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Thirty Years of Global Literature on Bioleaching: A Scientometric Analysis

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ABSTRACT:

The study deals with the Scientometric analysis of thirty years publication on 'Bioleaching'. The records are collected from Web of Science Databases for the period of 1989 – 2018. A total of 2477 papers were identified in the Web of Science database. The study reveals that most of the researchers preferred to publish their research results in the form of journals articles and 82.8% of articles were published in journals. More numbers of articles were published in the year 2015. The authorship trend shows that, out of total 2477 publication published, 95% of the publications were published under the joint authorship. This study also identifies that Relative growth rate, Doubling Time, Degree of collaboration. Central South University with 268 (10.8%) publication tops in the institutional wise publications productivity. The study also identifies bibliographic coupling of the institution, language distribution, keyword distribution, geographical distribution of the literature and Historiography on Local and Global Citation is also analyzed.

KEYWORDS: Bioleaching, Scientometric, Relative growth rate, Doubling time, Authorship, Institutional Bibliographic coupling, Citations.

1. INTRODUCTION:

Scientometrics can be defined as the “quantitative study of science, communication in science, and science policy” (Hess, 1997).^[1] Scientometrics is the science of measuring and analyzing science. In practice, Scientometrics studies have been done using bibliometric methods (Wikipedia, 2014).^[2] Pritchard (1969).^[3] define Bibliometrics as “the application of mathematical and statistical methods to books and other media of communication”. All the studies concentrate on the merits and demerits of the research publications which will be helpful for its further development. This paper studies the global level productivity of research published in the Bioleaching from 1989 to 2018. Scientometric involves quantitative studies of scientific activities. The major focus of the study is to apply the scientometric analysis with a view to analyzing the growth and development of research output in Bioleaching at the global level. This study is related to authors and their productivity;

collaborative patterns and other aspects are important and useful to understand the mechanism underlying the growth of knowledge of a discipline. This study also analyses the growth and development of Bioleaching research output in terms of its content and coverage relative growth rates, doubling time, source wise. The degree of collaboration, authorship Pattern, and word frequency and citation analysis are also studied.

2. BIOLEACHING :

Bioremediation is a process used to treat contaminated media, including water, soil and subsurface material, by altering environmental conditions to stimulate the growth of microorganisms and degrade the target pollutants. In many cases, bioremediation is less expensive and more sustainable than other remediation alternatives. ^[4] Bioleaching is one type of bioremediation, which involves the extraction of metals from their ores through the use of living organisms. This is much cleaner than the traditional heap leaching using cyanide. ^[5] Bioleaching is one of several applications within bio-hydro metallurgy and several methods are used to recover copper, zinc, arsenic, antimony, nickel, molybdenum, gold, silver, and cobalt. Bioleaching is in general simpler and, therefore, cheaper to operate and maintain than traditional processes since fewer specialists are needed to operate complex chemical plants.

3. REVIEW OF LITERATURE:

C. Baskaran (2016) ^[6] examines the relative growth rate and doubling time of Bioinformatics Publication during 1999-2013. The mean relative growth was measured and doubling time observed from the analysis. Total number 20577 of records on bioinformatics publication during the study. The Maximum of Publication 2234 in 2012 was published compare to the rest of the years. The highest publication published in Bioinformatics journal and Harvard University scientists contributed the highest number of publication in the study. RGR and DT is exhibiting that fluctuating trend happening whole period of study.

C. Baskaran (2013) ^[7] analyzed the author productivity, discipline-wise and institution-wide collaboration and ranking of authors in the research contribution of Alagappa University during 1999-2011. Relative Growth Rate (RGR) was found to be a fluctuating trend during the study period. The Doubling time (Dt) was found to be increased and decreased trend in this study. The degree of collaboration and its means value is found to be 0.963. The top three institutions with Alagappa University is Central Electro Chemical Research Institute, National Cheng King University and Anna University.

C. Baskaran (2014) ^[8] examines the quantitative analysis of the productivity and characteristics of citations of Library and Information Science (LIS) publications during 2003-2012. A Total of 1942 contributions published and 12502 citations received in the LIS

journals indexed in SSCI. 21.36% of citations were received in 2012. The top-ranked authors, Bawden, B and Hjørland, B contributed 0.72% of papers out of which Hjørland, B cited 1.93% of articles. USA contributed 4.38% of papers and also received 24.85% of citations. It is followed by UK which contributed 9.99% of LIS research papers out of 9.68% of citations were received. Year-wise authors' productivity, Institution-wise position and ranking of journals with citations references are listed to indicate their productivity and degree of involvement in their publications of Library and Information Science research.

