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Growth and Impact of S&T Research in Madhya Pradesh during 2000-2009

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ABSTRACT

The paper discusses the scientific contribution from Madhya Pradesh (India) as per the *Web of Science*-expanded version during 2000-2009. The parameters studied include growth of publications and citations, international collaborations, national collaborations, subject-wise distribution of publications, citations, activity index and collaboration rate, ranking of research and academic institutions, authorship and collaboration patterns, channels of communications, and major journals preferred by scientists of Madhya Pradesh for publishing their research works.

Keywords: Scientometric, Madhya Pradesh, India, activity index, collaboration trend, S&T research

1. INTRODUCTION

Publication and citation counting techniques have been used in the assessment of scientific activity at least for the past 50 years. During the half-century of this activity, the main thrust of interest seems to flow along two connected but parallel paths: (i) the bibliometric path of publication and citation counts as tools for the librarian, (ii) and an evaluative path using the same tools to illuminate the mosaic of scientific activity[1]. The use of citations as a measure of research quality is based on the assumption that scientists and their published works receive citations in proportion to the degree to which their ideas and findings constitute a contribution to the advancement of knowledge.

As the scientific system gets larger, it becomes increasingly difficult to gauge the direction in which science is moving, as some parts will experience growth, other parts show decline in growth. Published papers, therefore, can indicate areas of growth of science[2]. Scientometrics is a discipline which analyses scientific publications and citations appended to the papers to gain an understanding of the structure of science, growth of science at global level, performance of a country in a particular domain, performance of institutions, departments/divisions, and scientific eminence of an individual scientist. It also helps in knowing the information-seeking behaviour of scientists and engineers by way of identifying where they publish and what they cite. Many scientometric studies have been presented in the literature to focus on the performance of science in various domains[3-16].

2. OBJECTIVES

The main objective of the study is to present the growth of S&T literature published by scientists of Madhya Pradesh during 2000-2009 as per the *Web of Science (WoS)* database and make the quantitative and qualitative assessments by way of analysing various features of research output such as year-wise trend of publications and citations; subject-wise distribution of publications and citations; ranking of institutions according to publication output and citation impact; authorship pattern versus citations, year-wise and domain-wise activity indices; channels of communications used by the scientists and collaboration trends.

3. MATERIALS AND METHODS

Data was collected using *WoS* for the duration between 2000-2009. The *Wos* provides researchers, administrators, faculty, and students a quick and powerful access to the world's leading citation

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databases. Using suitable search strategy, records pertaining to Madhya Pradesh in the address field (Madhya Pradesh in address or MP in address or M.P. in address or M.P. in address and India in address) were downloaded for 2000-2009. A total of 5576 publications and 36289 citations to these papers were downloaded. All the records were classified into 12 broad subject categories based on *WoS* subject categories. Ranking of institutions was done based on the number of papers and average number of citations per paper. Further, all the bibliographic details were transferred to spread sheet application. The data was analysed as per the objectives of the study.

4. RESULTS AND DISCUSSION

4.1 Growth of Publications and Citations

Figure 1 shows year-wise distribution of publications and citations. A total of 5576 publications were published by the scientists of MP during 2000-2009 as per *WoS*. These publications received 36289 citations during the period. The highest number of publications 925 (16.59 per cent) were published in 2009. While average number of publications per year was 557.60, the average number of citations per paper was 6.51. It was observed that the old publications tend to receive more citations than the latest publications as these require notice by researchers and to find context to cite them.The highest number of citations 6180 (15.37 per cent) were received in 2002. The average number of citations per year was 3628.90.

Figure 2 gives the top 20 Indian states and union territory actively pursuing research in S&T, producing 285269 publications, Maharashtra topped the list with 37471 (13.14 per cent) publications followed by Delhi with 35819 (12.56 per cent) publications, Uttar Pradesh with 34152 (11.97 per cent), Tamil Nadu with 31476 (11.03 per cent), and Karnataka with 31030 (10.88 per cent) publications.

4.2 International Collaboration

In recent years, many countries have initiated programmes that enable scientists to have more interactions among them, both at national and international levels. This study also measures the extent of international collaboration by the scientists of Madhya Pradesh. Table 1 gives the list of countries, which collaborated with the institutions located in Madhya Pradesh. There were 3715 (66.62 per cent) international collaborative papers by them with 86 countries. The USA ranked first with 617 collaborative publications and 14571 citations, England ranked 2nd with 358 collaborative publications and 5512 citations, and Germany ranked 3rd with 260 collaborative publications and 4284 citations.

4.3 National Collaborations

There were 1552 (27.83 per cent) collaborative papers with institutes across 28 Indian states. Chhattisgarh ranked the first with 561 collaborative publications and 1370 citations, Uttar Pradesh ranked the second with 290 collaborative publications and 944 citations, Delhi ranked third with 250 collaborative publications and 685 citations, Maharashtra ranked fourth with 233 collaborative publications and 853 citations, and Gujarat ranked the fifth with 90 publications and 191 citations. Table 2 gives the list of year-wise trend of institutional collaborations of other Indian states with Madhya Pradesh.

