics is a branch of sociology of science. in 1940's, the first intended consequences of research work emerged from Robert .K.Merton from the scientometrics perspective. In 1960's, the author Derek De Solla Price first mapped of science in Little science and Big science. Scientometric defined as the quantitative study of science, communication in science and science policy. It is the one of the science measuring analysis the term Scientometrics derived from the Russian "Naukometria" is used as the study of scientific and technological development. Nalivmov & Mulchenko (1969) explained that Scientometrics as " the application of those quantitative method which are dealing with the analysis of science observed as an incormation processs". Haitun (1980) defined "as an approach the science of science aimed at a reproducible measurement of science which reveals its objective in quantitative, regularities".

Objectives in studying the Microbial Technology Research Output

- To measure the Authorship Pattern
- To analyse the Collaborative Index, Co-Efficient and Degree of Collaboration
- To examine the Keyword Co-Occurrence with source wise analysed
- To define the Co-Authorship Pattern and Bibliographic Coupling, Co-Citation with authors
- To analyse the cited author with references.

Review of literature

Bajwa and Yaldram depicted that research in the field of biotechnology has raising in 1980s and 15 publicaitons increased 3273 databases in 2011. Majority of publications in Argicultural and biologiecal sciences followed by the other discipline in genetics, molecular biology and biochemistry. The research concentration in universities and the remaining improvement in R&D organizations.

Ramakrishna & Pangannaya (1999) described that quantitative studies in science journals identified the core and importance literature of animal cell culture, technology found in citations select from the journal publication of Animal Cell Biotechnology. This study was distributed chronological of core journals subject country wise and growth rate obsolescence and the maximum citation journal were examined. The Bibliometrics law was used in the subject verified by the Bradfors's Law

Kaur et al. (2009) suggested the India publication output in Immunology and Microbiology for the period 1999 to 2008. The research based on the several parameters, including India's annual average growth ratio, rank of global publications share, top selects 15 institutional profiles, international collaborative profile and major collaborative authors, national and international journal patterns of communication and individual of its top 15 most productive authors

Bagalkoti, Vithal and Hosamani, S.C.,(2014) explained that Scientometrics analysis of biochemistry and molecular biology research output for 15 years using web of science. The study focused on india and its comparision within other countries. It evulate the research performance of major research output in growth of literature in India has produced 35864 publications and 265740 citation received during the year1999-2013. The highest publications of 17344 databases during the year 2008-2013.The publications of databases increased by gradually every year in india. The research contribution of analysis including citation impact of most productive countires, leading international collaboration, Indian institutuiion authors pattern of communications of Indian output publications.

Singh, Y.A.(2014) depicts that bibliometric analysis of microbiology publications in sub-saharan Africa during the year 2000-2014. It concluded that most of the literature published over the period journal impact factor 3.7 in2014, average impact factor of 6.1.

Materials and Methodology

This study is based on the Microbial Technology research output publication database retrieved from web of science for the period extending from 1990 up to 2018. The data pertaining to research output in Microbial Technology was derived using the string words title, abstract, author, source, country and publications. the methodology used for deriving the data included collaborative co-efficiency, authorship pattern, collaborative index, co-authorship pattern, keyword co-occurrence, source wise and country wise publication index, and bibliographic coupling.

The following statistical techniques have been used for authorship pattern in percentage analysis, collaborative index formaula are $\text{Formula for CI} = \sum_{J=1}^{A} jFJ / N$

fj = the number of papers having j authors in collection k;
N = the total number of papers in k. N= ∑ j fj; and
A = the total number of authors in collection k

∫j refers to ☺the number of co- authored papers appearing in a subject; n is the total number of papers in the subject over the same time interval, and k indicates the greatest number of authors per paper in the discipline. Ajiferuke et al. (1988) has pointed out that, in the absence of the collaborative index at the primary level, there is no way of interpreting the numbers generated, and the method imputed a non-zero weight to single authors papers.

Collaborative co-efficient formula are

$CC = 1 - \sum_{j=1}^{A} 1(1/j) \int j/N$

where as

Fj = the number of authored per papers
N = the total number of research published
A = the greatest number of authors per paper

CC is an interesting measure of collaborative strength in a discipline that has the merit of lying between 0 and 1 and tends to 0 as single authored papers dominate

Subramaniam's (1983) formulas offer an ample scope for observing the extent of research collaboration among scientists and engineering scientists. The degree of collaboration (DC), a measure of proportion of multiple authored papers are given by the formula

C = Nm / (Nm + Ns)
C = Degree of Collaboration of scientists
Nm = Number of Multiple authored papers
Ns = Number of single authored papers

VOS viewer is a software tool for constructing and visualizing bibliomteric networks. These networks have been constructed based on the bibliographic coupling, co-citaion, keyword co-occurrences, country wise, documetnwise, co-authorship etc., Van Eck & Waltman,2010 introduced the free software online.