C. Baskaran (2015) ^[9] analysis the total enzymes publications records of 4962 from 1999-2013. Relative Growth rate (RGR) and doubling time of publication were found RGR has been increasing from 2001, 2002 (0.001) to 2013 (0.023). This study and it confront the publications output trend among USA scientists; Wang Y has secured top level as measured 0.226%. USA scientists have contributed totally 15832 (30.815%) items and include 87.947% per cent appear as journal articles. Harvard University scientists are much attention in a produced large number of research papers and they hold top level among research collaboration in enzyme research.

Liang Zhang et, all (2010) ^[10] reviewed published wetland research, 1991–2008: Ecological engineering and ecosystem restoration. The results showed the significant wetland research issues in the SCI database. From 1991 to 2008, the annual number of journal articles published and the number of articles cited to wetland research increased more than six-fold and nine fold respectively. The USA produced the most single-country articles and international collaborative articles, followed by Canada and UK.

Kirti Joshi, Avinash Kshitij, Garg (2010) ^[11] studied the field of forest mycology indicates that the number of publications has increased significantly during the year 2004-2008. A total of 3313 publications scattered 619 journals title from 50 countries and 839 institutions highest rate of annual growth of published articles.

Subramaniam K (1983) ^[12] Bibliometric Studies of Research Collaboration, Published in A review, Journal of Information Science. In this paper, several types of collaboration have been identified, and earlier research on collaboration has been reviewed. Further research is needed to refine the methods of defining and assessing collaboration and its impact on the organization of research and communication in science.

4. OBJECTIVES:

The main purpose of this study was to analyze the 30 years of scientometric features of Biobleaching research activities at global and to identify the pattern of distribution of Biobleaching research output, the rate of growth of Biobleaching research productivity by calculating relative growth rate and doubling time of publications, Authorship pattern, degree of collaboration, ranking of authors based on publications, journal wise distribution of publications, institution wise research concentration and bibliographic coupling, country wise distribution, source wise distribution of publications, language wise and key word distribution on biobleaching research output,

5. METHODOLOGY

The data for the study of Bioleaching research output on a global level were downloaded from the web of science database in September 2018. All the Publications were retrieved from the Web of Science database on Bioleaching by using the keyword in “BIOLEACHING” in the title field and cover the period from 1989 to 2018. Further, the researcher has downloaded the bibliographical data in the form of plain text files. Then, the bibliographical details are converted using Histcite software (developed by Thomson Reuter), VOSviewer (developed by Universiteit Leiden, Netherlands) for further analysis. Overall data retrieved by the researcher are 2477 records and all the 2477 records were analyzed for the present study.

6. ANALYSIS AND DISCUSSIONS:

6.1.The growth of Publications:

Total of 2477 publications was published on Bioleaching during 1989 – 2018 globally. Table 1 shows the year-wise distribution of publication on Bioleaching research. The maximum number of publications 183 (7.4%) were recorded in 2015 with a Total Local Citation Scores (TLCS) 555 and Total Global Citation Scores (TGCS) 1358.

Table 1: Shows Year wise Distribution of Publications

S.No	Year	Publications	%	TLCS	TGCS
1	1989	6	0.2	51	98
2	1990	15	0.6	67	128
3	1991	16	0.6	110	271
4	1992	31	1.3	350	750
5	1993	46	1.9	384	818
6	1994	27	1.1	263	891
7	1995	36	1.5	340	804
8	1996	32	1.3	343	790
9	1997	43	1.7	545	1112
10	1998	39	1.6	513	1353
11	1999	39	1.6	508	1111
12	2000	38	1.5	607	1359
13	2001	66	2.7	1300	3318
14	2002	49	2	341	1475
15	2003	63	2.5	1164	2991
16	2004	56	2.3	783	1492
17	2005	55	2.2	774	1477
18	2006	88	3.6	1204	2663
19	2007	72	2.9	805	1818

20	2008	152	6.1	1784	4267
21	2009	133	5.4	1284	3091
22	2010	131	5.3	1063	2356
23	2011	125	5	878	1878
24	2012	134	5.4	690	1742
25	2013	173	7	1063	2272
26	2014	163	6.6	650	1520
27	2015	183	7.4	555	1358
28	2016	165	6.7	267	787
29	2017	159	6.4	137	396
30	2018	142	5.7	17	38
Total		2477	100	18840	44424

The minimum number of publications 6 (0.2%) were recorded in 1989 with 51 TLCS and 98 TGCS. The maximum TLCS 1784 were recorded in 2008 and minimum 17 in 2018. The maximum TGCS 4267 were recorded in 2008 and minimum 38 in 2018. It also indicates that all these 2477 publications have 83544 cited references, which indicates a healthy trend in citing reference found among the global researcher of bioleaching area of study.