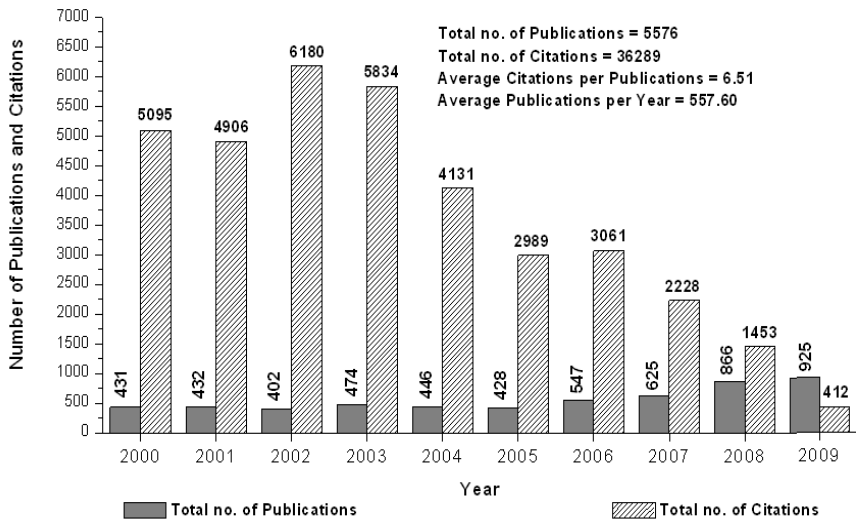

Figure 1. Year-wise publications and citations of S&T research in Madhya Pradesh during 2000-2009.

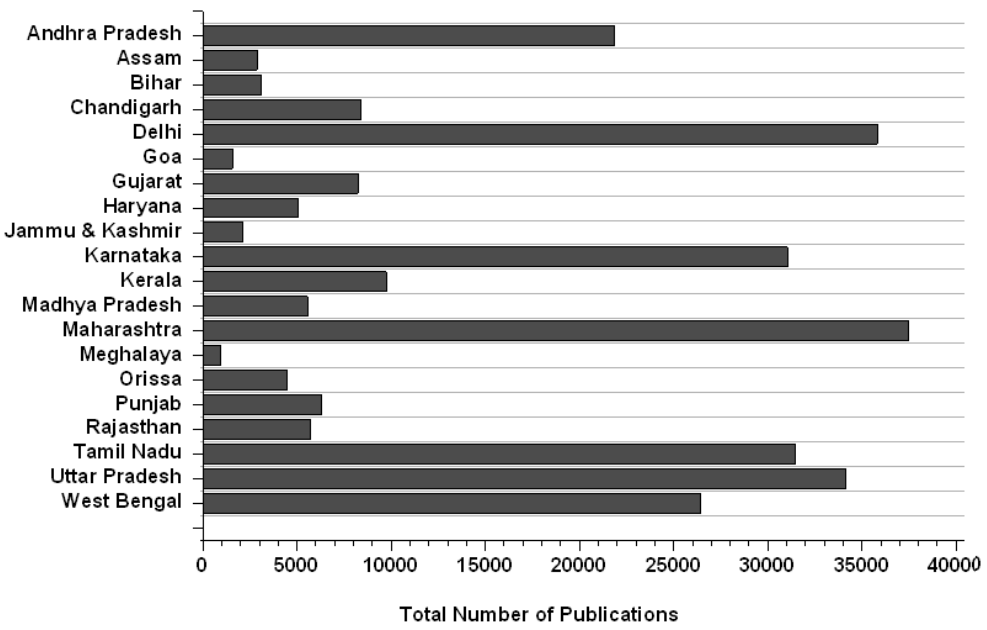

Figure 2. Twenty highly productive Indian states of R&D publications during 2000-2009.

4.4 Subject-wise Distribution of Publications and Citations

Table 3 gives subject-wise distribution of papers and citations. The highest number of publications 1309 (23.48 per cent) were published in Clinical Medicine followed by Chemistry with 963 (17.27 per cent), Agriculture with 719 (12.89 per cent), Biology with 705 (12.64 per cent), Physics with 647 (11.60 per cent), Engineering with 374 (6.71 per cent) and Materials Science with 302 (5.42 per cent) publications. The highest number of citations 18676 (51.46 per cent) were in Clinical Medicine followed by Chemistry with 3373 (9.29 per cent) citations, Agriculture with 1842 (5.08 per cent), Biology with 5380 (14.83 per cent), Physics with 2050 (5.65 per cent), Engineering with 1572 (4.33 per cent) citations and Materials Science with 928 (2.56 per cent) citations.

4.5 Subject-wise Activity Index

The Activity Index (AI) characterises the relative research efforts of a country in a given subject[17]. Analysis of growth and decline in publication productivity using normalised AI showed that the highest AI in various subject categories were: Clinical Medicine (129.41) in 2003, Chemistry (117.1) in 2009, Agriculture (174.13) in 2001, Biology (118.85) in 2009, Physics (126.86) in 2005, Engineering (117.07) in 2008, Materials Science (157.69) in 2009, Multidisciplinary Science (131.57) in 2000, Earth and Space Science (133.52) in 2007, Biomedical Research (178.43) in 2007, Mathematics (272.46) in 2002, and Computers and Communications (217.13) in 2005 (Table 4).

4.6 Subject-wise Distribution of Publications, Citations and Collaboration Rates

Analysis of subject-wise collaboration in S&T research in MP showed that the highest collaboration rate was in Clinical Medicine (0.95) in 2004; Chemistry (0.98) in 2002; Agriculture (0.97) in 2008; Biology (1.00) in 2004; Physics (0.99) in 2008; Engineering (1.00) in 2005 and 2007; Materials Science (1.00) in 2003, 2004 and 2009; Multidisciplinary Sciences (1.00) in 2001; Earth and Space Science (1.00) in 2006; Biomedical Research (0.83) in 2004 and 2005; Mathematics (1.00) in 2005 and 2006 and Computers and Communications (1.00) in 2001, 2007 and 2009. Tables 5-16 give year-wise distribution of publications, citations and collaboration rates in various domains of research.

