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Activity and Growth of Chemical Research in India during 1987-2007

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ABSTRACT

This paper discusses the Indian chemical research activity during 1987 to 2007 using Scopus database. It tries to quantify the national contribution to world efforts, and identify areas of relative strengths and weaknesses. It also models out the trend of growth in the output of Indian chemical research to world as a whole and in sub-fields of chemical science. These details have been discussed by using the activity index for the world and India. It also estimates the contribution of different institutions and sub-specialties in chemical sciences.

Keywords: Chemical science, research output, activity index, scientometrics, India, world

1. INTRODUCTION

Knowledge is science. Nowadays, the importance of knowledge has been recognised and every country is trying to improve their knowledge base, since knowledge is power. Therefore, there is a tremendous growth in the knowledge world over, of course with differences in their growth geographically. Due to this increase, channels of communication for science like research articles, patents, chapters in books, conference proceedings, etc., been increased. Therefore, quantification of research output of an institution/a country is a topic of interest for all. Especially, it is very useful to the managers of scientific activity in decision making towards the direction of scientific research, allocation of funds, and identifying the bottle necks in the growth of research.

Presently, chemical science research is being treated as one of the world's leading and essential research compared to all other subject areas, as chemistry is a field that has undergone significant changes during the past two decades. It has been expanding very fast and had sub-specialties like organic, inorganic, applied chemistry, etc. But no one can audit accurately regarding which field is important and in the same way it is difficult to identify which institution is providing the best knowledge with regard to their research.

This has resulted in a comprehensive development of chemical science literature in the form of research articles in scientific journals, patents, technical reports, conference proceedings, books, and monographs emanating from different nations and different institutions situated in different parts of the world.

Bibliometric studies, particularly, dealing with different aspects of chemical research have been carried out by Magyar[1], Granberg[2], Jain & Garg[3], Noyons[4], Garg & Padhi[5-9], and Vlachy[10].

Objective of the present study is to discuss the Indian chemical science research activity during the 1987-2007 period using the Scopus database to focus on the following aspects:

- To compare world output vs. India's output in chemistry in terms of the number of publications for 1987-2007 on a year by year basis.
- To study the change in priorities of chemical science research during 1987 to 2007 for India as well as the world, its sub-fields and also to identify the areas of strengths and weaknesses of Indian chemistry.
- To study world and Indian literature output for different sub-fields of chemistry and also for different types of institutions.

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- To identify most productive institutions and their activity profile of India.

2. DATA, METHODOLOGY AND LIMITATIONS

Data has been taken from *Scopus*, the largest database of 15,000 peer-reviewed journals from more than 4,000 international publishers, ensuring broad interdisciplinary coverage with *h*-index and its visual aids that help authors, department heads and university administrators to track and interpret their performance[11]. Therefore, *Scopus* has been considered as a basic source for bibliometric data for chemistry research output for the present study. *Scopus,* having a wider scope, includes peripheral journals also in its database to quantify the exact proportion.

The search query used while searching the database for retrieving the publications data of about 79118 papers by the Indian scientists in the field of chemical sciences during the period of study is as follows:

Set 1—India in affiliation field and period 1987 to 2007

Set 2—Limiting chemistry in subject field

Set 3—Set 1 and Set 2, (i.e., chemical science papers published from India during 1987-2007)

However, there were certain limitations to the present study, because of the limitations in *Scopus* database coverage of publications for pre-1996 period as the publishers of *Scopus* database (Elsevier) do not claim the completeness of coverage for pre-1996 period.

3. RESULTS AND DISCUSSIONS

3.1 World Output Vs. Indian Output

Data contains total publications of 79118 by Indian scientists in the field of chemical science during the period of study. The total publication output constituted about 6.03 per cent of the world output. Here, activity index (*AI*) suggested by Frame[12] and elaborated by Schubert & Braun[13], Garg,[14] & Nagpaul,[15] has been used to compare India's research performance with the world's research performance. The *AI* characterises the relative research effort of a country in a given subject field. It is defined as:

AI= Given field's share in the country's publication outputs)/(Given field's share in the world's publication output.