Results and Analysis

Table 1: Year & Authorship Pattern Wise Research Output of Microbial Technology

year	Single author	Double author	Three author	Four author	Five author	Six author	Seven author	Eight author	Nine author	Ten & above author	Total
1990	1	2	-	-	-	-		-	-	-	3
1991	10	4	2	-	2	-	1	1		-	20
1992	10	6	4	3	-	-	-	-	-	-	23
1993	7	7	-	2	2	-	-	-	-	-	18
1994	8	3	3	1	-	2	-	-	-	-	17
1995	9	6	2	1	1	-	-	-	-	-	19
1996	11	4	4	3	3	-	-	-	-	-	25
1997	9	4	3	2	1	1	1	-	-	-	21
1998	7	12	2	6	1	3	-	-	-	-	31
1999	7	11	4	3	2	3	1	1	-	1	33
2000	14	11	7	4	1	4	-	-	-	-	41
2001	15	9	13	1	4	1	1	1	-	-	45
2002	5	12	9	5	4	-	-	-	-	1	36
2003	11	12	3	6	3	6	-	-	-	1	42
2004	13	8	11	7	7	7	2	-	1	-	56
2005	10	17	9	16	8	5	6	-	-	-	71
2006	11	7	11	10	12	5	5	2		1	64
2007	12	15	16	8	7	7	3	3	1	3	75
2008	11	16	18	21	19	7	2	2	1	5	102
2009	18	15	25	18	15	12	6	6	1	2	118
2010	21	17	24	36	20	15	5	8	3	4	153
2011	12	25	21	23	22	16	12	6	3	4	144
2012	10	27	44	29	28	13	11	3	4	10	179
2013	7	19	36	30	33	21	18	8	3	10	185
2014	19	31	35	39	27	26	14	9	6	14	220
2015	23	46	40	45	45	24	18	14	6	18	279
2016	14	36	43	57	40	32	22	18	10	29	301
2017	19	48	51	57	42	41	24	13	7	26	328
2018	11	39	46	58	44	46	23	20	10	22	319
	335	469	486	491	393	297	175	115	56	151	2968

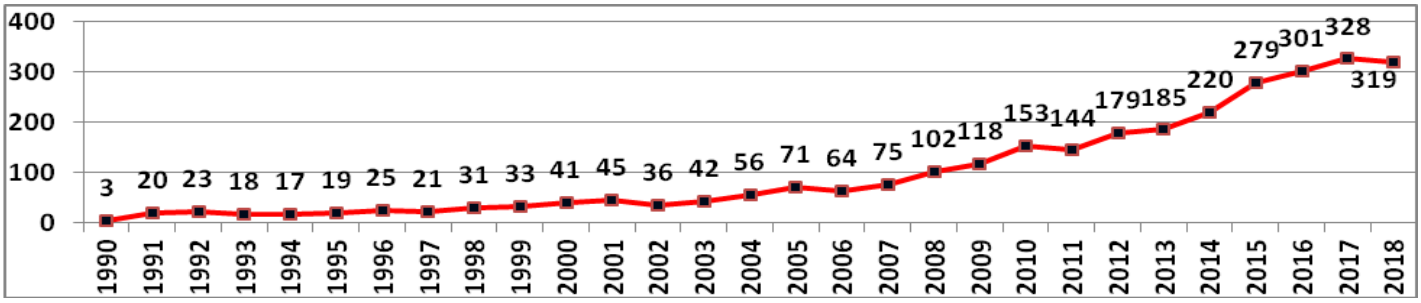

Figure 1

Table 1 and Figure 1reflects year & Authorship Pattern wise Micribial Technology research output. A total of 2968 records were traced to have appeared in this period, the research output in the opening year in Microbial Technology being 3 articles in 1990 and the closing year accounting to 319 articles in 2018. The database gradually increased in 1990 to 2007. In the year 2007 onwards suddenly increased the year wise research output. Highest number of (328) articles published in the year 2017. Span of 29 years the publishing growth of Micribial Technology research output is not enough growth compare to another field of research.

