

Research Publications Growth Rate of Chemistry and Related Subject Areas in Pakistan and Fifty Countries from 2001 to 2020

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Summary: The study was designed to provide a comprehensive view of the chemistry research publications growth (%) of fifty (50) countries after 2000/01. Scopus; the world's largest abstract and citation database as well as Scifinder; the subject specific database for chemistry were primarily used for the purpose. According to the Scopus database, from 2001 to March, 2020 total 10,013,057 chemistry documents (majorly research articles, reviews and conference papers) were published. From 2001-2020, The United States secured the top position (2403235/ 24.00%) followed by China, (1929345/ 19.26%), Germany (727246/7.27), Japan (708947/7.08%) and UK (589025/ 5.88%). The highest growth rate was recorded for the year 2005 (9.17%), followed by 2011 (8.08%) and 2004 (7.52%). Furthermore, we also calculated the % growth rate of fifty (50) countries. As per growth rate calculations, the top three slots in the last nineteen (19) years are majorly occupied by Iran (11) Pakistan (10), China (7) Malaysia (6) and Egypt (5). Emerging economies like Brazil, Mexico, Serbia, Turkey, South Africa, Romania, Mexico, Slovenia, Slovakia and Bulgaria etc... also showed significant progress in research output. For the 1st time Pakistan has topped the relative growth rate in chemistry publications for three consecutive years (for 2017-19). The growth rate for 2017-19 was found to be 18.51, 14.17 and 17.57 %, respectively. In fact, Pakistan topped the ranking in 2006 and 2013 as well. To further extend the idea, we retrieved the per year chemistry publications data of Pakistan from 1947 to 2000. Data from World Bank, Pakistan Ministry of Finance, Pakistan Education Statistics, Pakistan Research Repository, Higher Education Commission (HEC) and Pakistan Federal Ministry of Education was also acquired to possibly explain the increase in chemistry research growth rate in Pakistan. However, although the publication growth rate of Pakistan significantly improved from 2002 onwards, it still has a meager global share of 0.5 % (approximately) and highlights that concrete policy measures must be taken to improve the publication output.

Key Words: Scopus; Chemistry Research Publications; Growth Rate, 50 Countries and Pakistan, Scifinder.

Introduction

In the contemporary world, a country's economic and social development is proportionate to the size of research, development and innovation in science and technology. The growth and progress of scientific research in a country is thus an important indicator of the country's overall progress over the years. With the phenomenal increase in global investment in research and development it is important to track and monitor the research progress of a country. Also, in an era where research is becoming more internationally collaborative and researchers are working across boundaries, a comparison of a country's research performance with its peer countries is of great significance. While such a comparison holds importance for all nations, however it is more necessary for developing countries which generally suffer from the problem of resource constrained research [1].

While there may be a number of ways to track research performance and progress of a country, bibliometric analysis is one way to track such progress and make useful comparisons. Bibliometric studies are quantitative studies to measure the research progress. Bibliometric data can be found and assessed for a broad spectrum of disciplines using appropriate databases: for example, Web of Science (WoS) or Scopus. The productivity and impact of large research units can be measured with reasonable effort. With the help of quantitative analysis and statistics, the patterns of publications within a given field can be properly tracked [2, 3]. In fact, the total number of papers and their citations, can provide detail information about the quality and quantity of research in a specific field. It also provides detail information about the growth pattern, progress and spread of any particular discipline, centers of excellence, most potential authors, international collaborations or countries involved etc.. The micro-

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applications of bibliographic studies include, but are not limited to, identifying the core literature in specific areas and exhibiting academic journals or sources progress [4]. While the macro-applications may improve the process efficiency, predicting trends in a specific area development and policy making and/or implementation for future [4, 5].

There is considerable literature, where the authors applied bibliometrics approach to track and understand various themes, areas and trends in different regions and especially various countries. In fact detail studies are reported which focused on international scientific migration [6], international competitiveness [7], household energy consumption [8], long-noncoding (Lnc) RNA research [9] and global health research and policy [10] to name a few avenues.

In another study Bornmann et al., reported the growth rates of the BRICS countries (Brazil, Russia, India, China, and South Africa). They compared them with top-performing countries worldwide [11]. In fact, Kumar and Asheulova (2011) and Adams et al. (2013) confirmed a rapid rise in the scientific output of the BRICS countries [12, 13].

Pakistan is a developing country and over the past 20 years many steps have been taken by the public and private sectors to promote research in scientific and technological fields. Evaluation and assessment of the research progress over the last two decades is the need of the hour. The present scientometric study is designed to explore the research output of Pakistan in Chemistry and related subject areas in comparison with other fifty (5) developing or developed countries of the 21st century. Scopus, the largest database of scientific literature was primarily employed for the purpose. Scifinder, which is considered a subject specific database for chemistry was also used for data retrieval and analysis. The project may help to highlight the research progress. Infact it may further help the researchers, scientists as well as policy makers.

Experimental

Data retrieval from Scopus

Scopus launched in 2004 is Elsevier's abstract and citation database. It covers nearly 36,377 titles from approximately 11,678 publishers, of which 34,346 are peer reviewed journals in top-level subject fields of social sciences,

life sciences, health sciences and physical sciences. In Scopus advance search options, the word "Chemistry" was used in March, 2020. Precisely, from subject area Chemistry was selected. The years range selected is 2001-2020. Below details of the search are exactly copied from Scopus.

Code: SUBJAREA (CHEM)

Name: Subject area search for "Chemistry"

Description: A search field which returns documents related to "Chemistry".