AI= 100 indicates that the country's research effort in the given field corresponds precisely to the world's average.

AI>100 reflects higher activity than the world's average, and

AI<100 indicates lower activity than the world's average.

Here, *AI* for India has been calculated for different years to analyse how India's performance changed during different years using the above formula, but in a modified way suggested by Price[16] and used by Karki & Garg[17] in their study on alkaloid chemistry research in India. Here, *AI* has been calculated as followed:

AI = {(India's output in a particular year)/(Total Indian output)}/{(World's output in a particular year)/(Total world's output)} x 100

Mathematically, $AI = \{(I_i/I_o)/(W_i/W_o)\} \times 100$

Here, I_i is the Indian output in the year *i;* I_o is the total Indian output; W_i is the world output in the year *i;* and W_o is the total world output. Table 1 presents the results of the *AI* of India in the field of chemical science. It indicates that India's effort in chemical science were lower than world during the first two years (1987 and 1988) and also

Table 1. World and Indian output in chemical science during 1987-2007

Year	World output	Indian output	Activity index
1987	23000	1378	99
1988	24177	1433	98
1989	24402	1690	115
1990	25902	1835	117
1991	26895	2002	123
1992	27022	1647	101
1993	29205	1707	97
1994	30230	1912	105
1995	32504	1983	101
1996	74764	4034	89
1997	75886	3668	80
1998	77453	3959	85
1999	78594	4181	88
2000	80635	4030	83
2001	83449	4333	86
2002	87118	4922	94
2003	88333	5798	109
2004	96639	6150	106
2005	102503	6699	108
2006	108123	7557	116
2007	114888	8200	118
Total	**1311722**	**79118 (6.03)***	**100.9****

**Percentage of world output; **Average activity index of India*

for 1996 to 2002. However, as reflected by the values of the *AI*, the activity has picked up during 1989-1995 and also during 2003-2007. It was at peak in 1991. The average value of the *AI* for India during 1987-2007 was 100.9 which indicates that India's research effort in chemical science was slightly more when compared to the world average.

Other features of output, as reflected by the plots of the output for world (Fig. 1(a)) and India (Fig. 1(b)) indicate that the world output grew steeply during 1995-96 and from then onwards a steady increasing pace has been maintained upto 2007. In case of the Indian output also there is a steep growth during 1995-96 with an inconsistent growth rate upto 2001 and from then onwards a steady increasing pace has been maintained upto 2007.

3.2 Change in Research Priority for Research, and Fields of Strength/Weakness

The results of research output for world and India in different sub-fields of chemical science and its activity/ priority index have been given in Table 2 and research output for different sub specialties of chemical science have been shown in Figs 2(a) and 2(b) for the period of study, viz.,1987-2007. For convenience sake the main field chemistry has been divided into four subfields, viz., organic, inorganic, applied chemistry and miscellaneous chemistry. If *AI* > 100, it implies higher activity than world average in case of world and India's average in case of India and vice versa if *AI*<100.

In Table 2, it was observed that in case of world data during 1987-1996 the priorities have been given to miscellaneous chemistry and from 1996 onwards upto 2007 organic and inorganic chemistry have been given more priorities. From 2000 onwards applied chemistry has also shown the same trend like organic and inorganic chemistry with having high activity but with a consistent increase in growth rate. India has also shown the same trend like the world. From 1987-1995 the value of *AI* for miscellaneous chemistry was high and from 1996-2007 organic and inorganic chemistry have shown higher priority indices. From 2001 onwards, applied chemistry has also shown almost the same trend like organic and inorganic chemistry with high *AI* but with a consistent increase in growth rate.The measure of shift