4.7 Ranking of Academic and Research Institutions based on Publications and Citations per Publication in all Disciplines

Table 17 gives ranking of all academic institutions in MP based on number of publications and average number of citations in all disciplines. Dr H.S. Gour University, Sagar ranked Ist in terms of publications and ranked 2nd in terms of citations per publication (5.31) followed by Devi Ahilya University, Indore which ranked 2nd with 374 publications and 4th in terms of citations per publication (4.57), Vikram University, Ujain ranked 3rd with 250 publications and ranked 6th in terms of citations per publication (2.82) and APS Univ, Rewa ranked 4th with 146 publications and ranked Ist in terms of citations per publication (5.49).

Table 1. International collaboration of S&T research in all academic and research institutions of Madhya Pradesh

Rank by collaborative papers	Country	TP	TC	ACP	Rank by collaborative papers	Country	TP	TC	ACP
1	USA	617	14571	23.62	33	Pakistan	5	148	29.60
2	England	358	5512	15.40	34	Cyprus	4	1	0.25
3	Germany	260	4284	16.48	34	Lithuania	4	26	6.50
4	Zimbabwe	232	1077	4.64	34	Papua N Guinea	4	17	4.25
5	Italy	231	4175	18.07	34	Saudi Arabia	4	14	3.50
6	France	229	3674	16.04	34	Tanzania	4	45	11.25
7	The Netherlands	203	3456	17.02	34	Turkey	4	15	3.75
8	Spain	175	3040	17.37	34	Vietnam	4	63	15.75
9	Canada	160	2385	14.91	35	Malawi	3	44	14.67
10	Sweden	143	2663	18.62	35	Serbia Montenegro	3	7	2.33
11	Denmark	138	2616	18.96	35	Syria	3	52	17.33
12	Greece	134	2806	20.94	35	Uzbekistan	3	34	11.33
13	Norway	94	1895	20.16	35	Wales	3	20	6.67
14	Israel	91	623	6.85	35	Yugoslavia	3	30	10.00
15	Russia	77	1845	23.96	36	Belarus	2	0	0
16	Japan	62	427	6.89	36	Estonia	2	7	3.50
17	Australia	46	312	6.78	36	Ghana	2	6	3.00
18	Switzerland	35	232	6.63	36	Kenya	2	17	8.50
19	South Korea	33	141	4.27	36	Latvia	2	19	9.50
20	Peoples R China	30	267	8.90	36	Zambia	2	13	6.50
21	South Africa	29	111	3.83	37	Algeria	1	8	8.00
22	Bangladesh	22	178	8.09	37	Argentina	1	2	2.00
22	Brazil	22	56	2.55	37	Armenia	1	13	13.00
23	Scotland	20	209	10.45	37	Bolivia	1	0	0
24	Hungary	19	86	4.53	37	Botswana	1	2	2.00
25	Portugal	16	286	17.88	37	Cameroon	1	2	2.00
26	Mexico	14	121	8.64	37	Colombia	1	7	7.00
27	Singapore	13	52	4.00	37	Cuba	1	16	16.00
28	Finland	12	194	16.17	37	Iceland	1	0	0
28	Poland	12	43	3.58	37	Indonesia	1	59	59.00
28	Taiwan	12	36	3.00	37	Iran	1	1	1.00
29	Austria	9	33	3.67	37	Jamaica	1	3	3.00
29	Ireland	9	65	7.22	37	Jordan	1	3	3.00
29	Philippines	9	78	8.67	37	Kazakhstan	1	2	2.00
29	Slovakia	9	51	5.67	37	Laos	1	13	13.00
30	Chile	8	91	11.38	37	Mauritius	1	1	1.00
30	Czech Republic	8	33	4.13	37	Morocco	1	0	0
30	Ukraine	8	32	4.00	37	Nepal	1	2	2.00
31	Malaysia	7	62	8.86	37	Nigeria	1	12	12.00
32	Belgium	6	94	15.67	37	Romania	1	0	0
32	Oman	6	13	2.17	37	Sri Lanka	1	13	13.00
32	Thailand	6	12	2.00	37	Uganda	1	1	1.00
33	New Zealand	5	8	1.60	37	Venezuela	1	0	0

TP=Total number of Publications; TC= Total number of Citations; ACP=Average number of Citations per Publication

Table 2. Year-wise trend of institutional collaboration of all academic and research institutions of Madhya Pradesh with academic and R&D institutions of other Indian states

