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Mapping of Bioremediation Research Output in India: A Scientometric Study

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Abstract

An analysis of 1981 publications published by Indian scientists during 1994 to 2018 indexed by Web of Science online Database indicates the Bioremediation Research Publication. This study tries to map the number of publications, growth rate and doubling time, scattering of publication over journals, and its impact on publication output, authorship patterns and Global citation score of bioremediation research publication in India using the HistCite, VOSviewer software. Indian Institute of technology, Baba atomic research centre and CSIR are the major producers of research output in the area of bioremediation.

Keywords: Scientometric, Bioremediation, Global Citation Score, the degree of collaboration, authorship pattern

INTRODUCTION

Bioremediation is a procedure used to treat contaminated media, including water, soil and subsurface material, by modifying natural conditions to invigorate development of microorganisms and corrupt the objective toxins. Much of the time, bioremediation is more affordable and more economical than other remediation choices. Natural treatment is a comparable approach used to treat wastewater, modern waste and strong waste. Most bioremediation forms include oxidation-reduction where either an electron acceptor (regularly oxygen) is added to invigorate oxidation of a lessened contamination (e.g. hydrocarbons) or an electron contributor (normally a natural substrate) is added to lessen oxidized toxins (nitrate, perchlorate, oxidized metals, chlorinated solvents, explosives and propellants). In both these methodologies, extra supplements, vitamins, minerals, and pH cushions might be added to

upgrade conditions for the microorganisms. At times, particular microbial societies are included (bioaugmentation) to additionally upgrade biodegradation. A few cases of bioremediation related innovations are phytoremediation, mycoremediation, bioventing, bioleaching, landfarming, bioreactor, treating the soil, bioaugmentation, rhizofiltration, and biostimulation.

OBJECTIVES

The main objective of this study was to use Scientometric mapping and analyze the key features of Bioremediation research activities at Indian level such as : the rate of growth and doubling time on bioremediation research, to identify document wise distribution of publications, to analyze the authorship pattern and examine the extent of research collaboration, to identify the ranking of authors based on publications, to identify journal wise distribution of publications and to assess the Institution wise research concentration and Global citation score of the publications.

METHODOLOGY

The research publications were retrieved from the Web of Science core collections database on the topic Bioremediation, which is scattered over the period from 1994 to 2018. The data was collected during the first week of July 2018. The search was carried out using the keyword Bioremediation in the ‘topic field’ and refined to the Country “India”. A total of 1981 publications were downloaded and the same was analyzed using the software HistCite, VoSviewer and Microsoft Excel as per the objectives of the study.

ANALYSIS AND INTERPRETATION

Relative Growth rate and Doubling Time

To analyze the year wise publication of research on Bioremediation, the data has been presented in Table 1. The research output on Bioremediation publication is taken as a tool to evaluate the performance at various levels. It also shows that chronological histogram of citations, demonstrating that citation frequency grew steadily from 1994; it reached a maximum TGCS of 3479 and TLCS of 323 in the same year 2011.

Table 1 could clearly see that during the period 1994 to 2018 a total of 1981 publications were published at India level. The highest publication is 238 in the year 2016 and 2017 with 1101 and 381 TGCS followed by 200 papers in 2015 with 1363 TGCS and 196 papers in 2014 with 2104 TGCS. The lowest publication is 2 in 1994 with 28 TGCS. Table 1 shows that even minimum numbers of records were scored higher global citations, such as in the year 1997 and 2000 has produced only 7 and 9 papers respectively, but it has received as TGCS of 1517 and 1619. The study also reveals all these 1981 publications have 37149 TGSC, it shows that there is a healthy trend in citation found in bioremediation research output.

It is observed that its relative growth rates have decreased gradually from 1.26 in 1994 to 0.13 in 2017. The whole study period records the mean relative growth rate of 0.276. Contrarily, the doubling time for publication of all sources of output has increased from 0.55 in 1994 to 11.5 in 2018. The doubling time for publications at the aggregate level has been computed as 3.11 years.