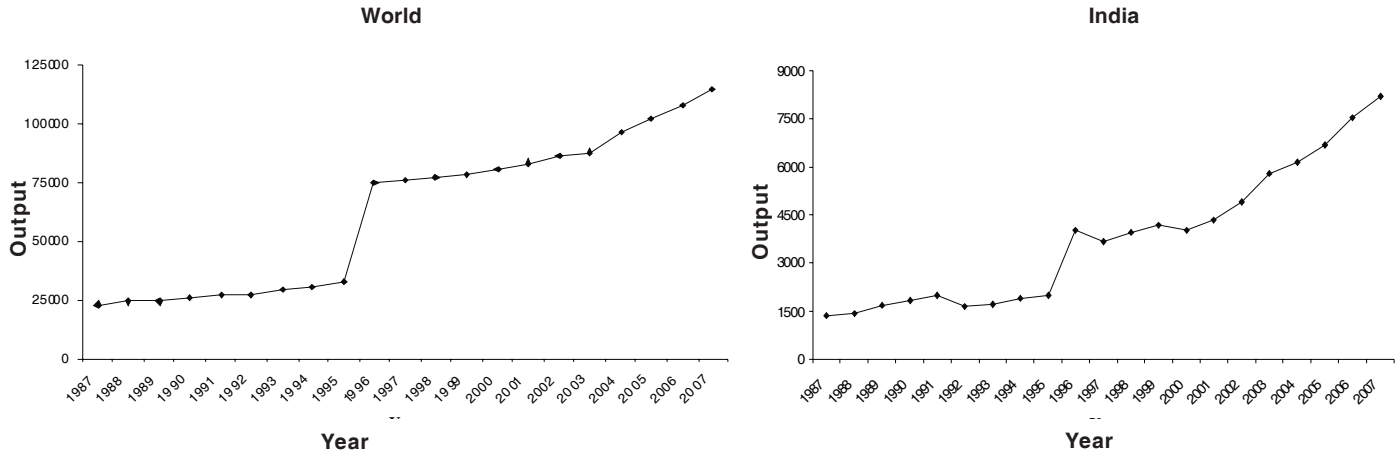

Figure 1. Research output in chemical science during 1987-2007 for: (a) World and (b) India.

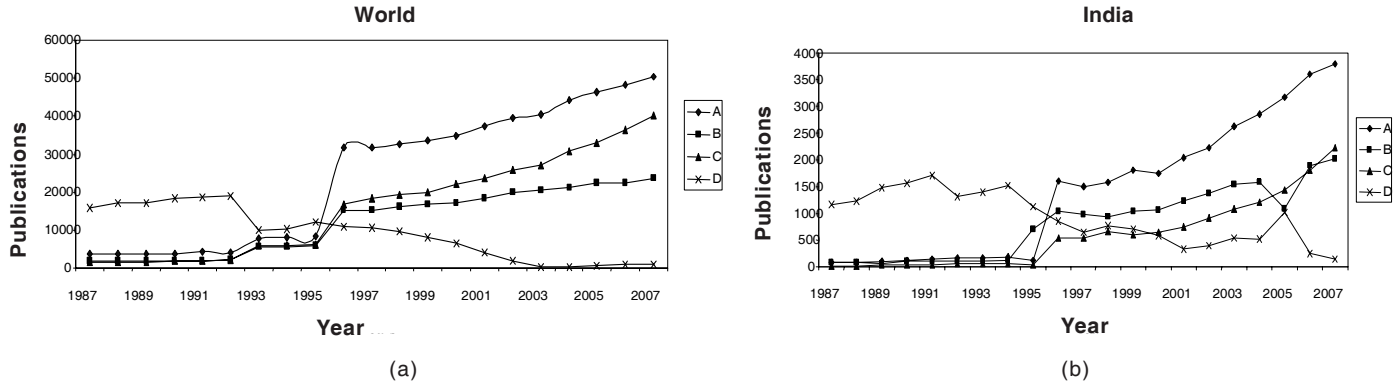

Figure 2. Research output in different sub-specialities of chemical science during 1987-2007 in: (a) World and (b) India.