State	Year of Collaboration										TP	TC	ACP
	2000	01	02	03	04	05	06	07	08	09			
Chhattisgarh	48	44	35	41	51	46	50	91	90	65	561	1370	2.44
Uttar Pradesh	15	14	11	14	9	11	26	43	64	83	290	944	3.26
Delhi	4	15	6	14	12	16	23	42	49	69	250	685	2.74
Maharashtra	8	10	16	18	19	17	21	26	41	57	233	853	3.66
Gujarat	1	5		6	10	7	13	10	18	20	90	191	2.12
Tamil Nadu	6	3	3	2	5	6	6	5	23	27	86	387	4.50
West Bengal	8	6	2	2	3	5	13	5	14	24	82	511	6.23
Karnataka	-	2	8	4	4	1	5	13	17	17	71	252	3.55
Rajasthan	1	1	3	5	3	5	6	6	20	20	70	260	3.71
Andhra Pradesh	3	2	5	2	1	3	5	8	11	17	57	170	2.98
Haryana	3	3	3	3	1	2	3	9	14	13	54	97	1.80
Chandigarh	-	2	3	3	1	-	7	8	8	17	49	195	3.98
Kerala	1	-	-	1	3	2	1	2	7	15	32	60	1.88
Punjab	1	2	-	4	1	2	5	5	-	6	26	200	7.69
Orissa	-	2	-	2	1	1	3	1	3	9	22	64	2.91
Bihar	1	3	-	-	-	-	2	5	5	-	16	43	2.69
Uttarkhand	1	1	-	5	-	-	-	1	4	11	23	45	1.96
Himachal Pradesh	1	-	1	-	-	1	1	3	1	5	13	16	1.23
Jammu & Kashmir	-	1	-	1	-	1	-	1	2	4	10	59	5.90
Assam	-	-	-	1	-	-	-	2	1	3	7	5	0.71
Jharkhand	-	-	-	-	-	-	1	2	2	2	7	5	0.71
Meghalaya	1	-	1	-	-	-	-	-	2	2	6	4	0.67
Tripura	1	1	-	1	1	-	1	-	-	-	5	181	36.20
Manipur	-	-	-	-	-	-	-	3	-	-	3	3	1.00
Andaman Nicobar	-	-	-	-	1	-	-	1	-	-	2	14	7.00
Goa	-	-	2	-	-	-	-	-	-	-	2	38	19.00
Mizoram	-	-	-	-	-	-	-	-	-	1	1	0	0.00

Table 3. Subject wise distribution of publications and citations published by scientists of Madhya Pradesh

Subject category	Publication year										TP	TC	ACP
	2000	01	02	03	04	05	06	07	08	09			
Clinical Medicine	96	92	120	144	96	111	126	165	182	177	1309	18676	14.27
Chemistry	62	67	64	63	83	67	107	106	157	187	963	3373	3.50
Agriculture	95	97	53	74	62	54	73	54	89	68	719	1842	2.56
Biology	52	47	47	55	52	51	59	91	112	139	705	5380	7.63
Physics	38	37	32	47	55	63	58	71	111	135	647	2050	3.17
Engineering	16	30	28	29	34	18	40	39	68	72	374	1572	4.20
Materials Science	18	17	13	12	14	19	35	30	65	79	302	928	3.07
Multidisciplinary Sciences	24	22	15	20	23	17	21	22	37	35	236	1026	4.35
Earth and Space Science	11	13	11	15	13	9	18	22	24	11	147	462	3.14
Biomedical Research	7	2	4	4	6	6	8	14	8	11	70	713	10.19
Mathematics	8	5	11	4	3	5	2	5	6	7	56	150	2.68
Computers & Communications	4	3	4	7	5	8		6	7	4	48	117	2.44
Total	**431**	**432**	**402**	**474**	**446**	**428**	**547**	**625**	**866**	**925**	**5576**	**36289**	**6.51**

Table 4. Subject-wise activity index of S&T research in Madhya Pradesh

Year	Activity Index											
	A	B	C	D	E	F	G	H	I	J	K	L
2000	94.9	83.3	170.9	95.4	76.0	55.3	77.1	**131.6**	96.8	129.4	184.8	107.8
2001	90.7	89.8	**174.1**	86.0	73.8	103.5	72.7	120.3	114.1	36.9	115.2	80.7
2002	127.2	92.2	102.2	92.5	68.6	103.8	59.7	88.2	103.8	79.3	**272.5**	115.6
2003	**129.4**	77.0	121.1	91.8	85.5	91.2	46.7	99.7	120.0	67.2	84.0	171.6
2004	91.7	107.8	107.8	92.2	106.3	113.7	58.0	121.8	110.6	107.2	67.0	130.2
2005	110.5	90.6	97.8	94.2	**126.9**	62.7	82.0	93.8	79.8	111.7	116.3	**217.1**
2006	98.1	113.3	103.5	85.3	91.4	109.0	118.1	90.7	124.8	116.5	36.4	0.0
2007	112.5	98.2	67.0	115.2	97.9	93.0	88.6	83.2	**133.5**	**178.4**	79.7	111.5
2008	89.5	105.0	79.7	102.3	110.5	**117.1**	138.6	100.9	105.1	73.6	69.0	93.9
2009	81.5	**117.1**	57.0	**118.9**	125.8	116.0	**157.7**	89.4	45.1	94.7	75.4	50.2

A=Clinical Medicine, B=Chemistry, C=Agriculture, D=Biology, E=Physics, F=Engineering, G=Materials Science, H=Multidisciplinary Science, I=Earth and Space Science, J=Biomedical Research, K=Mathematics and L=Computers & Communications

Table 5. Year-wise distribution of publications, citations and collaboration rate in Clinical Medicine

Year	Clinical Medicine		ACP	Author(s) byline		Collaboration Rate
	TP	TC		Single	Multi	
2000	96	2786	29.02	11	85	0.89
2001	92	2367	25.73	9	83	0.90
2002	120	3715	30.96	10	110	0.92
2003	144	3840	26.67	13	131	0.91
2004	96	1750	18.23	5	91	0.95
2005	111	1365	12.30	17	94	0.85
2006	126	1337	10.61	15	111	0.88
2007	165	930	5.64	23	142	0.86
2008	182	480	2.64	20	162	0.89
2009	177	106	0.60	22	155	0.88
Total	1309	18676	14.27	145	1164	0.89

Table 6. Year-wise distribution of publications, citations and collaboration rate in Chemistry

