Characteristics of Highly cited papers from Indian Institute of Science 1989-2013: A *Web of Science* based investigation

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Abstract

Characteristics of highly cited papers published by Indian Institute Science, Bangalore in Science Citation Index (Web of Science) between 1989-2013 were revealed. Bibliomteric indicators were applied to reveal the characteristics of highly cited papers. The paper has at least 100 citations in 31st December, 2015 published since 1989 were considered for the study. A total of 357 papers were highly cited papers were found for the study. The most highly cited papers were published in the year of 2000 and highest citation counts per paper were observed in the year 1990 and 1994. A total of 33 highly cited papers accounting for 9.2% of total papers were categorized under *The Chemistry, Multidisciplinary*.

Keywords

Highly cited papers: Indian Institute of Science, Bibliometric analysis, India

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1. INTRODUCTION

In recent years, bibliometric indicators have been widely used to evaluate the research performance of organizations. Citations are valuable indicators to reveal the impact of research work. Highly cited papers are "Classic Works" as they had higher impact on the particular field of research and researchers. Characteristics highly cited papers include, papers with larger numbers of references (Hamrick, Fricker, & Brown, 2010) contributed by large number of researchers from large institutions, countries and more internationally collaborative (Barbosa & Schneck, 2015). Enamors authors have been studied the highly cited papers of research institutions to measure the research performance i.e., Institutions in Taiwan (Garfield, 1993), Peking University (Zhu, Wu, Zheng, & Ma, 2004), Ranking the universities worldwide (Bornmann, Stefaner, Anegón, & Mutz, 2013), University in Romania (Silaghi-Dumitrescu & Sabau, 2014), Iranian medical universities (Abolghassemi Fakhree & Jouyban, 2011). Likewise, large number of authors did a study on highly cited papers on particular subjects and topics, skull base neurosurgery (Khan et al., 2015), spinal deformity surgery (O'Neill, Butler, McGoldrick, O'Leary, & Synnott, 2014), Environmental and Occupational Health (Smith, 2009), hand surgery (Joyce, Kelly, & Carroll, 2013), biomass research (Chen & Ho, 2015), orthopaedic surgery (Kelly, Glynn, O'Briain, Felle, & McCabe, 2010; Lefaivre, Shadgan, & O'Brien, 2011), European physics papers (Glánzel, Rinia, & Brocken, 1995), cancer (Llovet, Kras, & Iii, 2011), clinical research (Tao et al., 2012).

The Indian Institute of Science (IISc) was founded in 1909 as a result of the joint efforts of Jamsetji Nusserwanji Tata, the Government of India, and the Maharaja of Mysore. In 1886, Jamsetji Tata conceived of a university of science that will work for the benefit of India, and in 1898 created an endowment for establishing such an institution. The Government of India then took up the effort, and, in consultation with scientists in England and in India, decided to locate the Institute in Bangalore, where the Maharaja of Mysore, Shri Krishnaraja Wodeyar IV, donated 372 acres of land. The Institute was formally vested in 1909, the foundation stone was laid in 1911, and the first batch of students started their studies in the same year. Over the 106 years since its establishment, IISc has become the premier institute for advanced scientific and technological research and education in India (Indian Institute of Science, 2015).

In this paper, we evaluated the highly cited papers characteristics published in 1989-2013 from Indian Institute of Science, Bangalore and had at least 100 citation counts on 31st December, 2015. Analysis includes, annual publication, *WoS* subject category, most prolific authors, top ten papers with at least 494 TC in 2015, top eleven most active journals that published maximum papers at least one co-author from the IISc.

2. OBJECTIVES OF THE STUDY

1. To find out year wise publication of highly cited papers from Indian Institute of Science published in 1989-2003 with their number references, citation counts, page counts and average citation counts, references and page counts per paper;
2. To find out the top 10 most frequently cited papers and their characteristics;
3. To know the most prolific authors from Indian Institute of Science who has contributed highly cited papers;
4. To find out *WoS* subject category wise distribution of papers and
5. To discover the most productive journals;