Table 2. Activity index in different sub-specialties during 1987-2007

Year	World					India				
	A (*AI*)	B (*AI*)	C (*AI*)	D (*AI*)	Total	A (*AI*)	B (*AI*)	C (*AI*)	D (*AI*)	Total
1987	3749 (41)	1903 (42)	1439 (24)	15909 (469)	23000	86 (17)	87 (29)	29 (13)	1176 (350)	1378
1988	3779 (40)	1909 (40)	1540 (24)	16949 (475)	24177	90 (17)	87 (28)	28 (12)	1228 (352)	1433
1989	3625 (38)	1934 (40)	1704 (27)	17139 (476)	24402	96 (15)	68 (18)	38 (14)	1488 (362)	1690
1990	3705 (36)	2007 (39)	1732 (26)	18458 (483)	25902	118 (17)	107 (27)	45 (15)	1565 (350)	1835
1991	4260 (40)	2009 (38)	1851 (26)	18775 (473)	26895	147 (20)	104 (24)	49 (15)	1702 (349)	2002
1992	3949 (37)	2070 (38)	2064 (29)	18939 (475)	27022	161 (26)	114 (32)	65 (24)	1307 (326)	1647
1993	7889 (68)	5610 (98)	5912 (78)	9794 (227)	29205	161 (25)	103 (28)	57 (21)	1386 (333)	1707
1994	8125 (68)	5730 (96)	6035 (77)	10340 (232)	30230	191 (27)	127 (30)	69 (22)	1525 (328)	1912
1995	8247 (64)	5856 (92)	6296 (74)	12105 (252)	32504	120 (16)	705 (163)	42 (13)	1116 (231)	1983
1996	31611 (107)	15298 (104)	16820 (86)	11035 (100)	74764	1607 (106)	1033 (117)	536 (82)	858 (87)	4034
1997	31677 (106)	15307 (103)	18326 (93)	10576 (94)	75886	1491 (108)	987 (123)	544 (92)	646 (72)	3668
1998	32610 (107)	16021 (105)	19251 (95)	9571 (84)	77453	1583 (106)	940 (109)	659 (103)	777 (81)	3959
1999	33657 (108)	16907 (109)	19876 (97)	8154 (70)	78594	1818 (116)	1046 (115)	606 (89)	711 (70)	4181
2000	34926 (110)	17024 (107)	22021 (105)	6664 (56)	80635	1754 (116)	1054 (120)	641 (98)	581 (59)	4030
2001	37166 (113)	18494 (113)	23666 (109)	4123 (33)	83449	2032 (125)	1222 (129)	744 (106)	335 (32)	4333
2002	39415 (115)	20017 (117)	25927 (114)	1759 (14)	87118	2238 (121)	1372 (128)	912 (114)	400 (33)	4922
2003	40268 (115)	20488 (118)	27143 (118)	434 (3)	88333	2625 (120)	1547 (122)	1089 (116)	537 (38)	5798
2004	44288 (116)	21019 (111)	30906 (123)	426 (3)	96639	2864 (124)	1576 (117)	1198 (120)	512 (34)	6150
2005	46415 (115)	22520 (112)	33000 (123)	568 (4)	102503	3166 (126)	1083 (74)	1430 (132)	1020 (63)	6699
2006	48262 (113)	22352 (105)	36446 (129)	1063 (7)	108123	3594 (127)	1903 (115)	1809 (148)	251 (14)	7557
2007	50228 (111)	23618 (104)	40208 (134)	834 (5)	114888	3802 (123)	2022 (113)	2233 (168)	143 (7)	8200
Total	**517851**	**258093**	**342163**	**193615**	**1311722**	**29744**	**17287**	**12823**	**19264**	**79118**

( ) indicates activity index to the nearest whole number.