Year	Chemistry		ACP	Author(s) byline		Collaboration Rate
	TP	TC		Single	Multi	
2000	62	294	4.74	2	60	0.97
2001	67	557	8.31	2	65	0.97
2002	64	503	7.86	1	63	0.98
2003	63	324	5.14	3	60	0.95
2004	83	437	5.27	5	78	0.94
2005	67	314	4.69	2	65	0.97
2006	107	356	3.33	7	100	0.93
2007	106	266	2.51	6	100	0.94
2008	157	220	1.40	4	153	0.97
2009	187	102	0.55	7	180	0.96
Total	963	3373	3.50	39	924	0.96

Table 7. Year-wise distribution of publications, citations and collaboration rate in Agriculture

Year	Agriculture		ACP	Author(s) byline		Collaboration Rate
	TP	TC		Single	Multi	
2000	95	387	4.07	6	89	0.94
2001	97	317	3.27	7	90	0.93
2002	53	248	4.68	3	50	0.94
2003	74	234	3.16	7	67	0.91
2004	62	189	3.05	5	57	0.92
2005	54	144	2.67	5	49	0.91
2006	73	193	2.64	6	67	0.92
2007	54	63	1.17	3	51	0.94
2008	89	55	0.62	3	86	0.97
2009	68	12	0.18	3	65	0.96
Total	719	1842	2.56	48	671	0.93

Table 8. Year-wise distribution of publications, citations and collaboration rate in Biology

Year	Biology		ACP	Author(s) byline		Collaboration Rate
	TP	TC		Single	Multi	
2000	52	860	16.54	3	49	0.94
2001	47	845	17.98	8	39	0.83
2002	47	809	17.21	5	42	0.89
2003	55	697	12.67	8	47	0.85
2004	52	609	11.71		52	1.00
2005	51	549	10.76	2	49	0.96
2006	59	498	8.44	2	57	0.97
2007	91	293	3.22	6	85	0.93
2008	112	163	1.46	7	105	0.94
2009	139	57	0.41	8	131	0.94
Total	705	5380	7.63	49	656	0.93

Table 9. Year-wise distribution of publications, citations and collaboration rate in Physics

Year	Physics		ACP	Author(s) byline		Collaboration Rate
	TP	TC		Single	Multi	
2000	38	159	4.18	3	35	0.92
2001	37	239	6.46	2	35	0.95
2002	32	148	4.63	1	31	0.97
2003	47	256	5.45	4	43	0.91
2004	55	284	5.16	3	52	0.95
2005	63	276	4.38	1	62	0.98
2006	58	261	4.50	6	52	0.90
2007	71	180	2.54	2	69	0.97
2008	111	187	1.68	1	110	0.99
2009	135	60	0.44	7	128	0.95
Total	647	2050	3.17	30	617	0.95

Table 10. Year-wise distribution of publications, citations and collaboration rate in Engineering

Year	Engineering		Avg. Citations/ Publications	Author(s) in by-Line		Collaboration Rate
	TP	TC		Single	Multi	
2000	16	56	3.50	4	12	0.75
2001	30	221	7.37	3	27	0.90
2002	28	359	12.82	6	22	0.79
2003	29	93	3.21	6	23	0.79
2004	34	280	8.24	5	29	0.85
2005	18	73	4.06		18	1.00
2006	40	130	3.25	4	36	0.90
2007	39	192	4.92		39	1.00
2008	68	125	1.84	4	64	0.94
2009	72	43	0.60	1	71	0.99
Total	374	1572	4.20	33	341	0.91

Table 11. Year-wise distribution of publications, citations and collaboration rate in Materials Science

Year	Materials Science		ACP	Author(s) by-Line		Collaboration Rate
	TP	TC		Single	Multi	
2000	18	82	4.56	1	17	0.94
2001	17	124	7.29	1	16	0.94
2002	13	82	6.31	3	10	0.77
2003	12	85	7.08		12	1.00
2004	14	93	6.64		14	1.00
2005	19	88	4.63	3	16	0.84
2006	35	95	2.71	1	34	0.97
2007	30	100	3.33	2	28	0.93
2008	65	156	2.40	2	63	0.97
2009	79	23	0.29		79	1.00
Total	302	928	3.07	13	289	0.96

Table 12. Year-wise distribution of publications, citations and collaboration rate in multidisciplinary science

Year	Multidisciplinary Science		ACP	Author(s) byline		Collaboration Rate
	TP	TC		Single	Multi	
2000	24	265	11.04	2	22	0.92
2001	22	146	6.64		22	1.00
2002	15	90	6.00	4	11	0.73
2003	20	110	5.50	2	18	0.90
2004	23	271	11.78	2	21	0.91
2005	17	52	3.06	4	13	0.76
2006	21	26	1.24	3	18	0.86
2007	22	34	1.55	1	21	0.95
2008	37	29	0.78	4	33	0.89
2009	35	3	0.09	6	29	0.83
Total	236	1026	4.35	28	208	0.88

Table 13. Year-wise distribution of publications, citations and collaboration rate in Earth and Space sciences

Year	Earth and Space Sciences		ACP	Author(s) in byline		Collaboration Rate
	TP	TC		Single	Multi	
2000	11	54	4.91	1	10	0.91
2001	13	60	4.62	3	10	0.77
2002	11	42	3.82	4	7	0.64
2003	15	57	3.80	4	11	0.73
2004	13	94	7.23	3	10	0.77
2005	9	27	3.00	2	7	0.78
2006	18	60	3.33		18	1.00
2007	22	38	1.73	1	21	0.95
2008	24	26	1.08	5	19	0.79
2009	11	4	0.36	3	8	0.73
Total	147	462	3.14	26	121	0.82