The following subjects are classified under the subject code:

1. Chemistry (all),
2. Chemistry (miscellaneous)
3. Analytical chemistry
4. Electrochemistry
5. Inorganic chemistry
6. Organic chemistry
7. Physical and theoretical chemistry
8. Spectroscopy

Data retrieval from Scifinder

In an attempt to quantify the research contribution in chemistry and other related subject areas from different universities and institutes across Pakistan, we sought the help from SciFinder which is by date considered the most comprehensive database for chemical literature. It is the core research tool for chemistry as well as related domains including biochemistry, chemical engineering, material science, nanotechnology, physics, environmental science and engineering disciplines. Two main Scifinder databases are CAPLUS and Medline, of which CAPLUS covers international journals, patents, patent families, technical reports, books, conference proceedings, and dissertations from all areas of chemistry, biochemistry, chemical engineering, and related sciences from 1907 to the present. The list of Pakistani universities was taken from Higher Education Commission (HEC) website and data for their respective publications indexed on Scifinder was retrieved using company name search option on SciFinder. The search was later refined by using Refine Search option, entering the publication years as 2001-2020. Also the data from CALPUS and MEDLINE was separately retrieved and analysed

Results and Discussion

The numbers of per year chemistry research publications retrieved from Scopus are shown in Fig. 1. As apparent from the data there is gradual and consistent increase in number of publications.

However, an irregular growth rate (%) was observed from the years 2001-2020 as shown in Fig. 2. The number of different types of documents (article, reviews and conference papers etc... are depicted in

Fig. 3. Collectively, based on the number of publications, the top ten (10) countries are shown in Fig. 4.

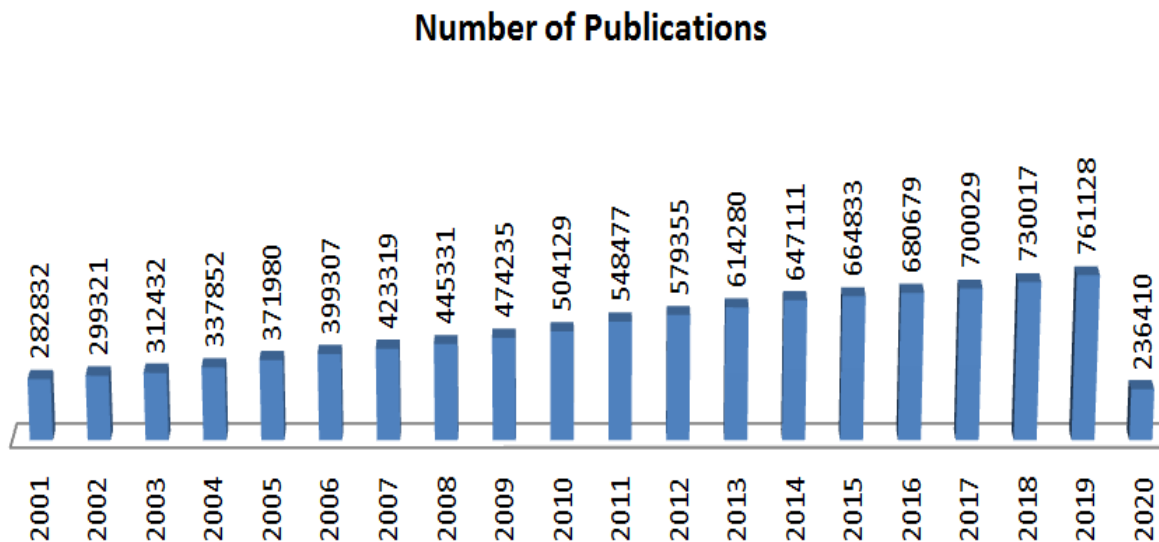


Fig. 1 Year-wise number of publications in 50 countries.

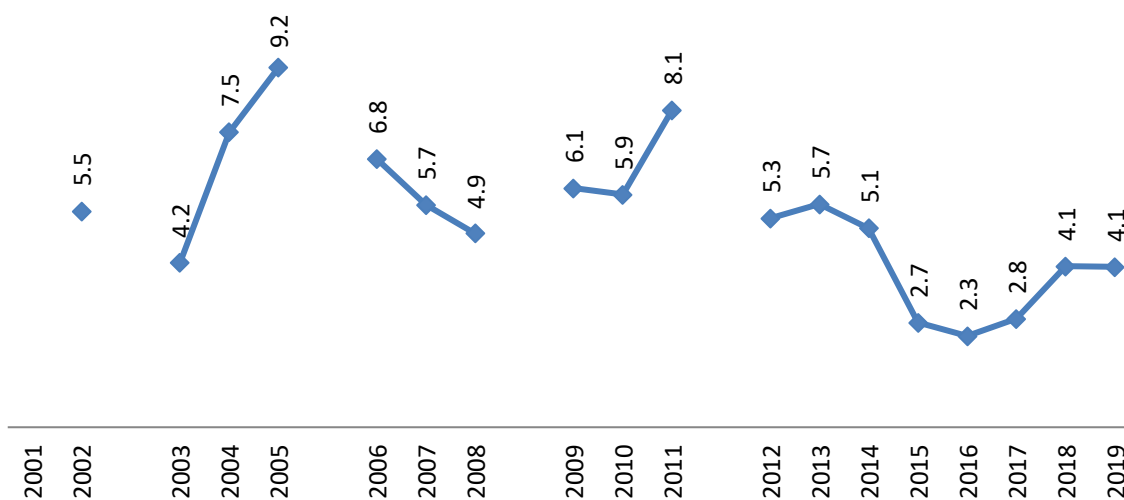


Fig. 2: Chemistry publications growth rate in 50 countries.