A: Organic chemistry; B: Inorganic chemistry; C: Applied chemistry; D: Miscellaneous chemistry

in the *AI* for various sub-fields indicates that presently, organic, inorganic, and applied chemistry research are the current areas of strength, while miscellaneous chemistry research is the weak area of research both for world and India. From the Figs 2(a) and 2(b) it is evident that 1995 and 1996 were crucial for world and India, respectively, where there were prominent changes in research output of sub-specialties of chemical science.

3.3 Sub-fields of Study by Institutions

It has been observed that universities and research institutions were the primary centres of scientific research in India. In order to examine the priority given by these institutions to different sub-specialties of chemical science, *AI* has been used for comparing different types of institutions. However, in the present context the *AI* for different types of institutions have been calculated to identify the emphasis given by these institutions to different sub-specialties of chemical science.

Here, *AI* has been defined as follows:

AI = {(Output of a particular type of institution in a particular sub-specialty)/(Total output in all sub-specialties of that type of institutions)}{(Total output of different type of institutions in that sub-specialty)/(Total output)} x 100

Similar to the *AI* calculated for different sub-specialties of chemical science, the same is true with the *AI* of different types of institutions for world and India. If *AI* >100, it implies higher activity than world average in case of world and India's average in case of India and vice versa if *AI*<100.

In Table 3 the data on research publications produced by different types of institutions like universities, R&D organisations, private/industrial and other organisations have been given. Other organisations include colleges, affiliated bodies, NGOs, etc. The research output of world and India in different sub-specialties along with their AI have been given.Data indicate that the research output for different types of institutions for world is: Universities>R&D> private institutions>others. Whereas in India, the trend in different types of institutions is: R&D>universities>private institutions>others

Similarly, it has been observed that the research output for different types of sub-fields for world has been: Organic chemistry>applied chemistry>inorganic chemistry >miscellaneous chemistry

For India the following sequence has been observed: Organic chemistry>miscellaneous chemistry>inorganic chemistry>applied chemistry

From the *AI* it was evident that in case of world except other type of institutions and miscellaneous chemistry, rest of the institutions (i.e., universities, R&D, and private) and other sub-fields (organic, inorganic, and applied) have relatively high *AI*. But in case of India, except miscellaneous chemistry the other sub-fields in universities have greater activity index. Similarly, except inorganic chemistry rest other sub-fields in R&D institutions have high *AI*. But in private only applied and miscellaneous chemistry have high activity index. From this it has been inferred that the patterns of priorities in university for world and India were similar. Whereas, in case of R&D institutions India has shown an opposite trend to world by showing high priorities for miscellaneous chemistry and low in inorganic chemistry. In case of private/industries India has shown an opposite trend to world by having low priorities for organic and inorganic and high in miscellaneous chemistry and same

Table 3. Publication output of different type of institutions in different sub-specialties

Types of institutions	Sub-specialties									
	World					India				
	A (*AI*)	B (*AI*)	C (*AI*)	D (*AI*)	Total	A (*AI*)	B (*AI*)	C (*AI*)	D (*AI*)	Total
Universities	247336 (101)	123494 102)	162313 (101)	92095 (93)	625238	13144 (101)	7801 (103)	5652 (100)	8178 (97)	34775
R&D	144841 (102)	72340 (103)	94632 (101)	53764 (88)	365577	13916 (100)	8010 (99)	5964 (100)	9058 (101)	36948
Private/industries	112479 (103)	56217 (103)	73246 (102)	41665 (85)	283607	2030 (99)	1129 (95)	921 (104)	1382 (104)	5462
Others	13195 (57)	6042 (52)	11972 (79)	6091 (70)	37300	654 (89)	347 (82)	286 (91)	646 (67)	1933
Total	**517851**	**258093**	**342163**	**193615**	**1311722**	**29744**	**17287**	**12823**	**19264**	**79118**

( ) indicates activity index to the nearest whole number.
A: Organic chemistry; B: Inorganic chemistry; C: Applied chemistry; D: Miscellaneous chemistry