Table 14. Year-wise distribution of publications, citations and collaboration rate in Biomedical Research

Year	Biomedical Research		ACP	Author(s) byline		Collaboration Rate
	TP	TC		Single	Multi	
2000	7	118	16.86	1	6	0.86
2001	2	14	7.00		2	1.00
2002	4	136	34.00		4	1.00
2003	4	65	16.25		4	1.00
2004	6	89	14.83	1	5	0.83
2005	6	67	11.17	1	5	0.83
2006	8	101	12.63	1	7	0.88
2007	14	113	8.07		14	1.00
2008	8	10	1.25	1	7	0.88
2009	11	0	0.00	1	10	0.91
Total	70	713	10.19	6	64	0.91

Table 15. Year-wise distribution of publications, citations and collaboration rate in Mathematics

Year	Mathematics		Avg. Citations/ Publications	Author(s) in by-Line		Collaboration Rate
	TP	TC		Single	Multi	
2000	8	21	2.63	1	7	0.88
2001	5	10	2.00	1	4	0.80
2002	11	32	2.91	3	8	0.73
2003	4	49	12.25	1	3	0.75
2004	3	5	1.67	1	2	0.67
2005	5	26	5.20		5	1.00
2006	2	4	2.00		2	1.00
2007	5	1	0.20	1	4	0.80
2008	6	0	0.00	1	5	0.83
2009	7	2	0.29	2	5	0.71
Total	56	150	2.68	11	45	0.80

Table 16: Year-wise distribution of publications, citations and collaboration rate in computers and communications

Year	Computers & Communications		ACP	Author(s) byline		Collaboration Rate
	TP	TC		Single	Multi	
2000	4	13	3.25	1	3	0.75
2001	3	6	2.00		3	1.00
2002	4	16	4.00	1	3	0.75
2003	7	24	3.43	3	4	0.57
2004	5	30	6.00	1	4	0.80
2005	8	8	1.00	2	6	0.75
2006	-	-	-	-	-	-
2007	6	18	3.00		6	1.00
2008	7	2	0.29	1	6	0.86
2009	4	0	0.00		4	1.00
Total	48	117	2.44	9	39	0.81

Table 17. Top 10 academic institutions of MP based on number of publications and citations per publication in all disciplines during 2000-2009

Rank by TP	Rank by ACP	Academic Institution	TP	TC	ACP
1	2	Dr H.S. Gour University, Sagar	508	2699	5.31
2	4	Devi Ahilya University, Indore	374	1711	4.57
3	6	Vikram University, Ujjain	250	704	2.82
4	1	APS University, Rewa	146	801	5.49
5	3	Govt Autonomous Science College, Jabalpur	131	624	4.76
6	7	Rani Durgavati University, Jabalpur	110	250	2.27
7	8	Jiwaji University, Gwalior	94	170	1.81
8	9	Barkatullah University, Bhopal	89	155	1.74
8	10	Jawaharial Nehru Krishi Vishwa Vidyalaya, Jabalpur	89	57	0.64
9	5	MP Bhoj Open University, Bhopal	28	97	3.46

Table 18 gives ranking of research institutions in MP based on number of publications and average number of citations in all disciplines. DAE-UGC Consortium Science Research, Indore ranked Ist in terms of publications (363) and ranked 4th in terms of citations per publication (3.88) followed by Raja Ramanna Centre for Advanced Technology, Indore ranked 2nd with 213 publications and 2nd in terms of citations per publication (4.23), Defence Research & Development Establishment, Gwalior 3rd with 130 publications and 5th in terms of citations per publication (3.77) and Shri Govindram Saksena, Institute of Technology & Science, Indore ranked 4th with 146 publications and 7th in terms of citations per publication (1.73).

4.8 Authorship and Collaboration Pattern

During the 20th century, professionalisation of science had its greatest impact on the members of scientific community and an increasing trend towards collaboration in almost all fields of science and technology. However, the extent of collaboration and their rate of growth varied from one subject to another, from one branch to another branch of the same subject, and from one country to another country. The major impact of collaboration on scholarly research was the increase in productivity associated with multiple authorship[18-20]. On analysing the extent of collaboration in S&T research in MP during 2000-2009, it was found that only 7.84 per cent publications (437) were by single authors and these received 1518 (4.18 per cent) citations. There were 5139 multi-authored (92.16 per cent) publications which received 34771 (95.81 per cent) citations, indicating very large collaborative output from scientists of MP.

Among the multi-authored collaborative papers, the share of three-authored papers was 1285 (23.05 per cent) with 6312 (17.39 per cent) citations followed by two-authored papers were 1144 (20.52 per cent) with 4342 (11.97 per cent) citations; four-authored papers were 955 (17.13 per cent) with 4686 (12.91 per cent)

Table 18. Top 10 Research Institutions of MP based on number of publications and citations per publication in all disciplines during 2000-2009

Rank by TP	Rank by ACP	Research Institutions	TP	TC	ACP
1	4	DAE-UGC Consortium Science Research, Indore	363	1408	3.88
2	2	Raja Ramanna Ctr Adv Technol, Indore	213	901	4.23
3	5	Def Res & Dev Estab, Gwalior	130	490	3.77
4	7	Shri Govindram Sakseria Inst Technol & Sci, Indore	83	144	1.73
5	3	Indian Inst Soil Sci, Bhopal	81	328	4.05
6	9	Padhar Hosp, Padhar	76	91	1.20
7	1	Laxmi Fumigat & Pest Control Pvt Ltd, Indore	59	539	9.14
8	8	SGS Inst Sci & Technol, Indore	53	88	1.66
9	10	Natl Res Ctr Soybean, Indore	38	42	1.11
10	6	Cent Inst Agr Engn, Bhopal	37	126	3.41

citations; and five-authored papers 615 (11.03 per cent) with 4181 (11.52 per cent) citations. It can be visualised from the Tables 19 and 20 that the more intensive collaboration trend was observed as papers with as many as 52 authors were identified. Karki, *et al.*[17], have observed measure the collaborative research pattern with a simple indicator called collaboration rate (number of collaborative papers divided by total number of papers). The highest collaboration rate (0.94) was observed in 2008 and 2009.