6.2. Relative Growth Rate and Doubling Time

Relative growth rates of bioleaching literature and also the doubling time for publications is analyzed in Table -2. It could be observed that the relative growth rates for all sources of bioleaching research output have decreased from 0.916 in 1990 to -0.113 in 2018. The mean relative growth rates for the periods are divided into three blocks of 10 years each and they were 0.871, 0.136 and 0.006 respectively. The overall study period has witnessed a mean relative growth rate of 0.337. Contradictory to this, the doubling time for publication of all sources of bioleaching research output has increased from 0.76 in 1990 to 6.13 in 2018. The mean doubling time for publications for the periods of three blocks of 10 years each is found to be 0.47, 7.03 and 9.02 years respectively. The whole study period has witnessed a doubling time for publications at 5.50 years. In general, bioleaching research output has shown a declining trend as far as the publications are concerned; inversely doubling time for publications has increased progressively.

Table 2: Relative Growth Rate and Doubling Time of Bioleaching Publications

Year	Publications	W1	W2	R(a)= (W2- W1)	Mean R(a)	Dt = 0.693/R(a)	Mean Dt(a)
1989	6	-	1.792	-		-	
1990	15	1.792	2.708	0.916		0.76	
1991	16	2.708	2.773	0.065		10.74	
1992	31	2.773	3.434	0.661		1.05	
1993	46	3.434	3.829	0.395		1.76	
1994	27	3.829	3.296	-0.533	0.871	1.30	0.47 Years
1995	36	3.296	3.584	0.288		2.41	
1996	32	3.584	3.466	-0.118		5.88	

1997	43	3.466	3.761	0.295		2.35	
1998	39	3.761	3.664	-0.098		7.10	
1999	39	3.664	3.664	0.000		0.00	
2000	38	3.664	3.638	-0.026		26.68	
2001	66	3.638	4.190	0.552		1.26	
2002	49	4.190	3.892	-0.298		2.33	
2003	63	3.892	4.143	0.251	0.136	2.76	7.03 Years
2004	56	4.143	4.025	-0.118		5.88	
2005	55	4.025	4.007	-0.018		38.46	
2006	88	4.007	4.477	0.470		1.47	
2007	72	4.477	4.277	-0.201		3.45	
2008	152	4.277	5.024	0.747		0.93	
2009	133	5.024	4.890	-0.134		5.19	
2010	131	4.890	4.875	-0.015		45.74	
2011	125	4.875	4.828	-0.047		14.78	
2012	134	4.828	4.898	0.070		9.97	
2013	173	4.898	5.153	0.255		2.71	9.02 Years
2014	163	5.153	5.094	-0.060	0.006	11.64	
2015	183	5.094	5.209	0.116		5.99	
2016	165	5.209	5.106	-0.104		6.69	
2017	159	5.106	5.069	-0.037		18.71	
2018	142	5.069	4.956	-0.113		6.13	
	2477			3.164	0.337		5.50 ears

6.3. Authorship Pattern and Degree of Collaboration in Bioleaching Research

Below Table 3 shows the authorship pattern in bioleaching research globally. There were 4172 authors contributed 2477 publications. Out of 2477 publications, 504 (20.35%) publications were contributed by four authors, followed by 490 (19.78%) publications were contributed by three authors, whereas single author publications were 107 (4.32%) only.

Table 3: Authorship pattern in Bioleaching research

Authorship Pattern	Publications	Percentage %
Single Authors	107	4.32
Two Authors	357	14.41
Three Authors	490	19.78
Four Authors	504	20.35
Five Authors	402	16.23
Six Authors	268	10.82
Seven Authors	124	5.01
Eight Authors	102	4.12
Nine Authors	52	2.10
Ten and More Authors	71	2.87

	2477	100.0
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The degree of collaborations:

The Degree of Collaboration (DC) is measured by the proportion of multiple authored papers derived by Subramanyam (1983) as,

$$DC = \frac{N_m}{N_m + N_s}$$

Where DC = degree of collaboration in a discipline.

N_m = Number of multiple-authored research papers in the discipline published during a year.

N_s = Number of single-authored research papers in the discipline published during the same year.

Degree of Collaboration:

$$DC = \frac{2370}{2370 + 107} = 0.956$$

It could be drawn from the above table that the degree of collaboration in producing research output on bioleaching research. Based on this study, the result of the degree of collaboration (DC) =0.956 i.e., 95 per cent of collaboration authors articles published during the study periods.