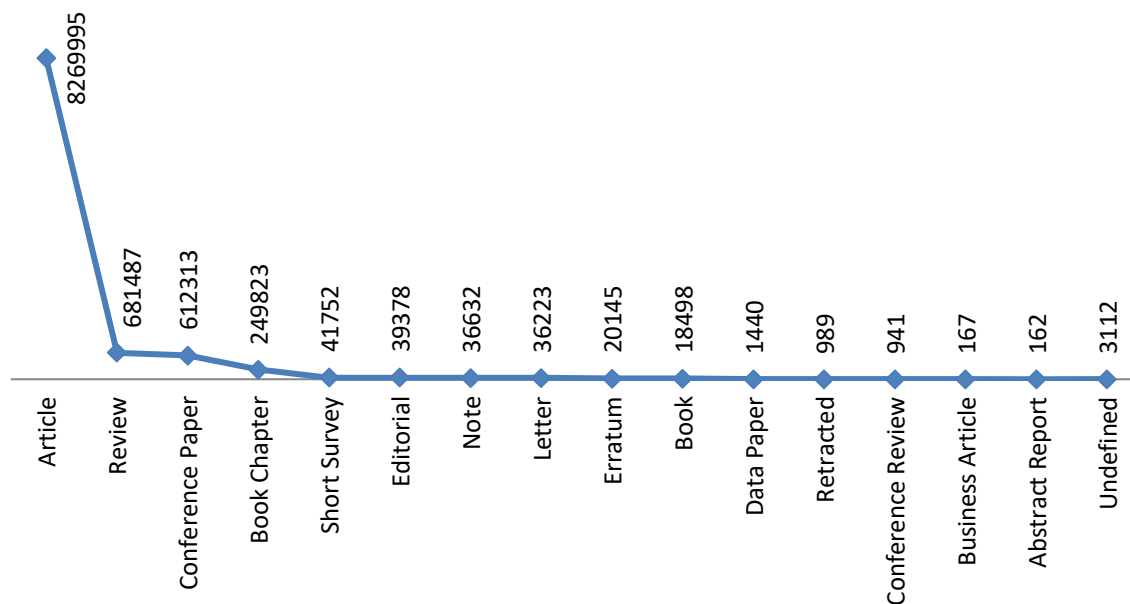


Fig. 3 Types of Chemistry publications documents in 50 countries.

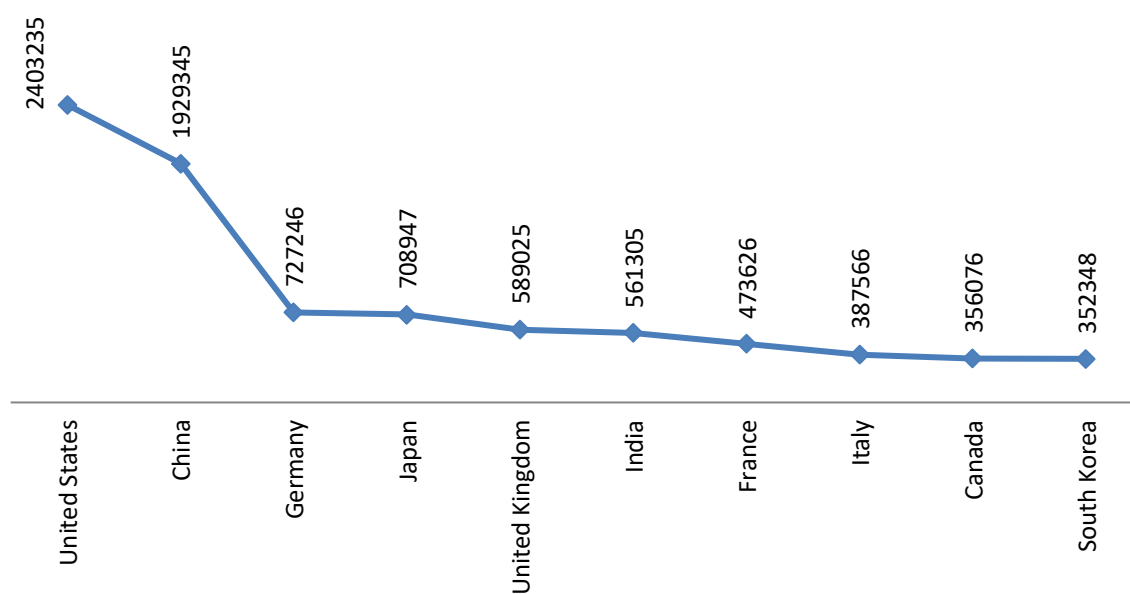


Fig. 4: List of top ten countries in chemistry publications (number of documents).

The Top three Countries, BASED on the Number of Publications

On the basis of number of publications, the list of top three countries is provided in table 1. We

also provided the year-wise publications growth rates of the top three countries in table 2. While, their collective details are provided in tables 3-9.

Table 1: List of top three countries on the basis of total number of publications (NOP).

S#	2001	NOP	2002	NOP	2003	NOP	2004	NOP	2006	NOP
1.	USA	85618	USA	96247	USA	96247	USA	103168	USA	109857
2.	Japan	32141	Japan	34400	Japan	34400	Japan	35328	Japan	37122
3.	Germany	24262	Germany	26784	Germany	26784	Germany	28482	China	37054
S#	2006	NOP	2007	NOP	2008	NOP	2009	NOP	2010	NOP
1.	USA	114462	USA	116030	USA	118912	USA	122456	USA	128850
2.	China	45686	China	53589	China	61367	China	73183	China	80441
3.	Japan	38546	Japan	36300	Japan	36452	Japan	37140	Germany	38118
S#	2011	NOP	2012	NOP	2013	NOP	2014	NOP	2015	NOP
1.	USA	133915	USA	138941	USA	142924	China	145307	China	155165
2.	China	97374	China	109631	China	126274	USA	142869	USA	144550
3.	Germany	39588	Germany	41930	Germany	43057	Germany	44145	Germany	45891
S#	2016	NOP	2017	NOP	2018	NOP	2019	NOP		
1.	China	165737	China	180982	China	202531	China	231328		
2.	USA	143450	USA	144964	USA	144405	USA	139174		
3.	Germany	45894	Germany	46834	India	49007	India	50588		

Table 2: List of top three countries on the basis of % growth or relative growth rate (RGR).