Table 1: Shows relative growth and doubling time of Bioremediation Publications

| S.No | Year | Records | Cumulative | Per cent % | W1 | W2 | R (a) (W2-W1) | Dt | TLCS | TGCS |
|------|------|---------|------------|------------|------|------|---------------|------|------|------|
| 1 | 1994 | 2 | 2 | 0.1 | - | 0.69 | - | - | 1 | 28 |
| 2 | 1995 | 5 | 7 | 0.3 | 0.69 | 1.95 | 1.26 | 0.55 | 11 | 79 |
| 3 | 1996 | 5 | 12 | 0.3 | 1.95 | 2.48 | 0.53 | 1.31 | 16 | 64 |
| 4 | 1997 | 7 | 19 | 0.4 | 2.48 | 2.94 | 0.46 | 1.51 | 101 | 1517 |
| 5 | 1998 | 8 | 27 | 0.4 | 2.94 | 3.30 | 0.36 | 1.93 | 25 | 372 |
| 6 | 1999 | 8 | 35 | 0.4 | 3.30 | 3.56 | 0.26 | 2.67 | 10 | 254 |
| 7 | 2000 | 9 | 44 | 0.5 | 3.56 | 3.78 | 0.22 | 3.15 | 78 | 1619 |
| 8 | 2001 | 14 | 58 | 0.7 | 3.78 | 4.06 | 0.28 | 2.48 | 93 | 666 |
| 9 | 2002 | 24 | 82 | 1.2 | 4.06 | 4.41 | 0.35 | 1.98 | 133 | 2276 |
| 10 | 2003 | 18 | 100 | 0.9 | 4.41 | 4.61 | 0.20 | 3.47 | 25 | 1063 |
| 11 | 2004 | 22 | 122 | 1.1 | 4.61 | 4.80 | 0.19 | 3.65 | 90 | 951 |
| 12 | 2005 | 37 | 159 | 1.9 | 4.80 | 5.07 | 0.27 | 2.57 | 152 | 2543 |
| 13 | 2006 | 62 | 221 | 3.1 | 5.07 | 5.40 | 0.33 | 2.1 | 244 | 2499 |
| 14 | 2007 | 57 | 278 | 2.9 | 5.40 | 5.63 | 0.23 | 3.01 | 252 | 2067 |
| 15 | 2008 | 89 | 367 | 4.5 | 5.63 | 5.91 | 0.28 | 2.48 | 287 | 3401 |
| 16 | 2009 | 98 | 465 | 4.9 | 5.91 | 6.14 | 0.23 | 3.01 | 240 | 3025 |
| 17 | 2010 | 97 | 562 | 4.9 | 6.14 | 6.33 | 0.19 | 3.65 | 243 | 1983 |
| 18 | 2011 | 144 | 706 | 7.3 | 6.33 | 6.55 | 0.22 | 3.15 | 323 | 3479 |
| 19 | 2012 | 133 | 839 | 6.7 | 6.55 | 6.73 | 0.18 | 3.85 | 274 | 2137 |
| 20 | 2013 | 158 | 997 | 8 | 6.73 | 6.90 | 0.17 | 4.08 | 239 | 2239 |

| | | | | | | | | | | |
|--------------|------|-------------|------|------------|------|------|------------------------|-------------------------|-------------|--------------|
| 21 | 2014 | 196 | 1193 | 9.9 | 6.90 | 7.08 | 0.18 | 3.85 | 239 | 2104 |
| 22 | 2015 | 200 | 1393 | 10.1 | 7.08 | 7.24 | 0.16 | 4.33 | 148 | 1363 |
| 23 | 2016 | 238 | 1631 | 12 | 7.24 | 7.40 | 0.16 | 4.33 | 88 | 1011 |
| 24 | 2017 | 238 | 1869 | 12 | 7.40 | 7.53 | 0.13 | 5.33 | 50 | 381 |
| 25 | 2018 | 112 | 1981 | 5.7 | 7.53 | 7.59 | 0.06 | 11.55 | 0 | 28 |
| Total | | 1981 | | 100 | | | 6.9 (0.276) | 79.99 (3.11) | 3362 | 37149 |

Types of Document and its Citations

The study reveals that the major source of publications covered by a web of science on bioremediation research in journal articles (82.5%), while review comprises (13.3%) and conference proceedings with (2.3%) literature and remaining are meeting abstract, editorial materials and correction and so on. It is found from the table 2 that, the journal's articles were contributed to a most noteworthy number of distributions and most noteworthy number of TLCS and TGCS in bioremediation. The articles from reviews and proceeding papers were additionally having the most noteworthy citation scores.