6.4. Most Productive Authors in Bioleaching Research

S.No	Author	No. of Contribution	Percentage %	TLCS	TGC S
1	Qiu GZ	145	5.85	989	1585
2	Liu XD	52	2.10	275	506
3	Qin WQ	52	2.10	291	450
4	Wang J	52	2.10	251	438
5	Mousavi SM	45	1.82	419	711
6	Ballester A	44	1.78	582	988
7	Tuovinen OH	43	1.74	292	732
8	Blazquez ML	42	1.70	560	962
9	Gonzalez F	38	1.53	513	877
10	Sukla LB	37	1.49	433	744

Table 4: Most Productive Authors in Bioleaching Research

Table 4 shows that there were 4712 authors contributed 2477 publications in bioleaching research globally. Out of these 4712 authors, Qiu GZ contributed 145 (5.85%) publications and secured the first position with 989 TLCS and 1 TGCS, followed by three authors namely Liu XD, Qin WQ and Wang J Pereira, contributing 52 (2.10%) publications respectively with different Local and Global citation for their publications. Third position by Mousavi SM with 45 (1.82%) publications with 711GCS. The fourth place is got by Ballester A with 44 (1.78%) publications with second maximum TGCS of 988.

6.5. Journal Wise Distribution of Publications in Bioleaching Research

Table 7 shows the top ten most productive journals in bioleaching research globally. There were 425 journals published 2477 publications in bioleaching research. Out of these 425 journals, HYDROMETALLURGY were contributed 364 (14.71%) publications with 4926 TLCS and 9089 TGCS and secured the first position, followed by MINERALS ENGINEERING contributed 237 (9.6%) with 1861 TLCS and 4152 TGCS, TRANSACTIONS OF NONFERROUS METALS SOCIETY OF CHINA contributed 105 (4.2%) with 487 TLCS and 825TGCS and scored the third position respectively.

Table 7: Top ten highly contributing journals in bioleaching research

S.No	Name of the Journal	No. of Publications	Percentage %	TLCS	TGCS
1	HYDROMETALLURGY	364	14.7	4926	9089
2	MINERALS ENGINEERING	237	9.6	1861	4152
3	TRANSACTIONS OF NONFERROUS METALS SOCIETY OF CHINA	105	4.2	487	825
4	BIORESOURCE TECHNOLOGY	76	3.1	1035	1681
5	INTERNATIONAL JOURNAL OF MINERAL PROCESSING	47	1.9	487	1055
6	JOURNAL OF HAZARDOUS MATERIALS	45	1.8	756	1954
7	APPLIED AND ENVIRONMENTAL MICROBIOLOGY	38	1.5	841	2572
8	GEOMICROBIOLOGY JOURNAL	36	1.5	126	309
9	APPLIED MICROBIOLOGY AND BIOTECHNOLOGY	34	1.4	871	1648
10	CHEMOSPHERE	34	1.4	343	637

6.6. Institution wise Distribution of Publications

The table-8 analysis indicates Institution-wise research productivity. It is noted that 1439 institutions were contributed 2477 of the total research productivity. It is noted that Central South University contributed the highest number of research publications 268 (10.8%) with 1561 TLCS and 2585 TGCS. Chinese Academy of Sciences terms second in order 97 (3.9%) publications with Total Global Citation Source 1025 and the third in order is the University of Chile with 88 () publication having the TGCS of 1617

Table 8: Institution wise Distribution of Publications

S.No	Name of the Institution	No. of Publications	Percentage %	TLCS	TGCS
1	Central South University	268	10.8	1561	2585
2	Chinese Academy of Sciences	97	3.9	514	1025
3	University of Chile	88	3.6	601	1617
4	Ministry Education	79	3.2	616	917
5	The University of Cape Town	65	2.6	633	1229
6	Ohio State University	47	1.9	318	840
7	universities in Quebec	45	1.8	530	980
8	Tarbiat Modares University	44	1.8	332	570
9	University Complutense Madrid	39	1.6	517	868
10	Tampere University of Technology	37	1.5	273	614

6.7. Bibliographic coupling of Institution in Bioleaching research globally

The bibliographic coupling can be defined as “papers are bibliographically coupled when different authors cite one or more papers in common” (Garfield, 2001). The Web of Science source “.txt” data file was exported to VOSviewer to prepare the institutional bibliographical coupling. VOSviewer is used for analysing institutional bibliometrics networks. Fig. 1 shows the institutional-wise bibliographic coupling in bioleaching research globally. Bibliographic coupling was estimated with following criteria, the minimum number of documents of an institute 20 or above. Out of 1439 institutions, 184 institutions meet the threshold. For each of the 184 institutes, the number of bibliographic coupling link was calculated. The institutes with the largest number of the link were selected. Full count method was applied. Central South University had 264 Publications with 226023 bibliographic coupling with other institutes.