S#	2001	RGR	2002	RGR	2003	RGR	2004	RGR	2005	RGR
1.	Iran	29.49	Thailand	31.27	Iran	38.72	Serbia	68.23	China	35.95
2.	Turkey	28.55	Turkey	30.47	Malaysia	32.35	China	28.44	Iran	32.28
3.	China	21.60	Iran	29.46	China	22.01	Iran	26.40	Pakistan	29.72
S#	2006	RGR	2007	RGR	2008	RGR	2009	RGR	2010	RGR
1.	Pakistan	37.03	Serbia	36.18	Malaysia	35.75	Malaysia	62.61	Malaysia	46.19
2.	Thailand	34.70	Iran	32.82	Romania	23.85	Serbia	27.08	Iran	23.52
3.	Iran	30.26	Pakistan	24.47	Iran	23.47	Egypt	26.06	Pakistan	21.70
S#	2011	RGR	2012	RGR	2013	RGR	2014	RGR	2015	RGR
1.	Malaysia	35.45	Serbia	38.60	Pakistan	21.42	Malaysia	20.02	Russian Fed.	15.07
2.	Iran	29.51	Chile	22.11	China	15.18	China	15.07	Pakistan	14.38
3.	Pakistan	23.86	South Africa	15.67	Egypt	12.93	India	12.63	Egypt	12.64
S#	2016	RGR	2017	RGR	2018	RGR	2019	RGR		
1.	Chile	17.94	Pakistan	17.57	Pakistan	14.17	Pakistan	18.51		
2.	Iran	16.56	Mexico	12.38	Slovakia	12.76	Egypt	16.85		
3.	Russian Fed.	14.88	Brazil	9.68	Egypt	12.56	China	14.22		

Table-3; The year 2001/2002 and 2003 details of the number of publications and (%) growth of 50 countries.

2001			2002			2003		
Name of Country	Number of Publications	Growth (%)	Name of Country	Number of Publications	Growth (%)	Name of Country	Number of Publications	Growth (%)
Iran	808	29.49	Thailand	680	31.27	Iran	1451	38.72
Turkey	2107	28.55	Turkey	2749	30.47	Malaysia	540	32.35
China	15385	21.60	Iran	1046	29.46	China	21220	22.01
Taiwan	3624	19.13	Serbia	294	26.72	Hong Kong	1824	19.61
Portugal	1491	19.09	Pakistan	375	20.97	Croatia	592	18.64
South Korea	6135	17.66	Chile	743	18.88	Thailand	802	17.94
Singapore	1081	15.99	Brazil	4617	17.72	Turkey	3218	17.06
Thailand	518	15.88	Ireland	1023	17.32	Mexico	2139	16.89
Hong Kong	1485	15.30	Argentina	1930	16.62	Slovenia	730	16.61
Greece	1814	14.23	Croatia	499	14.45	Singapore	1417	15.67
Ukraine	1693	12.27	Singapore	1225	13.32	South Korea	7966	14.75
Mexico	1685	11.89	Egypt	1481	13.23	Pak	428	14.13
India	8733	11.35	South Korea	6942	13.15	Chile	845	13.73
Romania	930	10.71	China	17392	13.05	India	11129	13.28
Brazil	3922	10.08	India	9824	12.49	Taiwan	4359	12.87
Czech Republic	1984	8.30	Greece	2033	12.07	Switzerland	5854	12.06
South Africa	904	7.75	Slovenia	626	11.99	Ireland	1146	12.02
Austria	2592	7.28	Poland	5586	11.32	Egypt	1657	11.88
Pakistan	310	6.53	Bulgaria	776	10.86	New Zealand	1285	11.45
Spain	9082	6.42	Romania	1027	10.43	Denmark	3124	10.98
Poland	5018	6.38	Spain	10004	10.15	Austria	2937	10.91
Ireland	872	5.95	South Africa	995	10.07	Italy	13019	10.02
Italy	11011	5.42	Canada	11585	8.92	Hungary	2142	9.90
Sweden	5662	5.22	Mexico	1830	8.61	Canada	12719	9.79
Hungary	1957	4.71	Portugal	1614	8.25	Poland	6100	9.20
Malaysia	386	4.32	Israel	3184	8.23	Norway	1693	9.01
Egypt	1308	3.65	Czech Republic	2143	8.01	Belgium	4188	8.98
Israel	2942	3.23	Belgium	3843	7.92	Portugal	1742	7.93
Australia	5936	3.22	The United States	92072	7.54	Australia	6841	7.70
Russian Federation	10397	2.73	Italy	11833	7.47	Brazil	4969	7.62
Germany	24262	2.41	Australia	6352	7.01	Slovakia	837	7.58
Japan	32141	2.13	Taiwan	3862	6.57	Sweden	6163	7.43
The United	85618	1.78	Netherlands	6515	5.85	Czech	2280	6.39

States						Republic		
Switzerland	5065	0.94	Malaysia	408	5.70	Netherlands	6908	6.03
Finland	2624	0.88	Germany	25604	5.53	France	18767	5.93
			United					
Belgium	3561	0.88	Kingdom	21619	5.44	Finland	2879	5.85
						United		
France	17249	0.81	Slovakia	778	4.01	Kingdom	22731	5.14
Netherlands	6155	0.70	Japan	33412	3.95	Germany	26784	4.61
Canada	10636	0.56	Finland	2720	3.66	Spain	10462	4.58
						The United		
Denmark	2878	0.52	Switzerland	5224	3.14	States	96247	4.53
Argentina	1655	0.00	France	17716	2.71	South Africa	1037	4.22
						Russian		
Chile	625	0.00	Hong Kong	1525	2.69	Federation	10670	3.56
Croatia	436	0.00	Norway	1553	2.37	Bulgaria	803	3.48
Norway	1517	-0.07	New Zealand	1153	2.31	Japan	34400	2.96
United								
Kingdom	20504	-0.64	Austria	2648	2.16	Israel	3245	1.92
New Zealand	1127	-2.93	Sweden	5737	1.32	Argentina	1963	1.71
Serbia	232	-6.83	Ukraine	1696	0.18	Romania	1044	1.66
Bulgaria	700	-7.65	Hungary	1949	-0.41	Greece	2063	1.48
			Russian					
Slovenia	559	-8.81	Federation	10303	-0.90	Ukraine	1699	0.18
Slovakia	748	-15.86	Denmark	2815	-2.19	Serbia	277	-5.78

Table-4: The year 2004/2005 and 2006 details of the number of publications and (%) growth of 50 countries.