Table 4. Publication output and activity profile of highly productive institutions

Institutions	A (*AI*)	B (*AI*)	C (*AI*)	D (*AI*)	Total
Indian Institute of Science	1343 (103)	1018 (135)	600 (107)	501 (59)	3462
Indian Institute of Chemical Technology	2421 (193)	419 (57)	470 (87)	27 (3)	3337
Bhabha Atomic Research Centre	832 (78)	636 (103)	624 (137)	728 (106)	2820
National Chemical Laboratory	1470 (155)	444 (80)	597 (146)	14 (2)	2525
Indian Association for the Cultivation of Science	825 (108)	810 (182)	319 (97)	79 (16)	2033
Jadavpur University	590 (92)	697 (186)	270 (97)	158 (38)	1715
Indian Institute of Technology, Kanpur	749 (118)	418 (113)	238 (87)	281 (68)	1686
Indian Institute of Technology, Bombay	669 (112)	485 (139)	263 (102)	176 (45)	1593
Indian Institute of Technology, Madras	485 (88)	320 (100)	341 (144)	314 (88)	1460
University of Delhi	652 (126)	403 (134)	265 (119)	53 (16)	1373
Others	19708 (92)	11637 (93)	8836 (95)	16933 (122)	57114
Total	**29744**	**17287**	**12823**	**19264**	**79118**

( ) indicates activity index to the nearest whole number.
A: Organic chemistry; B: Inorganic chemistry; C: Applied chemistry; D: Miscellaneous chemistry

trend for applied chemistry. In other type of institutions less priority has been given to all sub-specialties of chemical sciences for both world and India.

3.4 Activity Profile of Highly Productive Institutions

The results of output for highly productive top 10 institutions in scientific literature in different sub-specialties of chemical science were shown in Table 4. Data indicates a considerable difference in the publication output of the institutions in different sub-specialties. These differences in the publication output can best be comprehended by using *AI*. In Table 4 from India's activity profile for different sub-specialties in chemical science the following observations were made:

In case of organic chemistry, 70 per cent of institutions have shown high *AI* (>100) except Bhabha Atomic Research Centre, Jadavpur University, Indian Institute of Technology, Madras and other types of institutions with low *AI*<100. Among the high activity profile institutions, top three were Indian Institute of Chemical Technology, National Chemical Laboratory, and University of Delhi, respectively.

In case of inorganic chemistry also 70 per cent of institutions have shown high *AI* (>100) except Indian Institute of Chemical Technology, National Chemical Laboratory and other types of institutions with low *AI*<100. Whereas activity index of Indian Institute of Technology, Madras was equal to the Indian average (*AI*=100). Among the high activity profile institutions, the top three were Jadavpur University, Indian Association for the Cultivation of Science, and Indian Institute of Technology, Bombay respectively.

In case of applied chemistry, 60 per cent of institutions have shown high *AI*>100 except Indian Institute of Chemical Technology, Indian Association for the Cultivation of Science, Jadavpur University, Indian Institute of Technology, Kanpur, and other types of institutions with low activity indices (*AI*<100). Among the high activity profile institutions, the top three were National Chemical Laboratory, Indian Institute of Technology, Madras, and Bhabha Atomic Research Centre, respectively. In case of miscellaneous chemistry only Bhabha Atomic Research Centre and other types of institutions have shown high *AI*>100 and rest showing low activity indices.

From the above discussion it has been inferred that out of the highly productive institutions, 70 per cent have given emphasis to both organic and inorganic chemistry and 60 per cent institutions have given emphasis to applied chemistry. Only Bhabha Atomic Research Centre and other type of institutions have given emphasis to miscellaneous chemistry.