3. METHODOLOGY

We built a data database of highly cited papers from the *Science Citation Index- Expanded* (SCI-EXPANDED) database of Thomson Reuters *WoS*. We searched the papers by assigning the Phrase "Indian Inst Sci" in "affiliation" field and time span selected from 1989-2015. A total of 357 research papers with TC=100 were found and same were retrieved *WoS* database. Then screening and checking was done in respect to citation counts field in the downloaded records. In this paper, the paper that had TC=100 till 31st December 2015 and at least one author from Indian Institute Science Bangalore considered as highly cited papers.The analysis includes year wise distribution of papers since 1989-2013, and their citations, references, page counts and an average citation counts, page counts and references per paper. The top ten cited papers from Indian Institute of Science with TC2015=494, further analysis includes, an average citation per year from its publication and title, journal and authors and number of references. Further, top eleven journals that published at least 50 highly cited papers identified and analyzed in terms of total papers published, % of total papers, total citation and average citation counts for each article. *Web of Science* subject category wise analysis of papers with citations counts per paper were also analyzed. The top contributed authors who contributed at least 6 highly cited articles also analyzed in the line of total papers, and total citation counts, average citation counts to each paper respectively. The major limitation of the study is that the data limited to publications covered and cited in the *WoS* database.

4. RESULTS AND DISCUSSIONS

Publication outputs and scientific descriptors

The table 1 gives the year wise distribution of highly cited papers published by Indian Institute of science, Bangalore, their references, citations, and page counts and average citation cunts, reference and page counts since 1989-2013. A total of 357 highly cited papers were contributed by the Indian Institute Science of Science, Bangalore. The citations are the indicators of the quality of papers, as the papers cited more time means, the impact is higher on the subject and researchers in the field. The highest papers (36) that received at least TC=100 were recorded in the year 2000 and lowest (3) in the year (1992). Usually any good research paper to get more citations, at least ten years of time needed but some papers receive good number of citation within limited time that may be due to the quality of research and topic relevance in the current condition. Number of references and page counts are considered as indicators of the quality of research papers. All the papers that are highly cited by IISc.Bangalore had received an average of 181.59 citations counts per paper, 35.89 references and 9.14 page length. Since 1996, the number of papers were kept increasing up to 2000 and later fluctuation in number of papers publications were observed. In the 2013, there four papers with at least TC=100 and an average of 200.75 citations counts which higher than average of all papers. The papers published in 1990 had received highest citation counts per paper (293.80) and lowest in 1989 (121.50) (Figure 1). Again the findings suggested that the papers will receive citations within ten to fifteen years, as they disappear from the current research topic. The oldest paper that had received at least TC=100 is written by Choudhuri, AR titled as "The Evolution of Loop Structures in Flux Rings within the Solar Convection Zone" in *Solar Physics and* had citations of 100 in 2015 (Choudhuri, 1989).

Table 1: Scientific descriptors of highly cited papers from India 1989-2013

PY	TP	%	TR	TC	PC	TR/PP	TC/PP	PC/PP
1989	2	0.6	76	243	32	38.00	121.50	16.00
1990	**5**	**1.4**	**197**	**1469**	**64**	**39.40**	**293.80**	**12.80**
1991	5	1.4	209	801	29	41.80	160.20	5.80
1992	3	0.8	86	601	17	28.67	200.33	5.67
1993	10	2.8	233	1526	88	23.30	152.60	8.80
1994	**7**	**2**	**236**	**2053**	**67**	**33.71**	**293.29**	**9.57**
1995	8	2.2	265	1466	81	33.13	183.25	10.13
1996	17	4.8	534	3350	167	31.41	197.06	9.82
1997	20	5.6	710	3094	140	35.50	154.70	7.00
1998	20	5.6	593	3511	229	29.65	175.55	11.45
1999	20	5.6	615	4959	162	30.75	247.95	8.10
2000	**36**	**10.1**	**929**	**6276**	**283**	**25.81**	**174.33**	**7.86**
2001	21	5.9	576	4379	184	27.43	208.52	8.76
2002	17	4.8	613	2735	125	36.06	160.88	7.35
2003	24	6.7	785	3880	271	32.71	161.67	11.29
2004	26	7.3	796	4460	233	30.62	171.54	8.96
2005	17	4.8	557	2537	156	32.76	149.24	9.18
2006	20	5.6	696	2890	178	34.80	144.50	8.90
2007	18	5	688	2639	154	38.22	146.61	8.56
2008	16	4.5	651	3552	138	40.69	222.00	8.63
2009	16	4.5	642	2942	125	40.13	183.88	7.81
2010	7	2	511	1809	72	73.00	258.43	10.29
2011	14	3.9	884	2329	177	63.14	166.36	12.64
2012	4	1.1	153	524	19	38.25	131.00	4.75
2013	**4**	**1.1**	**579**	**803**	**71**	**144.75**	**200.75**	**17.75**
Total	357		12814	64828	3262	35.89	181.59	9.14