2004			2005			2006		
Name of Country	Number of Publications	Growth (%)	Name of Country	Number of Publications	Growth (%)	Name of Country	Number of Publications	
Serbia	466	68.23	China	37054	35.94805	Pak	903	37.03
China	27256	28.44	Iran	2426	32.27917	Thailand	1572	34.70
Iran	1834	26.40	Pak	659	29.72441	Iran	3160	30.26
Malaysia	681	26.11	Thailand	1167	22.58403	China	45686	23.30
Singapore	1782	25.76	Slovenia	837	21.65698	Brazil	7581	21.92
Turkey	4035	25.39	Serbia	565	21.24464	Malaysia	959	21.55
South Africa	1275	22.95	Singapore	2112	18.51852	Greece	3164	20.35
Portugal	2135	22.56	Taiwan	5674	17.0621	Portugal	2720	18.83
Romania	1269	21.55	Malaysia	789	15.85903	India	16043	15.74
			Czech					
Thailand	952	18.70	Republic	2931	15.8498	Slovakia	1097	15.60
Pak	508	18.69	Ireland	1510	15.26718	Norway	2546	15.36
Norway	1999	18.07	India	13861	14.55372	South Korea	11583	14.75
South Korea	9187	15.33	Greece	2629	14.50348	Singapore	2422	14.68
Ireland	1310	14.31	Hong Kong	2258	12.56231	Turkey	4910	14.21
			New					
Brazil	5626	13.22	Zealand	1571	11.89459	South Africa	1520	12.18
Mexico	2421	13.18	Chile	966	11.6763	Egypt	1916	12.05
Croatia	668	12.84	Mexico	2690	11.11111	Serbia	633	12.04
						Czech		
Bulgaria	906	12.83	Germany	31595	10.92971	Republic	3278	11.84
Slovakia	933	11.47	Brazil	6218	10.52257	Taiwan	6330	11.56
Greece	2296	11.29	Norway	2207	10.4052	Spain	13789	11.22
Taiwan	4847	11.20	Croatia	737	10.32934	Slovenia	922	10.16
Czech								
Republic	2530	10.96	Canada	14952	10.29802	Hong Kong	2482	9.92
Spain	11532	10.23	Ukraine	2015	10.10929	Argentina	2340	9.19
Hong Kong	2006	9.98	South Korea	10094	9.872646	Australia	8883	8.71
Austria	3222	9.70	Australia	8171	9.252574	Switzerland	7253	7.84
Switzerland	6411	9.51	Belgium	4842	8.152781	Canada	16119	7.80
Australia	7479	9.33	Israel	3524	7.767584	Ireland	1616	7.02
New								
Zealand	1404	9.26	Hungary	2443	7.763564	Finland	3316	6.52
India	12100	8.72	Argentina	2143	7.688442	Bulgaria	1021	6.35
Poland	6607	8.31	Spain	12398	7.509539	Italy	15695	6.23
Italy	14061	8.00	Poland	7097	7.416377	Croatia	782	6.11
						United		
Ukraine	1830	7.71	Romania	1363	7.407407	Kingdom	26483	6.10
Netherlands	7414	7.32	Denmark	3507	7.313341	Romania	1443	5.87
The United								
States	103168	7.19	Portugal	2289	7.213115	Netherlands	8326	5.86
Belgium	4477	6.90	Austria	3451	7.107387	Israel	3718	5.51
Canada	13556	6.58	Turkey	4299	6.542751	Poland	7447	4.93
			The United					
Sweden	6566	6.54	States	109857	6.4836	Sweden	7100	4.77
Germany	28482	6.34	France	20640	6.380785	France	21567	4.49
Hungary	2267	5.84	South Africa	1355	6.27451	Denmark	3664	4.48
United								
Kingdom	24057	5.83	Netherlands	7865	6.083086	Chile	1007	4.24
Finland	3020	4.90	Bulgaria	960	5.960265	The United	114462	4.19

Denmark	3268	4.61	Egypt	1710	5.490438	States Belgium	5038	4.05
France	19402	3.38	Russian Federation	11365	5.104966	Japan New Zealand	38546	3.84
Japan	35328	2.70	Japan	37122	5.078125	Mexico	1628	3.63
Chile	865	2.37	Italy	14774	5.070763	Mexico	2744	2.01
Argentina	1990	1.38	Switzerland	6726	4.91343	Germany	32087	1.56
Russian Federation	10813	1.34	United Kingdom	24960	3.753585	Austria	3400	-1.48
Israel	3270	0.77	Sweden	6777	3.213524	Hungary	2374	-2.82
Egypt	1621	-2.17	Finland	3113	3.07947	Russian Federation	10778	-5.16
Slovenia	688	-5.75	Slovakia	949	1.714898	Ukraine	1886	-6.40

Table-5: The year 2007/2008 and 2009 details of the number of publications and (%) growth of 50 countries.