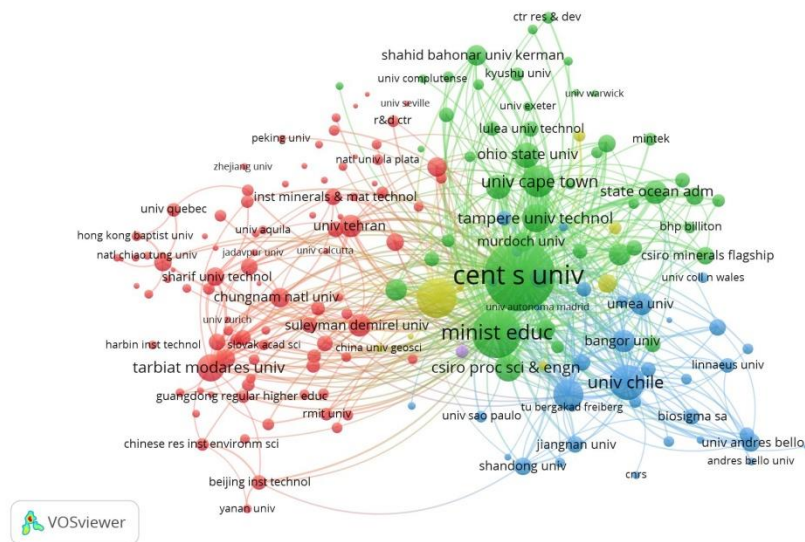


Figure 2: shows the institutional bibliographic coupling in bioleaching research globally.

6.8. Country wise Distribution of Publications in Bioleaching Research

The below table indicates that among the country-wise distribution of bioleaching covered by the study tops Peoples R China with 659(26.5%) publications followed by India with 224(8.2%), Australia with 177 (7.1%), research publications respectively. First place goes Peoples R China having total Global Citation Score of 6988 with 659 publications. Australia secured the second rank with 4496 TGCS and the minimum 2082 TGCS in this table is Spain.

Table 9: Country-wise distribution of Publications

S.No	Country	No. of Publications	Percentage %	TLCS	TGCS
1	Peoples R China	659	26.6	3644	6988
2	India	204	8.2	1215	3386
3	Australia	177	7.1	2094	4496
4	USA	174	7	1027	3596
5	Chile	145	5.9	966	2720
6	Iran	134	5.4	797	1518
7	Germany	121	4.9	1926	4187
8	Canada	112	4.5	1043	3101
9	South Africa	106	4.3	1205	2562
10	Spain	103	4.2	943	2082

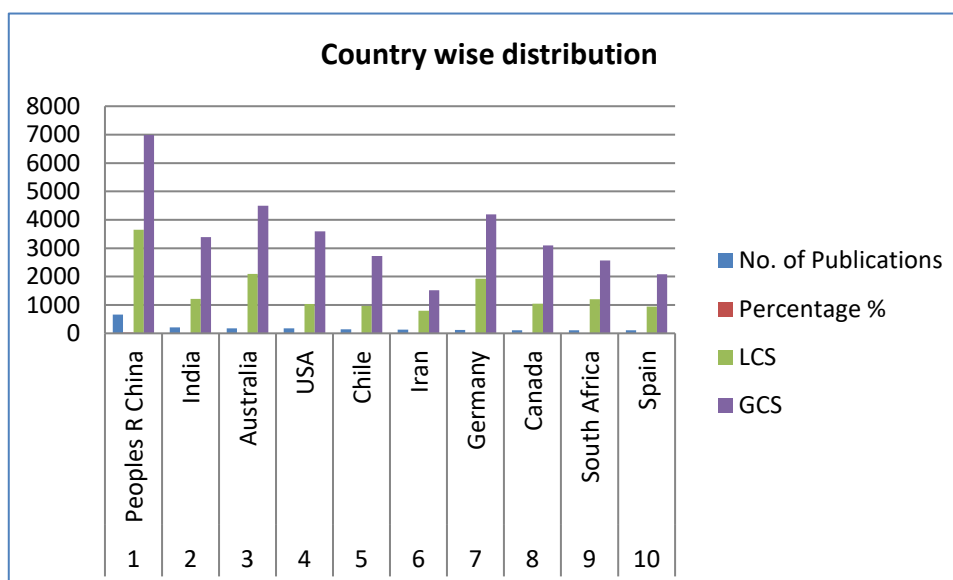


Figure 2: Country-wise distribution of Publications

6.9.Source wise Distribution of Publications

Table 9: Source wise distribution of Publications

S.No	Source Type	No. of Publications	Percentage %	TLCS	TGCS
1	Article	2050	82.8	13370	30285
2	Article; Proceedings Paper	246	9.9	3326	7467
3	Review	126	5.1	2091	6495
4	Meeting Abstract	28	1.1	5	9
5	Editorial Material	6	0.2	0	0
6	Note	6	0.2	22	36
7	Article; Book Chapter	3	0.1	24	94
8	Correction	3	0.1	0	0
9	Letter	3	0.1	0	2
10	Discussion	2	0.1	0	0
11	News Item	2	0.1	0	0
12	Review; Book Chapter	2	0.1	2	36

Table-9 indicates the source wise distribution of research output in bioleaching research. This study has observed a total of 2477 publications in bioleaching during the period from 1989 to 2018. Out of various sources of publications in bioleaching, journal articles that appeared in the journals have shown a predominant contribution (82.8%) with Total Global citation score of 30,285 and this source occupies the first position. The source of Proceeding Papers; Articles comes second in order (9.9%) with total Global citation scores 7467 of sharing total

research output in bioleaching during the period of analysis. The source of Review comes in the third position (5.1%) with total global citation scores of 6495 with respect to total output in bioleaching research during the study period and the minimum sharing of sources comes from correction, letter, discussion, news item, with less than 5 publications having no citations.