Table 2: Authorship Pattern of Microbial Technology Research Output

S.No	Authors	No. of Records	No. of Authors	Percentage %
1	Single author	335	335	11.29
2	Double author	469	938	15.80
3	Three author	486	1458	16.37
4	Four author	491	1964	16.54
5	Five author	393	1965	13.24
6	Six author	297	1782	10.01
7	Seven author	175	1225	5.90
8	Eight author	115	920	3.87
9	Nine author	56	504	1.89
10	Ten & above author	151	1510	5.09
		2968	12601	100.00

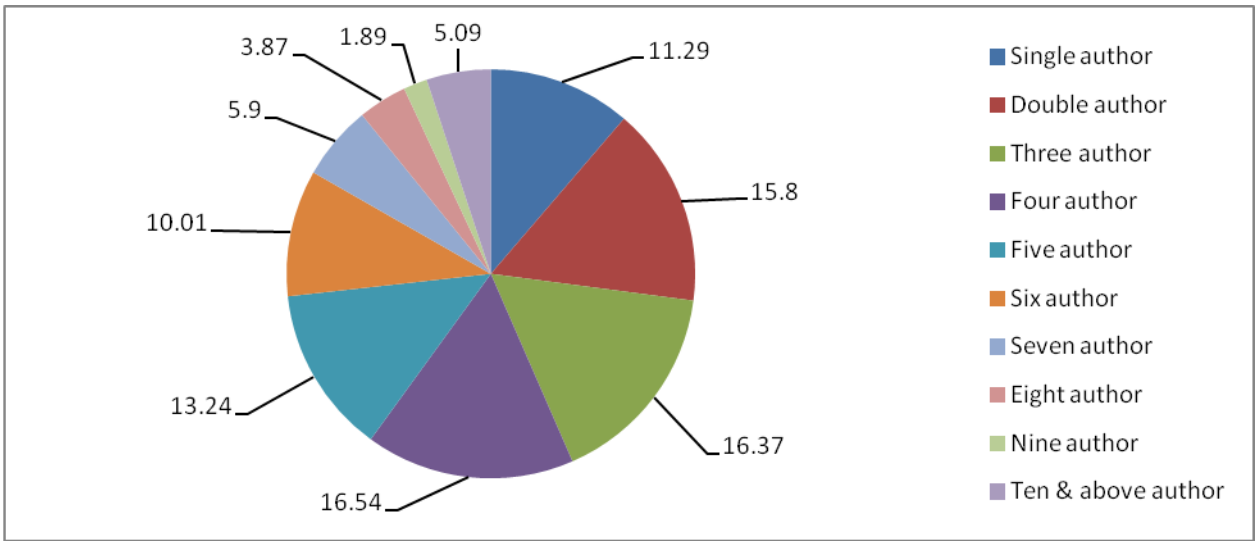

Figure 2

Table 2 and Figure 2 reflects the collaboration pattern of authorship. Out of 2968 records 335 are contributed by single authors of total output. 469 records are contributed by double authors of total output and which tops 491 records contribution by four authors and stands second with 486 records followed by three authors in the rank. Contribution by single author, double authors , three authors and four authors together stands more than 60 percent and remaining 40 percent contribution came from five and more than five authors with the major contribution of five authors. Analysis of this collaborative pattern in though quite good in collaboration but as compare to other areas of research it demands still more collaboration because majority of the papers came from three and four authors.

Table 3: Collaborative Index , Degree of collaboration, Collaboration Co-Efficiency

S.No	Year	Total Records	CI	DC	CC
1	1990	3	5.00	0.67	0.33

2	1991	20	2.95	0.50	0.33
3	1992	23	2.43	0.57	0.34
4	1993	18	2.72	0.61	0.37
5	1994	17	2.88	**0.53**	**0.25**
6	1995	19	**2.42**	0.53	0.31
7	1996	25	2.72	0.56	0.37
8	1997	21	2.95	0.57	0.34
9	1998	31	3.03	0.77	0.41
10	1999	33	3.21	0.79	0.44
11	2000	41	2.73	0.66	0.34
12	2001	45	2.82	0.67	0.42
13	2002	36	2.94	0.86	0.55
14	2003	42	3.07	0.74	0.38
15	2004	56	3.57	0.77	0.44
16	2005	71	3.62	0.86	0.54
17	2006	64	3.89	0.83	0.54
18	2007	75	3.51	0.84	0.51
19	2008	102	3.60	0.89	0.59
20	2009	118	3.82	0.85	0.53
21	2010	153	3.90	0.86	0.56
22	2011	144	**4.11**	0.92	0.58
23	2012	179	3.78	0.94	0.62
24	2013	185	**4.28**	0.96	**0.63**
25	2014	220	3.94	0.91	0.58
26	2015	279	3.89	0.92	0.60
27	2016	301	4.10	0.95	**0.63**
28	2017	328	3.95	0.94	0.60
29	2018	319	**4.31**	**0.97**	0.61
		2968	**3.45**	**0.77**	**0.47**