Table 2 shows the document wise distribution of Publications

| S.No | Document Type | Records | Percentage | TLCS | TGCS |
|--------------|-------------------------------|-------------|------------|-------------|--------------|
| 1 | Article | 1638 | 82.5 | 2568 | 21200 |
| 2 | Review | 264 | 13.3 | 690 | 14055 |
| 3 | Article; Proceedings Paper | 46 | 2.3 | 63 | 1054 |
| 4 | Meeting Abstract | 9 | 0.5 | 1 | 1 |
| 5 | Editorial Material | 7 | 0.4 | 13 | 127 |
| 6 | Review; Book Chapter | 6 | 0.3 | 17 | 305 |
| 7 | Article; Book Chapter | 5 | 0.3 | 5 | 100 |
| 8 | Correction | 2 | 0.1 | 1 | 1 |
| 9 | Letter | 2 | 0.1 | 1 | 2 |
| 10 | Article; Early Access | 1 | 0.1 | 0 | 0 |
| 11 | Review; Retracted Publication | 1 | 0.1 | 3 | 304 |
| Total | | 1981 | 100 | 3362 | 37149 |

Ranking of Highly Productive authors

Table 3 shows ranking of highly productive authors by number of research productivity, "Kumar A" contributed most number of articles for the investigated time frame with 36 records, next two

authors “Das S” and “Jain RK” contributed next most number of articles for the time frame with 34 and 33 records each, and author “Kumar M” and “Kumar S” ranked eleventh with the publication of 19 articles each. In this way, the TGSC distinguished from the most-published ones.

Table 3: Top 15 Highly productive Authors

| S.No | Author | Records | Per cent | TLCS | TGCS |
|------|--------------|---------|----------|------|------|
| 1 | Kumar A | 36 | 1.8 | 54 | 497 |
| 2 | Das S | 34 | 1.7 | 104 | 548 |
| 3 | Jain R | 33 | 1.7 | 169 | 1955 |
| 4 | Kumar R | 32 | 1.6 | 56 | 356 |
| 5 | Kumar V | 28 | 1.4 | 49 | 306 |
| 6 | Singh S | 23 | 1.2 | 22 | 173 |
| 7 | Madamwar D | 22 | 1.1 | 113 | 741 |
| 8 | Purohit HJ | 21 | 1.1 | 38 | 216 |
| 9 | Singh R | 21 | 1.1 | 47 | 462 |
| 10 | Mohan SV | 20 | 1 | 42 | 436 |
| 11 | Sar P | 20 | 1 | 85 | 528 |
| 12 | Singh N | 20 | 1 | 35 | 205 |
| 13 | Srivastava S | 20 | 1 | 41 | 242 |
| 14 | Kumar M | 19 | 1 | 38 | 251 |
| 15 | Kumar S | 19 | 1 | 17 | 160 |

Authorship Pattern

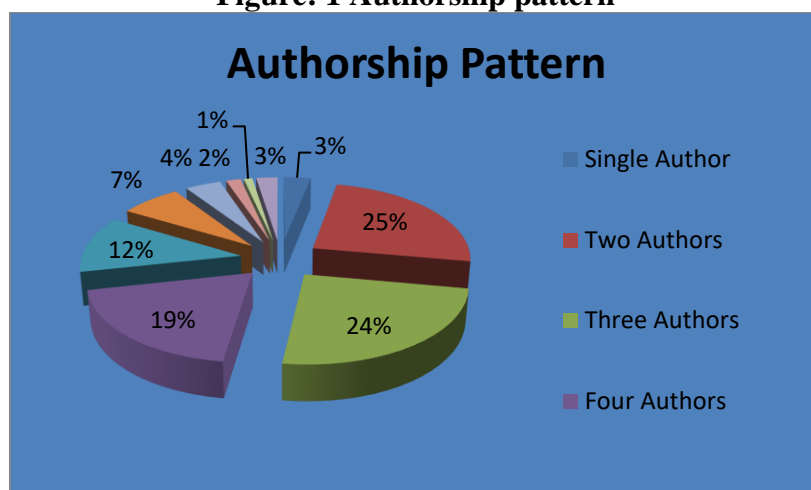
Table 4 shows the authorship patterns of research publications. It could be noted that two authored papers rank first in order sharing 24.68%. The next place is recorded by three authored papers sharing 24.38% of the total research contributions. Four authored contributions take that third position in order occupying 19.38% of the total research output during the study period followed by between Five and six authored 19.07 %. The least percentage was recorded by eight authored publications with 1.71%. It is inferred from the table - 4 that at the aggregate level, the degree of collaboration is of 0.79. This brings out clearly the high level of collaborative research in Bioremediation