6.10. Language-wise distribution of publications in bioleaching research

Table 10 shows the language-wise distribution of publication in bioleaching research. The total 2477 publication of study is distributed around 14 languages. Out of 14 languages, English was the most preferred language for publication. English language publications were contributed 2429 (98.1%) with 18777 TLCS and 44285 TGCS, followed by Spanish 12 (0.5%) and French 10 (0.4%) publications. Language such as Japanese, Malay, Rumanian and Turkish contribute single publication.

Table 10: Language-wise distribution of publications

S.No	Language	No. of Publications	Percentage %	TLCS	TGCS
1	English	2429	98.1	18777	44285
2	Spanish	12	0.5	7	11
3	French	10	0.4	37	67
4	Chinese	5	0.2	5	35
5	German	4	0.2	4	8
6	Portuguese	4	0.2	1	4
7	Polish	3	0.1	1	3
8	Czech	2	0.1	5	8
9	Russian	2	0.1	0	0
10	Serbian	2	0.1	2	2
11	Japanese	1	0	1	1
12	Malay	1	0	0	0
13	Rumanian	1	0	0	0
14	Turkish	1	0	0	0

6.11. Keywords Distribution in Bioleaching Research

The intensity of data focused on the titles of the papers is more than whatever remains of the segment of the papers. Consequently, if a word happens more every now and again than anticipated it to happen, at that point, it mirrors the accentuation given by the creators about the exploration field of their advantage. The essential words called 'Keyword' are a standout amongst other pointers to comprehend and get a handle on quickly the idea substance of the papers. Table 11 reveals that the high-frequency keywords are "BIOLEACHING" topped with 1291 publications with the highest Global Citation Score of 21872, next

“ACIDITHIOBACILLUS” with the Global Citation Score of 4592 respectively with 346 appearances.

Table 11: Key Word Appeared in the Publications

S.No	Keywords	Records	Percentage %	LCS	GCS
1	BIOLEACHING	1291	52.1	11689	21872
2	ACIDITHIOBACILLUS	346	14	2115	4592
3	FERROOXIDANS	339	13.7	2510	5797
4	COPPER	301	12.2	1932	3855
5	USING	285	11.5	2375	4745
6	LEACHING	280	11.3	2284	4663
7	CHALCOPYRITE	265	10.7	3030	4916
8	METALS	259	10.5	2397	5409
9	ORE	207	8.4	1119	2150
10	METAL	197	8	2314	5795

6.12. Historiography of Bioleaching research

An attempt has been made to trace the evolution of bioleaching research by constructing historiography using HistCite software (developed by Garfield and colleagues) in conjunction with Web of Science. All 2477 papers have been considered. All the references quoted in these 2477 papers have been included. All the papers that have cited these 2477 papers, as well as all the references quoted in those citing papers, have been added. The resulting aggregate is called the bioleaching Global Collection. The collection is exported to HistCite to obtain cited references along with their local and global citation scores (LCS and GCS).

Table 11: Local citation of Top 15 Publications in Bioleaching research

S.No	Node	Authors/Year/Journal	LCS	GCS
1	229	Bosecker K, 1997, FEMS MICROBIOL REV, V20, P591	195	370
2	281	Gehrke T, 1998, APPL ENVIRON MICROB, V64, P2743	124	255
3	382	Sand W, 2001, HYDROMETALLURGY, V59, P159	193	381
4	383	Tributsch H, 2001, HYDROMETALLURGY, V59, P177	88	144
5	384	Brierley JA, 2001, HYDROMETALLURGY, V59, P233	132	215
6	388	Brandl H, 2001, HYDROMETALLURGY, V59, P319	119	194
7	438	Rawlings DE, 2002, ANNU REV MICROBIOL, V56, P65	148	371
8	502	Okibe N, 2003, APPL ENVIRON MICROB, V69,	98	202

		P1936		
9	543	Rohwerder T, 2003, APPL MICROBIOL BIOT, V63, P239	266	540
10	544	Olson GJ, 2003, APPL MICROBIOL BIOT, V63, P249	167	274
11	663	Sand W, 2006, RES MICROBIOL, V157, P49	96	200
12	730	Watling HR, 2006, HYDROMETALLURGY, V84, P81	293	479
13	764	Rawlings DE, 2007, MICROBIOL-SGM, V153, P315	89	205
14	851	Pradhan N, 2008, MINER ENG, V21, P355	117	167
15	1634	Vera M, 2013, APPL MICROBIOL BIOT, V97, P7529	96	160