CI refers to Collaborative Index , DC refers to Degree of collaboration, and CC indicates Collaboration Co-Efficiency

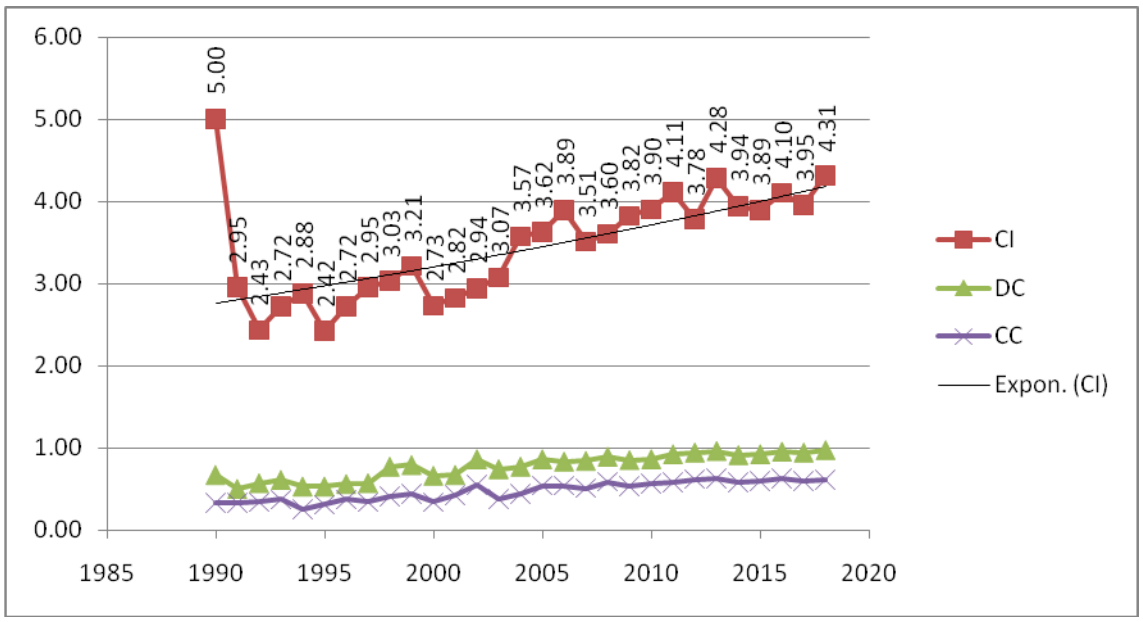

Figure 3

Table 3 and Figure 3 reveals that the highest value of Degree of collaboration was 0.97 as observed in the year 2018 and the least value of DC 0.53 in the year 1994 and mean value of 0.77 from the period 1990 to 2018. The CI can be observed that there was the highest value of 4.31 in 2018 and lowest value of 2.42 was found in 1995. There was an average collaborative Index value of 3.45 during the stipulated study span. In terms of collaborative co-efficiency, it has been found that maximum value of 0.63 occurred in the year 2013 followed by 0.62 and 0.61 in the years 2012 and 2018 respectively. The mean value of CC was 0.47 from the period 1990 to 2018.

Table 4: Organizational Co-Authorship Analysis in Microbial Technology Research Output

S.No	ID	Organization	Documents	Citations	Total link strength
1	2067	University of California, Berkeley	34	1096	71
2	335	Chinese Academy of Sciences	51	853	38
3	1872	Technical University of Denmark	32	1278	38
4	375	The French National Center for Scientific Research (CNRS)	19	315	36
5	2188	Ghent University	35	1254	34
6	1036	Joint BioEnergy Institute	10	406	32
7	2611	Wageningen University	17	338	28
8	1482	Oak Ridge National Laboratory	10	1128	24
9	2479	University of Tennessee	11	255	24
10	2487	University of Tokyo	26	822	22
11	2109	University of Copenhagen	13	399	21
12	1374	National Institute of Advanced Industrial Science and Technology	14	378	20
13	902	The Institut National de la Recherche Agronomique	17	847	19
14	1689	Sandia National Laboratories	8	292	19
15	1167	Lawrence Berkeley National Laboratory	8	188	18
16	1505	Osaka University	28	480	18
17	1839	Swedish University of Agricultural Sciences	11	292	18
18	2095	University of the Chinese Academy of Sciences	12	105	18
19	2198	University of Groningen	11	383	18
20	403	Cornell University	11	390	17