Table 4: Authorship Pattern

| Authorship | Publications | Cumulative | Percentage |
|------------|--------------|------------|------------|
|------------|--------------|------------|------------|

| Pattern | | | |
|-------------------------------|-----|------|-------|
| Single Author | 62 | 62 | 3.12 |
| Two Authors | 489 | 551 | 24.68 |
| Three Authors | 483 | 1034 | 24.38 |
| Four Authors | 384 | 1418 | 19.38 |
| Five Authors | 238 | 1656 | 12.01 |
| Six Authors | 140 | 1796 | 7.06 |
| Seven Authors | 82 | 1878 | 4.13 |
| Eight Authors | 34 | 1912 | 1.71 |
| Nine Authors | 20 | 1932 | 2.03 |
| Ten and More Than Ten Authors | 49 | 1981 | 2.47 |

Figure: 1 Authorship pattern



Journal wise Distribution of Publications

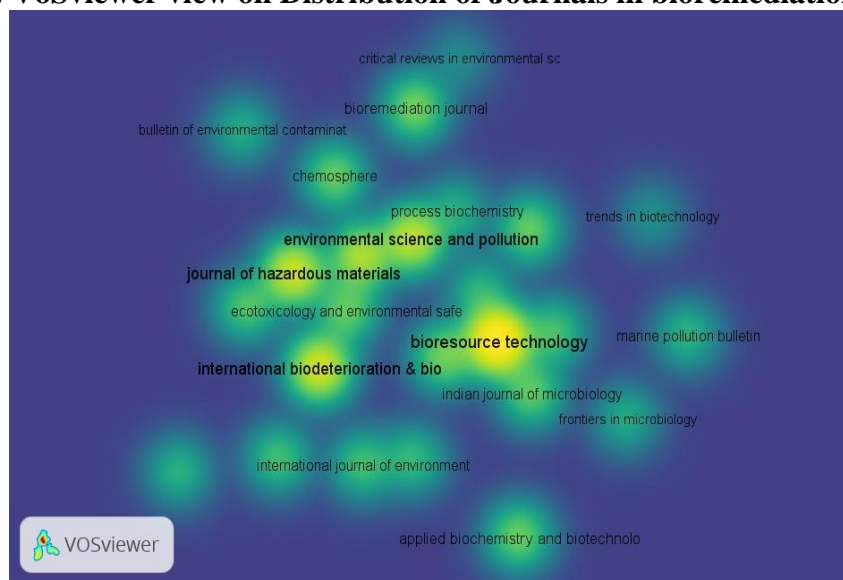
The study found that the total research output of the bioremediation for the study period (1994 – 2018) published in 411 journals. In Table 5 The journal “Bioresource Technology” topped with 113 publications with the Global Citation Score of 3331, next “International biodeterioration and biodegradation” with 68 publications with the Global Citation Score of 1141 and third position by “Journals of Hazardous materials with 64 publications with the Global Citation Score of 2305 respectively. “Applied microbiology and biotechnology” placed in ninth position got second highest global citation score of 2424 with just 31 records.