2007			2008			2009		
Name of Country	Number of Publications	Growth (%)	Name of Country	Number of Publications	Growth (%)	Name of Country	Number of Publications	Growth (%)
Serbia	862	36.18	Malaysia	1519	35.75	Malaysia	2470	62.61
Iran	4197	32.82	Romania	2145	23.85	Serbia	1314	27.08
Pak	1124	24.47	Iran	5182	23.47	Egypt	2999	26.06
Ireland	1966	21.66	Serbia	1034	19.95	Pak	1636	22.09
Thailand	1887	20.04	Thailand	2262	19.87	Romania	2588	20.65
Romania	1732	20.03	Pak	1340	19.22	Iran	6203	19.70
China	53589	17.30	Portugal	3445	16.82	China	73183	19.25
Malaysia	1119	16.68	China	61367	14.51	Ireland	2416	18.90
Bulgaria	1181	15.67	Singapore	2958	14.39	Chile	1388	15.38
Mexico	3127	13.96	South Korea	14990	14.12	South Africa	2039	15.33
Slovenia	1049	13.77	Slovenia	1191	13.54	India	22996	15.19
India	18202	13.46	Brazil	8974	12.55	Singapore	3390	14.60
South Korea	13135	13.40	Taiwan	7545	11.81	Argentina	2914	12.90
Turkey	5553	13.10	Slovakia	1272	10.23	Turkey	6432	12.59
Egypt	2160	12.73	Egypt	2379	10.14	Norway	2916	12.02
New Zealand	1807	11.00	India	19963	9.67	Croatia	1017	11.39
Austria	3755	10.44	Chile	1203	8.48	Australia	11395	11.38
Chile	1109	10.13	Czech Republic	3836	8.36	Bulgaria	1271	11.30
Croatia	857	9.59	Argentina	2581	8.31	Taiwan	8369	10.92
Italy	17116	9.05	Mexico	3350	7.13	Brazil	9840	9.65
South Africa	1656	8.95	South Africa	1768	6.76	South Korea	16417	9.52
Portugal	2949	8.42	Croatia	913	6.53	Netherlands	9469	9.32
Belgium	5459	8.36	Austria	3999	6.50	Mexico	3645	8.81
Australia	9608	8.16	Australia	10231	6.48	Spain	16588	7.91
Denmark	3957	8.00	New Zealand	1904	5.37	Austria	4315	7.90
Czech Republic	3540	7.99	Greece	3518	4.89	Switzerland	8423	7.40
Spain	14862	7.78	Russian Federation	11796	4.59	Czech Republic	4114	7.25
Singapore	2586	6.77	Hungary	2584	4.57	Italy	19080	7.03
Ukraine	2012	6.68	Poland	8026	4.46	Portugal	3685	6.97
Taiwan	6748	6.60	Belgium	5694	4.30	Thailand	2408	6.45
Greece	3354	6.01	Italy	17826	4.15	France	24289	6.42
Switzerland	7654	5.53	Germany	34972	3.55	Belgium	6038	6.04
Finland	3496	5.43	Hong Kong	2642	3.53	Canada	18102	5.21
Germany	33772	5.25	Spain	15372	3.43	Greece	3698	5.12
Slovakia	1154	5.20	Denmark	4090	3.36	Finland	3704	4.87
Brazil	7973	5.17	Ireland	2032	3.36	Denmark	4284	4.74
United Kingdom	27819	5.04	Turkey	5713	2.88	Germany	36588	4.62
Russian Federation	11278	4.64	United Kingdom	28608	2.84	Sweden	7653	4.46
Canada	16779	4.09	Canada	17206	2.54	Poland	8356	4.11
Hungary	2471	4.09	The United States	118912	2.48	Russian Federation	12269	4.01
France	22288	3.34	Switzerland	7843	2.47	Hong Kong	2742	3.79
Poland	7683	3.17	France	22824	2.40	Slovenia	1229	3.19
Hong Kong	2552	2.82	Israel	3867	2.09	The United States	122456	2.98
Netherlands	8528	2.43	Netherlands	8662	1.57	United Kingdom	29377	2.69
Norway	2600	2.12	Sweden	7326	1.10	Japan	37140	1.89
Sweden	7246	2.06	Finland	3532	1.03	New Zealand	1936	1.68
Israel	3788	1.88	Japan	36452	0.42	Ukraine	2025	0.30
Argentina	2383	1.84	Ukraine	2019	0.35	Slovakia	1261	-0.86
The United States	116030	1.37	Norway	2603	0.12	Israel	3770	-2.51
Japan	36300	-5.83	Bulgaria	1142	-3.30	Hungary	2464	-4.64

Table 6; The year 2010/2011 and 2012 details of the number of publications and (%) growth of 50 countries.