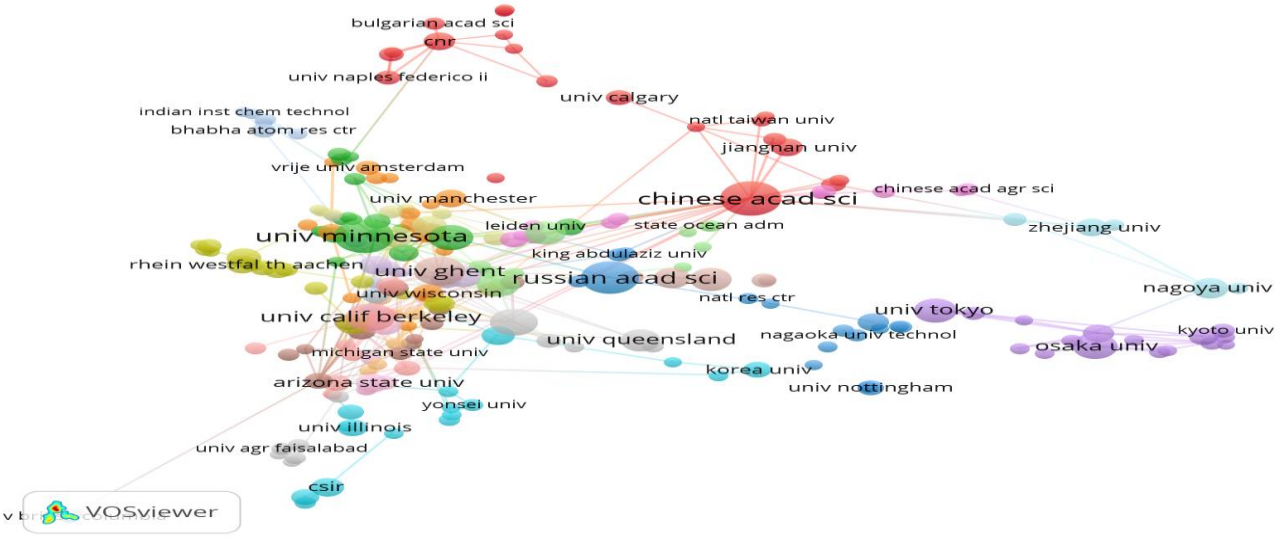

Figure 4

The Table 4 and Figure 4 presented above indicates the number of documents relationships among top 20 organization and co-authorship documents with their citations calculated. Among the 2693 organizations, 254 meet the thresholds. For each of the 2693 organizations, the total strength of the co-authorship link with other organizations has been calculated. The maximum number of organizations forums connected and clusters formed were 254. Therefore the co-authorship analysis of these 254 organizations has been performed. The Vos vierwer software separates these 254 organizations in to 9 clusters which forms 254 links with a total link strength of 2693. The total link strength represents the co-occurrence frequency. The big nodes represents the productive organizations. For each of the 254 organizations, the total strength of the co authorship links with other organizations was calculated. The organization with the greatest total link strength was selected, and the total number of organizations to be selected were 254. Some of the 254 items in this network were connected to each other. The largest set of connected items consisted of 236 items only. The co-authorship and organizations with documents map found that the highest number of 71 links were established by the University of California, Berkeley followed by the Chinese Academy of Sciences with 38 total links.