Table 5: Distribution of Bioremediation research in Journals Publications

| S.No | Journal | Records | Percentage | TLCS | TGCS | TLCR |
|------|----------------------------------|---------|------------|------|------|------|
| 1 | Bioresource Technology | 113 | 5.7 | 351 | 3331 | 191 |
| 2 | International Biodeterioration & | 68 | 3.4 | 174 | 1141 | 126 |

| | Biodegradation | | | | | |
|----|---|----|-----|-----|------|-----|
| 3 | Journal of Hazardous materials | 64 | 3.2 | 219 | 2305 | 111 |
| 4 | Environmental Science and Pollution Research | 58 | 2.9 | 115 | 518 | 164 |
| 5 | 3 BioTech | 50 | 2.5 | 7 | 104 | 93 |
| 6 | Bioremediation Journal | 35 | 1.8 | 15 | 126 | 65 |
| 7 | World Journal of Microbiology & Biotechnology | 34 | 1.7 | 87 | 576 | 48 |
| 8 | Applied Biochemistry and Biotechnology | 32 | 1.6 | 30 | 448 | 44 |
| 9 | Applied microbiology and biotechnology | 31 | 1.6 | 203 | 2424 | 100 |
| 10 | Chemosphere | 31 | 1.6 | 70 | 596 | 77 |

Figure: 2: VoSviewer view on Distribution of Journals in bioremediation Research



Institution wise Distribution of Publications

The below table 6 analysis indicates Institution-wise research productivity. It is noted that Indian Institute of technology contributed the highest number of research publications (124, 6.3%) and ranked first in publications and also in terms of Total Global Citation Score of 3573.

Table 6: Institution wise Distribution of Publications (Top 10)

| S.No | Institution | Records | % | TLCS | TGCS |
|------|-------------------------------|---------|-----|------|------|
| 1 | Indian Institute Technology | 124 | 6.3 | 280 | 3573 |
| 2 | Bhabha Atomic Research Centre | 64 | 3.2 | 113 | 1010 |
| 3 | CSIR | 58 | 2.9 | 100 | 1881 |

| | | | | | |
|----|---|----|-----|-----|------|
| 4 | University of Calcutta | 48 | 2.4 | 113 | 698 |
| 5 | Institute of Microbial Technology | 47 | 2.4 | 250 | 3502 |
| 6 | Banaras Hindu University | 46 | 2.3 | 118 | 904 |
| 7 | National institute of Technology | 44 | 2.2 | 95 | 380 |
| 8 | VIT University | 44 | 2.2 | 33 | 270 |
| 9 | University of Delhi | 43 | 2.2 | 163 | 1342 |
| 10 | National Environment Engineering Research Institute | 41 | 2.1 | 94 | 763 |

Top 10 Global Citation

The top 10 Global Citation Scores papers the most cited research papers span the period from 1997 to 2015 with one major network. There are only 81 links with GCS ranging between maximum 1281 and minimum. Figure 3: shows the interlinks of 100 GSC citation publication, which shows the healthy citation practices and development of the research in the area of bioremediation

Table 6: Global citation of Top Ten Publications

| S.No | Node | Author/Year/Journal | LSC | GCS |
|------|------|---|-----|------|
| 1. | 17 | Desai JD, 1997, MICROBIOL MOL BIOL R, V61, P47 | 66 | 1281 |
| 2. | 37 | Banat IM, 2000, APPL MICROBIOL BIOT, V53, P495 | 40 | 830 |
| 3. | 40 | Pandey A, 2000, PROCESS BIOCHEM, V35, P1153 | 3 | 564 |
| 4. | 66 | Samanta SK, 2002, TRENDS BIOTECHNOL, V20, P243 | 0 | 499 |
| 5. | 76 | Banerjee A, 2002, APPL MICROBIOL BIOT, V60, P33 | 3 | 304 |
| 6. | 91 | Pandey A, 2003, BIOCHEM ENG J, V13, P81 | 0 | 485 |
| 7. | 145 | Shanker AK, 2005, ENVIRON INT, V31, P739 | 11 | 756 |
| 8. | 217 | Mukherjee S, 2006, TRENDS BIOTECHNOL, V24, P509 | 15 | 351 |
| 9. | 289 | Kotay SM, 2008, INT J HYDROGEN ENERG, V33, P258 | 0 | 295 |
| 10. | 601 | Ma Y, 2011, BIOTECHNOL ADV, V29, P248 | 11 | 288 |