2010			2011			2012		
Name of Country	Number of Publications	Growth (%)	Name of Country	Number of Publications	Growth (%)	Name of Country	Number of Publications	Growth (%)
Malaysia	3611	46.19	Malaysia	4891	35.45	Serbia	2176	38.60
Iran	7662	23.52	Iran	9923	29.51	Chile	1900	22.11
Pak	1991	21.70	Pak	2466	23.86	South Africa	3196	15.67
Thailand	2835	17.73	India	33223	23.74	Malaysia	5647	15.46
Singapore	3988	17.64	Egypt	4201	23.41	Egypt	4850	15.45
India	26848	16.75	China	97374	21.05	Portugal	5327	14.91
Ireland	2802	15.98	South Africa	2763	18.58	Brazil	13351	14.07
South Africa	2330	14.27	Croatia	1256	17.82	Norway	3780	12.87
Egypt	3404	13.50	Slovenia	1473	16.26	Slovenia	1660	12.70
Portugal	4154	12.73	Serbia	1570	12.79	China	109631	12.59
New Zealand	2177	12.45	Thailand	3193	12.63	Slovakia	1525	11.80
Romania	2906	12.29	Hong Kong	3265	12.55	Iran	11046	11.32
South Korea	18283	11.37	Singapore	4482	12.39	Poland	9874	10.55
Israel	4171	10.64	South Korea	20479	12.01	New Zealand	2557	10.17
Denmark	4724	10.27	Portugal	4636	11.60	Spain	21208	9.47
Taiwan	9223	10.20	Ukraine	2423	11.40	South Korea	22393	9.35
Turkey	7079	10.06	Australia	13899	10.87	Australia	15195	9.32
Australia	12536	10.01	Mexico	4341	9.35	Argentina	3568	9.25
China	80441	9.92	Brazil	11704	8.89	Greece	4033	9.18
Brazil	10748	9.23	Norway	3349	8.77	Pak	2689	9.04
Mexico	3970	8.92	Denmark	5138	8.76	Sweden	8950	8.88
Finland	4010	8.26	Taiwan	10001	8.44	Hungary	2828	8.85
Spain	17933	8.11	Spain	19374	8.04	Thailand	3471	8.71
Austria	4638	7.49	Chile	1556	7.91	Singapore	4864	8.52
Ukraine	2175	7.41	Russian Federation	13420	7.90	Turkey	7866	8.36
Czech Republic	4412	7.24	Ireland	3018	7.71	Denmark	5559	8.19
Argentina	3124	7.21	Belgium	6802	6.70	Croatia	1357	8.04
Serbia	1392	5.94	New Zealand	2321	6.61	Italy	22269	7.79
Hong Kong	2901	5.80	Slovakia	1364	6.56	India	35770	7.67
Switzerland	8900	5.66	Austria	4941	6.53	Belgium	7315	7.54
Norway	3079	5.59	Hungary	2598	5.57	Hong Kong	3507	7.41
Belgium	6375	5.58	Romania	3064	5.44	Mexico	4662	7.39
United Kingdom	30986	5.48	Switzerland	9358	5.15	Switzerland	10025	7.13
Canada	19086	5.44	Czech Republic	4624	4.81	Netherlands	11046	6.67
The United States	128850	5.22	Canada	20002	4.80	Austria	5253	6.31
Netherlands	9929	4.86	Argentina	3266	4.55	Canada	21249	6.23
Croatia	1066	4.82	Italy	20660	4.44	Germany	41930	5.92
Germany	38118	4.18	Netherlands	10355	4.29	Israel	4287	5.18
France	25253	3.97	The United States	133915	3.93	United Kingdom	32861	4.71
Sweden	7953	3.92	Germany	39588	3.86	Czech Republic	4823	4.30
Chile	1442	3.89	Poland	8932	3.72	Romania	3192	4.18
Italy	19782	3.68	Sweden	8220	3.36	France	26966	4.04
Bulgaria	1311	3.15	France	25919	2.64	The United States	138941	3.75
Slovenia	1267	3.09	Japan	37737	2.60	Taiwan	10366	3.65
Poland	8612	3.06	Turkey	7259	2.54	Finland	4063	3.17
Slovakia	1280	1.51	United Kingdom	31384	1.28	Japan	38112	0.99
Russian Federation	12437	1.37	Greece	3694	0.33	Ireland	2992	-0.86
Hungary	2461	-0.12	Finland	3938	-1.80	Russian Federation	13289	-0.98
Greece	3682	-0.43	Israel	4076	-2.28	Bulgaria	1235	-2.37
Japan	36780	-0.97	Bulgaria	1265	-3.51	Ukraine	2338	-3.51

Table 7; The year 2013 and 2014 details of the number of publications and (%) growth of 50 countries.

2013			2014		
Name of Country	Number of Publications	Growth (%)	Name of Country	Number of Publications	Growth (%)
Pak	3265	21.42	Malaysia	7379	20.02
China	126274	15.18	China	145307	15.07
Egypt	5477	12.93	India	43363	12.63
Ukraine	2633	12.62	Chile	2221	12.40
Portugal	5980	12.26	Czech Republic	5886	12.20
Poland	10972	11.12	Egypt	6099	11.36
Romania	3532	10.65	Ukraine	2932	11.36
Australia	16775	10.40	South Africa	3841	10.85
Hong Kong	3870	10.35	Iran	13460	10.79

Russian Federation	14657	10.29	Thailand	4013	10.61
Iran	12149	9.99	Hong Kong	4274	10.44
Finland	4451	9.55	Brazil	15977	10.41
Malaysia	6148	8.87	South Korea	25757	9.43
Czech Republic	5246	8.77	Mexico	5430	9.28
South Africa	3465	8.42	Pak	3526	7.99
Brazil	14470	8.38	Australia	18011	7.37
Turkey	8506	8.14	Hungary	2993	7.08
Italy	24016	7.84	Slovakia	1757	6.87
Slovakia	1644	7.80	Russian Federation	15644	6.73
India	38499	7.63	Denmark	6328	6.42
Singapore	5226	7.44	Poland	11635	6.04
Denmark	5946	6.96	Croatia	1261	5.70
Mexico	4969	6.59	Sweden	9946	5.58
Bulgaria	1311	6.15	Finland	4699	5.57
France	28419	5.39	Singapore	5496	5.17
Sweden	9420	5.25	Austria	5654	4.86
South Korea	23538	5.11	Turkey	8902	4.66
Netherlands	11556	4.62	Serbia	2208	4.55
Thailand	3628	4.52	Belgium	7911	4.46
Argentina	3715	4.12	Israel	4518	4.34
Switzerland	10430	4.04	Switzerland	10873	4.25
Chile	1976	4.00	United Kingdom	35032	3.75
Belgium	7573	3.53	Argentina	3854	3.74
New Zealand	2640	3.25	Norway	3954	3.40
Taiwan	10687	3.10	Spain	22369	3.20
The United States	142924	2.87	Canada	21979	3.05
United Kingdom	33767	2.76	Italy	24644	2.61
Germany	43057	2.69	New Zealand	2708	2.58
Austria	5392	2.65	Germany	44145	2.53
Spain	21676	2.21	Taiwan	10952	2.48
Japan	38884	2.03	Netherlands	11797	2.09
Norway	3824	1.16	Slovenia	1693	1.44
Greece	4079	1.14	Ireland	3037	1.37
Israel	4330	1.00	France	28618	0.70
Slovenia	1669	0.54	Bulgaria	1320	0.69
Canada	21329	0.38	The United States	142869	-0.04
Ireland	2996	0.13	Greece	4052	-0.66
Hungary	2795	-1.17	Portugal	5927	-0.89
Serbia	2112	-2.94	Japan	38177	-1.82
Croatia	1193	-12.09	Romania	3391	-3.99

Table 8; The year 2015 and 2016 details of the number of publications and (%) growth of 50 countries.