Table 5: Map of Keyword Co-Occurrence in Microbial Technology Research Output

S.No	ID	Keyword	Occurrences	Total link strength
1	1146	Biotechnology	291	473
2	1104	Bioremediation	85	146
3	4129	Metabolic Engineering	68	133
4	660	Bacteria	56	120
5	4167	Metagenomics	49	105
6	2627	Fermentation	51	96
7	6648	Synthetic Biology	48	92
8	3545	Industrial Biotechnology	45	87
9	3879	Lipase	49	77
10	891	Biodegradation	42	71
11	4370	Microbial Fuel Cell	51	70
12	959	Biofuels	26	62
13	1167	Biotransformation	35	62
14	2448	Enzymes	26	62
15	855	Biocatalysis	32	60
16	7185	Yeast	31	60
17	903	Biodiversity	25	54
18	4319	Microbial Community	34	51
19	4341	Microbial Ecology	29	51
20	7091	Wastewater Treatment	33	51

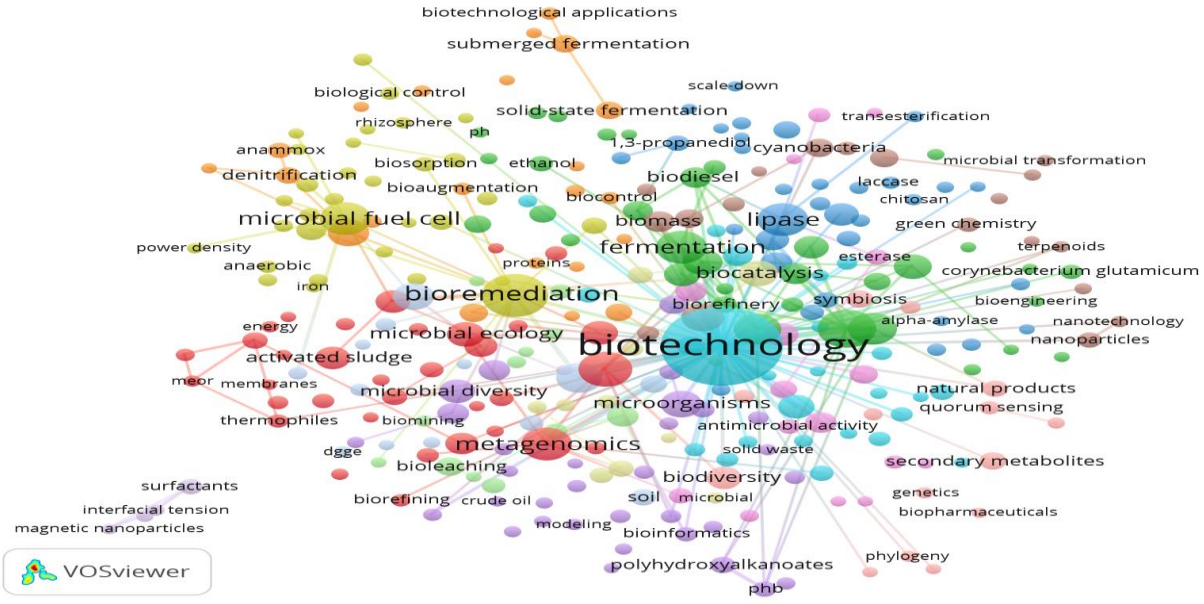

Figure 5

The social network map of keyword co-occurrence in Microbial Technology research output is presented in Table 5 and Figure 5. It reveals the size of nodes in relation to the frequency of keywords, highest occurrence of keyword and the larger size of node. The thickness of the line is proportional to the closeness of the connections between the two keywords. In addition, the thicker line between two or more words indicates the close relationship. The keywords with greatest total link strength were selected and of the 7221 keywords, 304 meet the threshold. For each of the 304 keywords, the total strength of the co occurrence links with other keywords was calculated. The keywords with the greatest total link strength was selected. Biotechnology topped the list with 291 highest occurrences out of 473 total link strength followed by bioremediation, metabolic engineering and bacteria.

Table 6: Bibliographic coupling and Vs Documents Analysis

S.No	ID	Document	Year	Citations	Total Link Strength
1	2149	Lynd	2002	2509	231
2	830	Hsu	2014	1795	109
3	1998	Rabaey	2005	1178	418
4	2105	Chaudhuri	2003	860	146
5	2154	Jaeger	2002	853	235
6	2205	Rothschild	2001	833	71
7	1833	Warnecke	2007	762	176
8	1685	Berg	2009	731	98
9	1547	Narayanan	2010	668	198
10	1714	Gadd	2009	507	67
11	2163	Liu	2002	499	68
12	2273	Pandey	1999	490	72
13	2280	Pandey	1999	403	161
14	1661	Vu	2009	400	90
15	2167	Subramaniyan	2002	382	121
16	1858	Kleerebezem	2007	308	104
17	1867	Rabaey	2007	302	440
18	1925	Ahn	2006	302	91
19	1890	Hau	2007	297	179
20	1996	Lorenz	2005	283	496