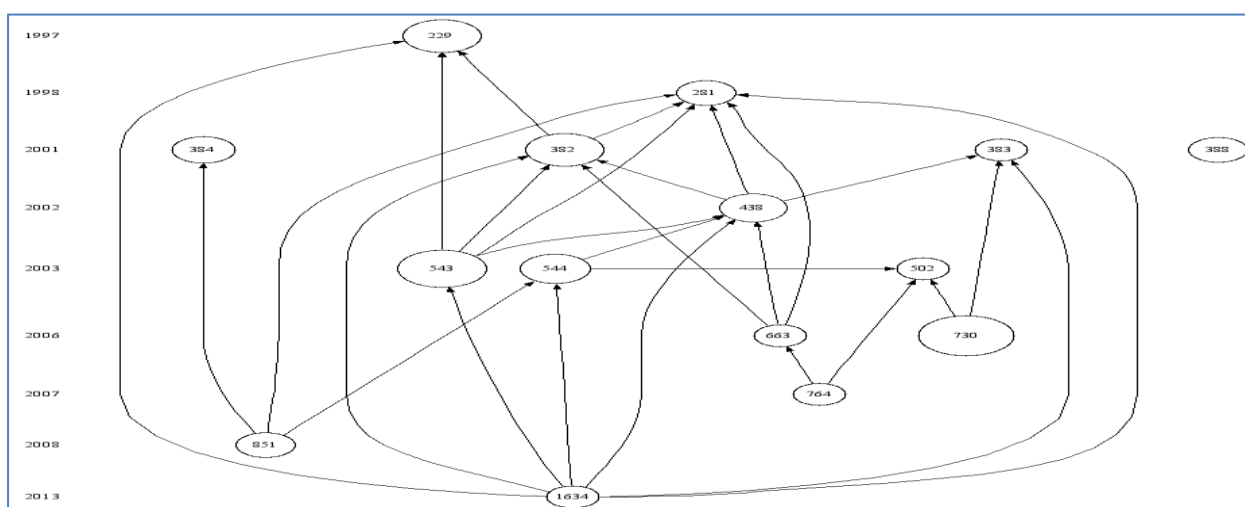


Figure 3: Nodes: 15, Links: 28 LCS, top 15; Min: 88, Max: 293 (LCS scaled)

Figure 3 is the Historiography of bioleaching research of the world based on the 15 most highly cited papers in the bioleaching Global Collection based on their LCS. It covers the period from 1997 to 2013. In this historiography, the story begins with a paper by Bosecker K, Bioleaching: Metal solubilization by microorganisms, 1997 JUL; 20 (3-4): 591-604. This paper node.229 (1997), has received 195 LCS citations so far. There are only 28 links with LCS ranging between 88 minimum to maximum 293.

Table 12: Global citation of Top 15 Publications in Bioleaching research

S.No	Node	Authors/Year/Journal	LCS	GCS
1	119	WARHURST AM, 1994, CRIT REV BIOTECHNOL, V14, P29	1	225
2	129	GOEBEL BM, 1994, APPL ENVIRON MICROB, V60, P1614	53	209
3	229	Bosecker K, 1997, FEMS MICROBIOL REV, V20, P591	195	370

4	281	Gehrke T, 1998, APPL ENVIRON MICROB, V64, P2743	124	255
5	382	Sand W, 2001, HYDROMETALLURGY, V59, P159	193	381
6	384	Brierley JA, 2001, HYDROMETALLURGY, V59, P233	132	215
7	410	Mulligan CN, 2001, ENG GEOL, V60, P193	12	715
8	438	Rawlings DE, 2002, ANNU REV MICROBIOL, V56, P65	148	371
9	497	Pandey A, 2003, BIOCHEM ENG J, V13, P81	0	501
10	543	Rohwerder T, 2003, APPL MICROBIOL BIOT, V63, P239	266	540
11	544	Olson GJ, 2003, APPL MICROBIOL BIOT, V63, P249	167	274
12	730	Watling HR, 2006, HYDROMETALLURGY, V84, P81	293	479
13	911	Cui JR, 2008, J HAZARD MATER, V158, P228	71	587
14	968	Valdes J, 2008, BMC GENOMICS, V9	0	212
15	1025	Singhanian RR, 2009, BIOCHEM ENG J, V44, P13	0	294