Note: PY, publication year, TP, total papers, TC, total citations, TR, total reference, PC, page counts , TC/PP,TR/PP, PC/PP= average per paper citations counts, references and page counts.

Productive authors

The bibliomteric indicators were used to evaluate research performance of authors by their total papers and their quality by citation counts (Ho, 2012; Yi, Ao, & Ho, 2008). The table 2 provides the details about total papers by author, % of the total papers and total citations and citations counts by per paper. A total of 1423 authors were contributed towards highly cited papers with an average of 3.98 authors per paper. Rao, CNR is most productive author with 48 papers and average of 187.35 citation counts which slightly higher than of total papers and he has contributed almost more than 13.45% of the highly cited papers from the Indian Institute of science, Bangalore. The first written by him as corresponding author with Palit, dk., et al., titled as "Photophysical Properties Of The Fullerenes, C-60 AND C-70" published in *Chemical Physics Letters* in 1992 had received TC=140 (Palit, et al., 1992). And recent one was co authored with Nag, a et al., titled as "Graphene Analogues of BN: Novel Synthesis and Properties" published in *ACS NANO* in 2010 and had citation counts of 24(Nag et al., 2010). Government of India by recognizing his contribution to research in science has conferred *Baratha Ratana* to him in 2014, which is highest civilian award given by Government of India. Second most prolific authors from Indian Institute of Science is Govindaraj, A., who contributed 22 highly cited papers with average of 211.59 citation counts per paper. Remaining authors had a contribution of at least eight or more highly cited papers (Table 2). Again one more interesting fact is the author 'Sood, ak, had contributed ten papers and his average citation counts per paper is highest (282). Almost 46.22% of the highly cited papers were contributed by these eleven authors and based this it can be noted that these were the highly involved researchers from the Indian Institute of Science, Bangalore (table 2).

Table 2: Most productive authors and their contribution

AU	TP	%	TC	TC/PP
Rao cnr	48	13.45	8993	187.35
Govindaraj A	22	6.16	4655	211.59
Sarma, DD	15	4.20	2573	171.53
Hegde Ms	14	3.92	2423	173.07
Satishkumar, BC	13	3.64	2375	182.69
Sood Ak	10	2.80	2823	282.30
Shukala Ak	10	2.80	1643	164.30
Madras G	9	2.52	1776	197.33
Bagchi B	8	2.24	1614	201.75
Balaram, p	8	2.24	1701	212.63
Ramaswamy S	8	2.24	1462	182.75
Total	165	46.22	32038	194.17

Note: AU, Author name, TP, total papers, %, percent of 357, TC, total citations and TC/PP, total citations per paper

***Web of Science* subject category**

Table 3 gives the list of the Web of Science subject category under highly cited papers were reported from the India Institute of Science, Bangalore in 1989-2013. A total of 33 highly cited papers accounting for 9.2% of total papers were categorized under *The Chemistry, Multidisciplinary* and the they receive average citation counts of 161.33 per paper, which less than total papers, followed by *Physics, Condensed Matter* (TP=29; TC/PP=167.10), *Multidisciplinary Sciences* (TP=23; TC/PP=278.96), *Chemistry, Physical; Materials Science, Multidisciplinary* (TP=21; TC/PP=176.48), *Physics, Multidisciplinary* (TP=19; TC/PP=161.53), *Chemistry, Physical; Physics, Atomic, Molecular & Chemical* (TP=16; TC/PP=157.75), *Biochemistry & Molecular Biology* (Tp=15; TC/PP=240.27), *Chemistry, Physical* (TP=7; TC/PP=411.14), *Materials Science, Multidisciplinary; Metallurgy & Metallurgical Engineering* (TP=7; TC/PP=206.00), and *Chemistry, Multidisciplinary; Chemistry, Physical; Nanoscience & Nanotechnology; Materials Science, Multi* (TP=7; TC/PP=323.29). Papers that were categorized under *Chemistry, Physical* had received highest citations counts per paper (411.14) and lowest citation counts per paper (157.75) were received by *Chemistry, Physical; Physics, Atomic, Molecular & Chemical* subject category.