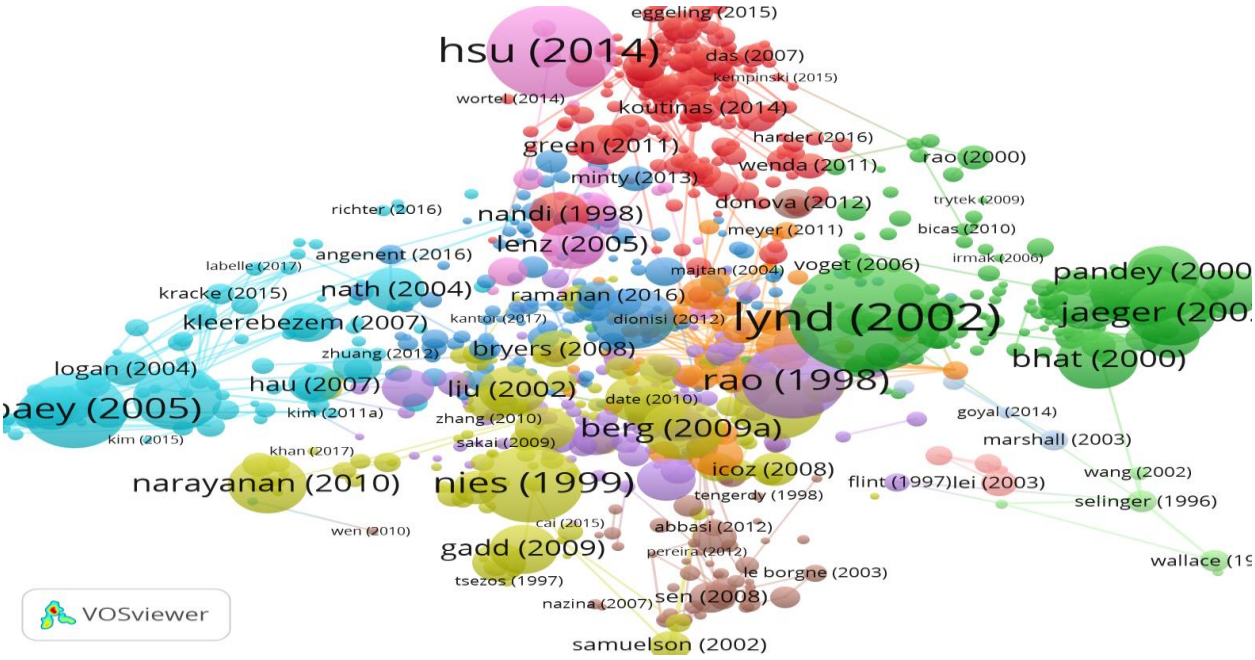

Figure 6

The Bibliographic coupling and Document total link strength was calculated. Minimum Number of citation of a document was found to be 5. Of the 2968 documents, 1752 were identified to have met the stipulated threshold. For each of the 1495 documents, the total strength of the bibliographic couplings links with other documents was calculated. The documents with the greatest total link strength were selected. In this process, the top 20 bibliographic coupling of Vs documents were shortlisted. The document Lynd in 2002 highest citations of 2509 and total link of 231 , followed another Hsu in 2014, total link of 109 and citation of 1795. Each document displays the node different colors**.** The first Lynd displays a color orange, Hsu (2014) red color, Rabaey (2005) in sky blue, Jaeger in (2005) Green, Rao (1998) violet and Narayanan (2010) yellow color displayed.

Table 7: Co-citation with cited authors Mapping

S.No	ID	Author	Co- citations	Total link strength
1	46760	Lovley, Dr	236	3450
2	35529	Jaeger, Ke	226	1617
3	62532	Rabaey, K	212	3554
4	58433	Pandey, A	198	1446

5	45933	Liu, H	131	2240
6	2233	Altschul, Sf	128	967
7	25085	Gadd, Gm	124	2132
8	54045	Muyzer, G	123	1357
9	2343	Amann, Ri	115	1372
10	46076	Liu, Y	114	1118
11	44112	Lee, Sy	112	1501
12	64765	Rittmann, Be	105	1367
13	5004	Banat, Im	102	1257
14	67184	Sambrook, J	102	759
15	82020	Wang, Y	98	1060
16	47340	Lynd, Lr	96	1589
17	75655	Tamura, K	94	827
18	11587	Caporaso, Jg	89	836
19	18071	Demain, Al	89	908
20	20773	Edgar, Rc	84	749