4. CONCLUSIONS

Some findings of the study are:

- The average value of the *AI* for India during 1987-2007 is 100.9 which indicate that India's research effort in chemical science is more when compared to the world average.
- The measure of shift in the *AI* for various sub-fields indicates that presently organic, inorganic, and applied chemistry research are the current areas of strength, while miscellaneous chemistry research is the weak area of research both for world and India.

- The patterns of priorities in university for world and India are similar.
- India has shown an opposite trend to world in case of R&D institutions by showing high priorities for miscellaneous chemistry and low in inorganic chemistry.
- India has also shown opposite trend to world in case of private/industries by having low priorities in organic and inorganic and high in miscellaneous and same trend for applied chemistry.
- Indian Institute of Chemical Technology leads top position in organic chemistry followed by National Chemical Laboratory and University of Delhi, whereas in inorganic chemistry, Jadavpur University scores top position followed by Indian Association for the Cultivation of Science and Indian Institute of Technology, Bombay.
- In case of applied chemistry, National Chemical Laboratory leads with top position followed by Indian Institute of Technology, Madras and Bhabha Atomic Research Centre.
- In case of miscellaneous chemistry, Bhabha Atomic Research Centre scores top position among these ten institutions.

Out of the highly productive institutions, 70 per cent have given importance to both organic and inorganic chemistry and 60 per cent institutions have given importance to applied chemistry. Only Bhabha Atomic Research Centre has given importance to miscellaneous chemistry.

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REFERENCES

1. Magyar. Bibliometric analysis of new research sub-field. *Journal of Documentation,* 1974, 32-40.
2. Granberg, A. A bibliometric study of laser research in Sweden, West Germany and Japan. Research Policy Institute, Sweden, 1986, 30.
3. J ain, A. & Garg, K.C. Laser research in India: Scientometric study and model projections. *Scientometrics*, 1992, **23**(3), 395-415.
4. Noyons, E.C.M., *et al.* Exploring the science and technology interface: inventor author relations in laser medicine research. *Research Policy*, 1994, **23**(4), 443-57.
5. Garg, K.C. & Padhi, P. Scientometric study of laser patent literature. *Scientometrics,* 1998, **43**(3), 443-54.
6. Garg, K.C. & Padhi, P. Scientometrics of laser research literature as viewed through the *Journal of Current Laser Abstracts. Scientometrics,*1999, **45**(2), 251-68.
7. Garg, K.C. & Padhi, P. Scientometrics of institutional productivity in laser science and technology. *Scientometrics,* 1999, **46**(1), 19-38.
8. Garg, K.C. & Padhi, P. Scientometrics of prolific and non-prolific authors in laser science and technology. *Scientometrics,* 2000, **49**(3), 359-71.
9. Garg, K.C. & Padhi, P. A study of collaborations in laser science and technology. *Scientometrics,* 2001, **51**(2), 451-27.
10. Valchy, J. World trends, publication output, research fronts and highly cited papers in optics, laser and quantum electronics. *Czech. J. Phys.,* 1987, **37**(2), 257-72.
11. Scopus. http://www.scopus.com
12. Frame, J.D. Mainstream research in Latin America and Caribbean. *Interciencia,* 1977, **2**, 143-47.
13. Schubert, A. & Braun, T. Relative indicators and relational charts of comparative assessment of publication output and citation impact. *Scientometrics,*1986, **9**(5,6), 281-91.
14. Garg, K.C. & Padhi, P. Scientometrics of laser research literature as viewed through the *Journal of Current Laser Abstracts*. *Scientometrics,*1999, **45**(2), 251-68.
15. Nagpaul, P.S. Contribution of Indian universities to the main-stream scientific literature: A bibliometric assessment. *Scientometrics,*1995, **32**(1), 11-36.
16. De Solla Price, D. The analysis of scientometric matrices for policy implications. *Scientometrics*, 1981, **39**(1), 47-53.
17. Karki, M.M.S. & Garg, K.C. Bibliometrics of alkaloid chemistry research in India. *J. Chem. Info. Comp. Sci.,* 1997, **37**(2), 157-61.

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