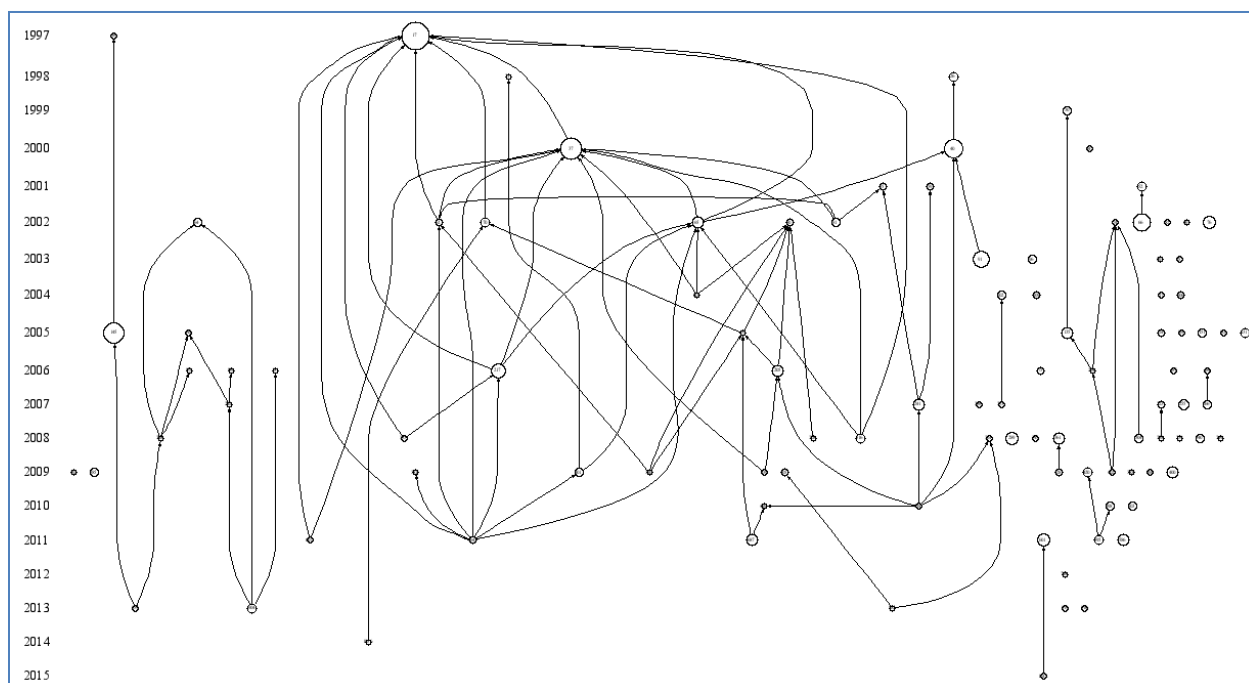


Figure:3: Shows Bioremediation Research - Historiograph by top 100 GCS Nodes: 100, Links: 81, GCS, top 100; Min: 17, Max: 1281 (GCS scaled)

Conclusion

Bioremediation research in India has been promising and need of the hour, its research development, has been studied using scientometric methods. The overall increase in the publication and citation in this field reveals that the impact of the bioremediation and is possibly going to outperform in the area of environmental studies in the coming years. The average number of publications produced per year was 79.24%. The highest number of publications produced in 2016 and 2017 was 238. It can be clearly visualized from Table 1 that the growth of the literature was very less during 1994 to 2009 and thereafter literature grows in consistent pace over the years, reaching the highest numbers 238 during the year 2017.

The most productive author is Kumar A with 36 papers dealing with bioremediation with GCS of 497 and third author with highest GSC of 1955 with only 33 publications. It has been observed that (1638) 82.5 % per cent of the article has been published in Article followed by (264)13.3% per cent in Review. It is found that collaborative authorship is prevailing in the authorship trends.

Among the top 10 most productive research Institutions, Indian Institute of technology (164) topped the study, followed by Bhabha atomic research centre (64) and next CSIR with 58 Publications. In this study , the key journals in bioremediation research has been identifies and represented using VoSviewer software and the major journals Bioresource Technology with 113 publications, followed by International Biodeterioration & Biodegradation with 68 publications

Reference :

Green Remediation Best Management Practices: Sites with Leaking Underground Storage Tank Systems. EPA 542-F-11-008" (PDF). EPA. June 2011.

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