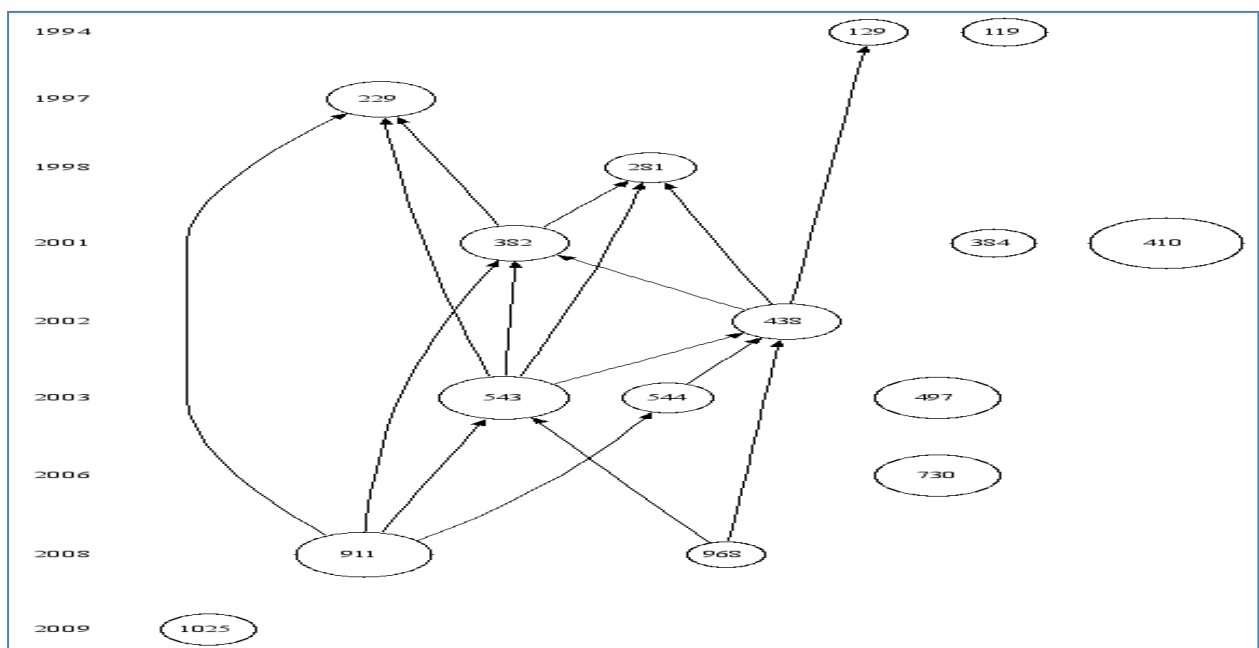


Figure 4: Historiograph of Bioleaching research based on Global citation scores GCS,
Nodes: 15, Links: 16 GCS, top 15; Min: 209, Max: 715 (GCS scaled)

Figure 4 is a similar Historiograph but based on the GCS. It includes period from 1994 to 2009. In this historiographs, the story begins with a paper by Warhurst AM, Biotransformation catalyzed by the genus rhodococcus, Critical Reviews in Biotechnology. 1994; 14 (1): 29-73. This paper node 119 received 225 GCS. There are only 16 links with GCS ranging between 209 minimum to maximum 715.

7. CONCLUSION:

A total of 2477 publications were published in Bioleaching research globally during the study period 1998 - 2018. The highest number of publications was published in 2015 with 183 (7.4%) The highest Total Local Citation Scores (TLCS) and Total Global Citation Scores (TGCS) were recorded in 2008, 1784 and 4267 respectively. The mean relative growth is 0.337 and the average doubling time is 5.50. The collaborative research is predominant in bioleaching research globally. The degree of collaboration is 0.956. There were 4712 authors contributed 2477 publications, out of these Qiu GZ score first position with 145 contributions (5.85%). There were 1439 institutions contributed 2477 publications globally. Out of these, Central South University contributed 268(10.8%) publications and score first rank. Research articles were predominant than any other document types. Thirteen types of documents were identified, out of these 2050 (82.8%) were research articles. There were 2477 publications published in 425 journals. Out of these, Hydrometallurgy contributed 364 (14.7%) publications and score first position. There were 78 countries contributed bioleaching research globally. Among these, Public R China contributed 659 (26.6%) publications and place first position and India comes next with 204 (8.2%) publications. English is most preferred language of bioleaching publications. There were 2477 publications published in 14 languages. There were 83544 references were cited in 2477 publications. Out of these, Watling HR, 2006, HYDROMETALLURGY, V84, P81, DOI 10.1016/j.hydromet.2006.05.001 was cited in 293 publications and score first position. Central South University contributed 268 Publications with 226023 bibliographic coupling with other institutes. Bioleaching is a method of natural remediation to extract metals from their ores through the use of living organisms. Generally, results of this study revealed that the contribution of bioleaching research literature is on gradual rise and need of the hour to reduce the chemical effect on the environment using living organism.

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