4.9 Channels of Communication

It was observed that 83.98 per cent of the literature was published in journals and received Scientists of MP communicated their research results through a variety of communication channels. Table 21 shows the distribution of publications and citations in various channels of communication 86.25 per cent citations followed by 5.76 per cent proceedings papers and received 4.71 per cent citations and 3.50 per cent in review articles and received 7.83 per cent citations.

The total publications from MP in S&T were published in over 1633 journals. *Indian Journal of Animal Sciences* ranked Ist in terms of publications and ranked 103rd in terms of citations per publication, *Indian Journal of Agricultural Sciences* ranked 2nd in terms of publications and ranked 100th in terms of citations per publication; *Indian Veterinary Journal* ranked 3rd in terms of publications and ranked 104th in terms of citations per publication; *Journal of the Indian Chemical Society* ranked 4th in terms of publications and ranked 99 in terms of citations per publication; *Asian Journal of Chemistry* ranked 5th in terms of publications and ranked 93 in terms of citations per publication; and *Cancer Epidemiology Biomarkers and Prevention* ranked 6th in terms of publications and 4th in terms of citations per publication. Table 22 gives the list of top 20 productive journals preferred by the scientists of MP.

Table 19. Trend of publication and citations of S&T research in MP during 2000-2009

Publication year	Single-authored publications			Multi-authored publications			Collaboration rate
	Total no. of publications	Total no. of citations	Avg. Citation/ publications	Total no. of publications	Total no. of citations	ACP	
2000	36	394	10.94	395	4701	11.90	0.92
2001	36	234	6.50	396	4672	11.80	0.92
2002	41	164	4.00	361	6016	16.66	0.90
2003	51	299	5.86	423	5535	13.09	0.89
2004	31	119	3.84	415	4012	9.67	0.93
2005	39	82	2.10	389	2907	7.47	0.91
2006	45	104	2.31	502	2957	5.89	0.92
2007	45	71	1.58	580	2157	3.72	0.93
2008	53	37	0.70	813	1416	1.74	0.94
2009	60	14	0.23	865	398	0.46	0.94
Total	437	1518	3.47	5139	34771	6.77	0.92

Table 20. Author-wise publications productivity and citations of S&T research in Madhya Pradesh during 2000-2009

Author(s) byline	Total no. of publications	% of total publications	Total no. of citations	% of Total citations	ACP
1	437	7.84	1518	4.18	3.47
2	1144	20.52	4342	11.97	3.80
3	1285	23.05	6312	17.39	4.91
4	955	17.13	4686	12.91	4.91
5	615	11.03	4181	11.52	6.80
6	365	6.55	3261	8.99	8.93
7	221	3.96	2465	6.79	11.15
8	141	2.53	1592	4.39	11.29
9	72	1.29	1153	3.18	16.01
10	61	1.09	1171	3.23	19.20
11	44	0.79	586	1.61	13.32
12	27	0.48	992	2.73	36.74
13	14	0.25	152	0.42	10.86
14	8	0.14	150	0.41	18.75
15	14	0.25	194	0.53	13.86
16	10	0.18	229	0.63	22.90
17	7	0.13	108	0.30	15.43
18	8	0.14	163	0.45	20.38
19	4	0.07	118	0.33	29.50
20	4	0.07	46	0.13	11.50
21-30	23	0.41	597	1.65	25.96
31-40	55	0.99	901	2.48	16.38
41-50	56	1.00	1347	3.71	24.05
51-52	6	0.11	25	0.07	4.17
Total	**5576**	**100**	**36289**	**100**	**6.51**

Table 21. Publication output by document type

Publication type	TP	% of TP	TC	% of TC	ACP
Journal articles	4683	83.98	31298	86.25	6.68
Proceedings papers	321	5.76	1708	4.71	5.32
Reviews	195	3.50	2841	7.83	14.57
Letters	139	2.49	220	0.61	1.58
Meeting abstracts	120	2.15	4	0.01	0.03
Editorial materials	103	1.85	218	0.60	2.12
Corrections	8	0.14	0	0.00	0.00
News Items	5	0.09	0	0.00	0.00
Biographical item	1	0.02	0	0.00	0.00
Book review	1	0.02	0	0.00	0.00
Total	**5576**	**100**	**36289**	**100**	**6.51**

Table 22. Major journals preferred by scientists of MP for publications

Source	TP	Rank by TP	TC	ACP	Rank by ACP
Indian Journal of Animal Sciences	99	1	35	0.35	103
Indian Journal of Agricultural Sciences	98	2	64	0.65	100
Indian Veterinary Journal	95	3	29	0.31	104
Journal of the Indian Chemical Society	82	4	57	0.70	99
Asian Journal of Chemistry	69	5	63	0.91	93
Cancer Epidemiology Biomarkers & Prevention	65	6	2399	36.91	4
Oxidation Communications	60	7	60	1.00	90
Indian Journal of Chemistry-A	49	8	133	2.71	61
Indian Journal of Pure & Applied Physics	48	9	38	0.79	95
Physical Review-B	45	10	439	9.76	22
Journal of Applied Physics	44	11	139	3.16	59
International Journal of Cancer	40	12	849	21.23	7
Indian Journal of Agronomy	39	13	39	1.00	90
Journal of Physics-Condensed Matter	38	14	138	3.63	56
Journal of Applied Polymer Science	35	15	223	6.37	35
Indian Pediatrics	35	15	26	0.74	96
Indian Journal of Physics	34	16	14	0.41	102
Physics and Chemistry of the Earth	33	17	146	4.42	44
Current Science	31	18	118	3.81	54
Journal of Physics-D	28	19	55	1.96	74