Table 3 :*WoS* category wise distribution of papers

WoS subject category	TP	%	TC	TC/PP
Chemistry, Multidisciplinary	33	9.24	5337	161.73
Physics, Condensed Matter	29	8.12	4846	167.10
Multidisciplinary Sciences	23	6.44	6416	278.96
Chemistry, Physical; Materials Science, Multidisciplinary	21	5.88	3706	176.48
Physics, Multidisciplinary	19	5.32	3069	161.53
Chemistry, Physical; Physics, Atomic, Molecular & Chemical	16	4.48	2524	157.75
Biochemistry & Molecular Biology	15	4.20	3604	240.27
Chemistry, Physical	7	1.96	2878	411.14
Materials Science, Multidisciplinary; Metallurgy & Metallurgical Engineering	7	1.96	1854	206.00
Chemistry, Multidisciplinary; Chemistry, Physical; Nanoscience & Nanotechnology; Materials Science, Multi	7	1.96	2263	323.29
Total	177	49.58	36497	203.89

Note: TP, total papers, %, percent of 357, TC, total citations, and TC/PP= Total citations per paper

Most frequently cited papers (TC=494)

Table 2 gives the list of top ten most frequently highly cited papers published from Indian Institute of Science had TC2015 > 494 since 1989. The most cited is titled as "A Dipole Mode in the Tropical Indian Ocean" written by Saji, Nh et al published in

Nature had received highest citations counts (1567). The article has received an average citations of 92.17 per year since it publication. Similarly, second highly cite paper is titled as "Monitoring Dopants By Raman Scattering In An Electrochemically Top-Gated Graphene Transistor" by Das, A et al., published *Nature Nanotechnology* had received 1265 citation counts and an average of 158.12 citations per year. As time passes, even "true classics" are gradually being cited less often because their substance has been absorbed by the current knowledge, by a phenomenon called "obliteration by incorporation". Five papers belong to computer science, two belong to Multidisciplinary Sciences, one belongs to Nanoscience & Nanotechnology, one belongs Biochemistry & Molecular Biology, and remaining one belongs to Chemistry, Multidisciplinary; Chemistry, Physical respectively.

One more interesting fact is that four highly cited papers (TC=494) published in *IEEE-Acm Transactions On Networking* (Branicky, Borkar, & Mitter, 1998; Kouro et al., 2010; Ramaswami & Sivarajan, 1995; Srinivas & Patnaik, 1994), two in *Nature*(Ramirez, Hayashi, Cava, Siddharthan, & Shastry, 1999; Saji, Goswami, Vinayachandran, & Yamagata, 1999) , one in *Nature Nanotechnology* (Das et al., 2008), one in *Biochemistry* (Karle & Balaram, 1990), one in *Advanced Materials* (Panchakarla et al., 2009), one in *Neural Computation* (Keerthi, Shevade, Bhattacharyya, & Murthy, 2001) respectively.