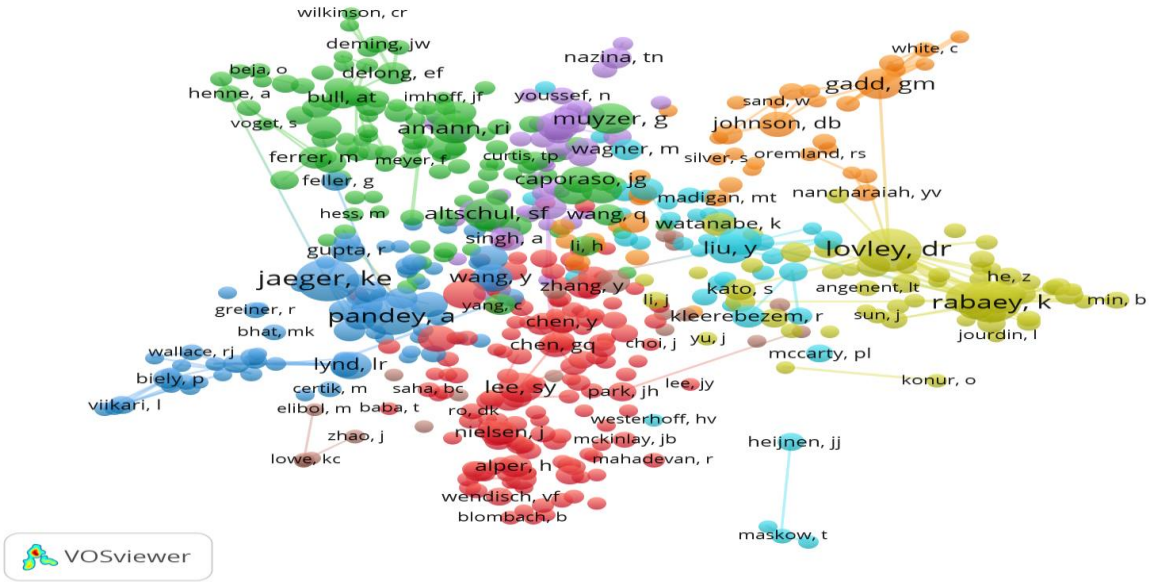

Figure 7

The list of most productive authors is shown in Table 7. The top 20 productive authors have their co- cited paper by maximum number of cited authors, While most authors have total link strength of co-citations. The Minimum number of citation of a source 20, Of the 87938 sources, 557 meet the threshold. For each of the 909 sources, the total strength of the co-citation links with other sources was calculated. The Authors with the greatest total link strength were selected. The total number of documents selected stood at 557. The largest set of connected items consist of 556 items only. The first authors of Lovley, Dr. has 236 citations and total link of strength is 3450 followed by Jaeger, Ke with 226 citations and Rabaey, K. with 212 co-citations out of total link of strength.

The Figure 5 shows the authors co-citations through the figures in various colors. The highest authors Lovely, Dr. has been highlighted with yellow color, Jaeger Ke, and Pandey K are indicated of their positions in the citation index list through Navy color, Muyzer, G. is represented in violet, Mann Ri in Green, Gadd Gm in Orange and Lee Sy in red in correspondence with total co-citation and total link of strength.

Conclusion

A widespread Scientometric study on Microbial Technology research output has been executed in VOS Viewer Mapping in Web of science Database in span of 29 years. Various variables have been executed for this study in terms of scientific publications, authorship pattern, mapping of VOS Viewer analysis in Keyword Co-occurrence and documents with organization, cited with co-authors references and citation in Bibliographic coupling. A scientometric study of Microbial Technology database in 2968 articles during the 1990 to 2018 has been analyzed. An analysis of authorship pattern of the research literature revealed that individual author produced lowest level of contribution and the highest number of articles with good citation index were published by multiple authors. The collaborative index was found to be ranging based on year wise lies between 2.42 to 4.31 and CC on 0.53 to 0.97 and DC on 0.25 to .063 respectively.

Bibliographic coupling of co-authorship Vs organization in with documents map found that highest total link of 71 in University of California, Berkeley and keyword occurrences highest of Biotechnology was 293 out of 491 total link. The document Lynd in 2002 highest citations of 2509 and total link of 231 , followed co-citation with author Lovley, Dr., have 236 citations and total link of strength is 3450.

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