4.10 Impact factor-wise distribution of publications and citations

Table 23 gives impact factor-wise distribution of publications and citations. While 89.04 per cent (4965) of the total publications were published in the journals with impact factors (IF) ranging from 0.001 to 52.589 and received 97.02 per cent (35273) citations, 3.60 per cent published in journals which were not covered by the *Journal Citations Report*-2008 and received 2.80 per cent (1016) citations. A significantly large number of publications, 35.81 per cent (1997), appeared in journals having IF from 0.01 to <1.00 followed by 23.37 (1303) per cent publications appeared in journal having IF from 1.00 to <2.00, 12.84 (716) per cent of publications appeared in journals having IF from 2.00 to <3.00. The

Table 23. Distribution of publications and citations as per IF during 2000-2009

Impact factor (*JCR* 2008)	Total no. of journals	Total no. of publications	% of publications	Total no. of citations	% of citations
0.01 to < 1.00	462	1997	35.81	3767	10.38
1.00 to < 2.00	429	1303	23.37	6674	18.39
2.00 to < 3.00	250	716	12.84	5803	15.99
3.00 to < 4.00	114	359	6.44	4113	11.33
4.00 to < 5.00	71	263	4.72	5503	15.16
5.00 to < 6.00	33	131	2.35	2923	8.05
6.00 to <59.00	73	196	3.52	6490	17.88
NA	201	611	10.96	1016	2.80
Total	**1633**	**5576**	**100**	**36289**	**100**

highest number of citations received 18.39 per cent (6674) in journals having IF from 1.00 to <2.00 followed by 17.88 per cent (6490) in journals having IF from 6.00 to <59.00, and 15.99 per cent (5803) in journals having IF from 2.00 to <3.00.

5. CONCLUSION

Institutions located in MP published 5576 publications during 2000-2009. These publications received a total of 36289 citations during the period. The average number of citations per paper was 6.51. The highest number of publications, 925, were published in 2009. There were 3715 international collaborative papers by the scientists from MP with 86 countries. The USA ranked Ist with 617 collaborative publications and 14571 citations, England ranked 2nd with 358 collaborative publications and 5512 citations, and Germany ranked 3rd with 260 collaborative publications and 4284 citations. There were 1552 (27.83 per cent) collaborative papers by the scientists from MP with 28 other Indian states. Chhattisgarh ranked Ist with 561 collaborative publications and 1370 citations, Uttar Pradesh ranked the 2nd with 290 collaborative publications and 944 citations and Delhi ranked 3rd with 250 collaborative publications and 685 citations.

The highest number of publications 1309 (23.48 per cent) were published in Clinical Medicine followed by Chemistry with 963 (17.27 per cent), Agriculture with 719 (12.89 per cent), Biology with 705 (12.64 per cent), Physics with 647 (11.60 per cent), Engineering with 374 (6.71 per cent) and Materials Science with 302 (5.42 per cent). The highest number of citations 18676 (51.46 per cent) were received in Clinical Medicine followed by Chemistry with 3373 (9.29 per cent) citations, Agriculture with 1842 (5.08 per cent), Biology with 5380 (14.83 per cent), Physics with 2050 (5.65 per cent), Engineering with 1572 (4.33 per cent) citations and Materials Science with 928 (2.56 per cent) citations.

The highest AI in various subject categories were: Clinical Medicine (129.41) in 2003, Chemistry (117.06) in 2009, Agriculture (174.13) in 2001, Biology (118.85) in 2009, Physics (126.86) in 2005, Engineering (117.07) in 2008, Materials Science (157.69) in 2009, Multidisciplinary Science (131.57) in 2000, Earth and Space Science (133.52) in 2007, Biomedical Research (178.43) in 2007, Mathematics (272.46) in 2002, and Computers and Communications (217.13) in 2005.

Among academic institutions, Dr H.S. Gour University, Sagar ranked Ist with 508 publications and ranked 2nd in terms of citations per publication (5.31) followed by Devi Ahilya University, Indore which ranked 2nd with 374 publications and 4th rank in terms of citations per publication (4.57), Vikram University, Uijain ranked 3rd with 250 publications and ranked 6th in terms of citations per publication (2.82) and APS University, Rewa ranked 4th with 146 publications and ranked 1st in terms of citations per publication (5.49) in ranking of academic institutions.

Among research institutions, DAE-UGC Consortium Science Resesrch, Indore ranked Ist with 363 publications and ranked 4th in terms of citations per publication (3.88) followed by Raja Ramanna Centre for Advanced Technology, Indore ranked 2nd with 213 publications and 2nd rank in terms of citations per publication (4.23), Defence Research and Development Establishment, Gwalior 3rd with 130 publications and ranked 5th in terms of citations per publication (3.77) and Shri Govindram Sakseria Institute of Technology and Science, Indore 4th with 146 publications and ranked 7th in terms of citations per publication (1.73) in ranking of research institutions.

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