Table 4 Most frequently cited papers TC=494

AU	TI	SO	PY	TC	TC/PY	*WOS/SC*	RS
Saji, Nh et al.,	A Dipole Mode In The Tropical Indian Ocean	Nature	1999	1567	92.17	Multidisciplinary Sciences	30
Das, A et al.,	Monitoring Dopants By Raman Scattering In An Electrochemically Top-Gated Graphene Transistor	Nature Nanotechnology	2008	1265	158.12	Nanoscience & Nanotechnology	32
Karle, Il and Balaram, P	Structural Characteristics Of Alpha-Helical Peptide Molecules Containing Aib Residues	Biochemistry	1990	796	31.84	Biochemistry & Molecular Biology	45
Srinivas, M and Patnaik, Lm	Adaptive Probabilities Of Crossover And Mutation In Genetic Algorithms	IEEE Transactions On Systems Man And Cybernetics	1994	691	31.40	Computer Science, Cybernetics;	25
Panchokarla, Ls et al.,	Synthesis, Structure, And Properties Of Boron-And Nitrogen-Doped Graphene	Advanced Materials	2009	623	89	Chemistry, Multidisciplinary; Chemistry, Physical	28
Kouro, S et al.,	Recent Advances And Industrial Applications Of Multilevel Converters	IEEE Transactions On Industrial Electronics	2010	613	102.16	Automation & Control Systems	257
Branicky, Ms et al.,	A Unified Framework For Hybrid Control: Model And Optimal Control Theory	IEEE Transactions On Automatic Control	1998	599	33.27	Automation & Control Systems	47
Ramirez, Ap et al.,	Zero-Point Entropy In 'Spin Ice'	Nature	1999	594	34.94	Multidisciplinary Sciences	16
Keerthi, Ss et al.,	Improvements To Platt's Smo Algorithm For Svm Classifier Design	Neural Computation	2001	513	34.2	Computer Science, Artificial Intelligence	12
Ramaswami, R and Sivarajan, Kn	Routing And Wavelength Assignment In All-Optical Networks	IEEE-Acm Transactions On Networking	1995	494	23.52	Computer Science, Hardware & Architecture;	24

Note: AU, Authors name, TI, title of the paper, SO, Journal name, PY, publication year, TC/PP, avarge citations per year and RS, references.

Most productive journals

The table 5 presents the list of top eleven journals that published more than 6 highly cited papers from Indian Institute of Science in the 1989-2013. A total of 129 highly cited papers published in 151 journals with an average of 2.36 papers per journal. Among them, *Physical Review B* is journal that published 24 papers accounting for more than 6.7 % of the total papers with average citation counts of 170.00 per paper followed by *Chemistry Of Materials* (TP=14; TC/PP=170.79), *Journal Of The American Chemical Society* (TP=14; TC/PP=161.07), *Physical Review Letters* (TP=14; TC/PP=166.71) and remaining seven journals with 6 or more papers and average citation per paper ranged between 195.83 to 522.33 respectively. Among these, two journals i. e., *Nature* and *Science* are had high impact factor. The paper published in nature and Science had received highest citation counts per paper 522.33 and 236.55 respectively. These journals (11) had published more than 36.2 % (357) of the highly cited papers published from the Indian Institute of Science, Bangalore. It is revealed that the papers published in higher impact factor tend to receive more citations counts than of low one.

Table 5 papers distribution by journals

Journal	TP	%	TC	TC/PP
Physical Review B	24	6.7	4080	170.00
Chemistry Of Materials	14	3.9	2391	170.79
Journal Of The American Chemical Society	14	3.9	2255	161.07
Physical Review Letters	14	3.9	2334	166.71
Journal Of Physical Chemistry B	12	3.4	2350	195.83
Chemical Physics Letters	11	3.1	1797	163.36
Science	11	3.1	2602	236.55
Chemical Communications	10	2.8	1521	152.10
Acta Materialia	7	2.0	972	138.86
Journal Of Materials Chemistry	6	1.7	1162	193.67
Nature	6	1.7	3134	522.33
Total	129	36.2	24598	190.68

Note: TP, total papers, %, percent of 357, TC, total citations and TC/PP, average citations per paper

CONCLUSION

In total, 357 highly cited papers of Indian institute of Science with at least 100 citations in 2015 published in 1989-2013 were found in the *Web of Science* database. The most highly cited papers of IISc were published in the year of 2000 and highest citation counts per paper were observed in the year 1990 and 1994. A total of 33 highly cited papers accounting for 9.2% of total papers were categorized under *The Chemistry, Multidisciplinary*. These highly cited papers were published in 151 journals and top eleven journals published 36.2% of the papers. *Physical Review B* was the most productive journal *and* the papers published in *Nature* and *Science* had received highest citation counts per article. The paper contributed by Saji, Nh et al.,had received maximum citation counts (1567) and remaining all the papers which had received at least 494 citations were collaborated with different countries authors. Rao, CNR was the leading author who contributed almost 48 papers which accounts for 13.45 % of the total papers.

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