2015			2016		
Name of Country	Number of Publications	Growth (%)	Name of Country	Number of Publications	Growth (%)
Russian Federation	18002	15.07	Chile	2807	17.94
Pak	4033	14.38	Iran	17275	16.56
Egypt	6870	12.64	Russian Federation	20680	14.88
Romania	3813	12.44	Pak	4615	14.43
Iran	14821	10.11	South Africa	4728	13.96
Turkey	9732	9.32	Thailand	4405	12.86
Poland	12569	8.03	Bulgaria	1309	12.26
South Africa	4149	8.02	Egypt	7630	11.06
Australia	19455	8.02	Malaysia	7980	9.43
Austria	6095	7.80	Turkey	10468	7.56
Hong Kong	4605	7.74	Poland	13449	7.00
Greece	4354	7.45	China	165737	6.81
Denmark	6790	7.30	Serbia	2380	6.63
Chile	2380	7.16	Brazil	17783	6.52
Singapore	5876	6.91	Mexico	6060	5.87
China	155165	6.78	Argentina	4009	5.67
Czech Republic	6240	6.01	Slovakia	1938	5.56
Switzerland	11462	5.42	Czech Republic	6545	4.89
Mexico	5724	5.41	Slovenia	1855	4.57
Belgium	8336	5.37	Norway	4336	4.26
Italy	25932	5.23	India	45162	3.71
South Korea	27094	5.19	Ireland	3186	2.91
Norway	4159	5.18	Sweden	10456	2.63
Slovenia	1774	4.78	Ukraine	2955	2.36
United Kingdom	36686	4.72	Hong Kong	4695	1.95
Slovakia	1836	4.50	Israel	4740	1.85
Brazil	16694	4.49	Australia	19782	1.68
Portugal	6184	4.34	Austria	6196	1.66
Croatia	1312	4.04	Spain	22921	1.58
New Zealand	2816	3.99	Croatia	1331	1.45
Germany	45891	3.96	United Kingdom	37185	1.36
Israel	4654	3.01	Italy	26117	0.71

Hungary	3083	3.01	Portugal	6225	0.66
Finland	4831	2.81	Netherlands	12182	0.64
Canada	22588	2.77	Hungary	3093	0.32
Netherlands	12104	2.60	Denmark	6794	0.06
Sweden	10188	2.43	Germany	45894	0.01
France	29258	2.24	France	29238	-0.07
Ireland	3096	1.94	Belgium	8326	-0.12
The United States	144550	1.18	New Zealand	2812	-0.14
Serbia	2232	1.09	Finland	4815	-0.33
Spain	22564	0.87	Singapore	5852	-0.41
India	43547	0.42	Japan	37703	-0.45
Japan	37873	-0.80	The United States	143450	-0.76
Malaysia	7292	-1.18	South Korea	26850	-0.90
Ukraine	2887	-1.53	Canada	22377	-0.93
Argentina	3794	-1.56	Switzerland	11338	-1.08
Thailand	3903	-2.74	Romania	3759	-1.42
Taiwan	10124	-7.56	Greece	4280	-1.70
Bulgaria	1166	-11.67	Taiwan	9929	-1.93

Table 9; The year 2017/2018 and 2019 details of the number of publications and (%) growth of 50 countries.

Country	2017		Country	2018		Country	2019	
	Number of Publications	Growth (%)		Number of Publications	Growth (%)		Number of Publications	Growth (%)
Pak	5426	17.57	Pak	6195	14.17	Pak	7342	18.51
Mexico	6810	12.38	Slovakia	2200	12.76	Egypt	10030	16.85
Brazil	19505	9.68	Egypt	8584	12.56	China	231328	14.22
China	180982	9.20	Thailand	5367	12.00	Serbia	2431	11.46
Ukraine	3222	9.04	China	202531	11.91	Turkey	11840	10.70
Thailand	4792	8.79	Russian Federation	25025	11.26	Iran	22026	10.35
Russian Federation	22492	8.76	Chile	3026	9.84	South Africa	5833	9.40
Hong Kong	5056	7.69	Hong Kong	5532	9.41	Russian Federation	26898	7.48
Iran	18487	7.02	Bulgaria	1477	7.97	Romania	3853	6.06
Slovenia	1985	7.01	Iran	19960	7.97	Mexico	7546	5.97
Norway	4592	5.90	South Africa	5332	7.89	Slovenia	2235	5.42
Croatia	1402	5.33	Ukraine	3463	7.48	Bulgaria	1557	5.42
South Africa	4942	4.53	India	49007	7.14	Portugal	6866	5.29
Bulgaria	1368	4.51	Slovenia	2120	6.80	Australia	21466	4.58
Singapore	6079	3.88	Croatia	1493	6.49	Czech Republic	7074	4.37
Switzerland	11759	3.71	Brazil	20662	5.93	Croatia	1553	4.02
Austria	6403	3.34	New Zealand	3065	5.51	Malaysia	8886	3.99
New Zealand	2905	3.31	Turkey	10696	5.35	Brazil	21478	3.95
Malaysia	8176	2.46	Mexico	7121	4.57	Chile	3141	3.80
Denmark	6948	2.27	Malaysia	8545	4.51	South Korea	28405	3.68
Germany	46834	2.05	Sweden	10926	3.81	India	50588	3.23
United Kingdom	37923	1.98	Argentina	4184	3.64	Finland	4976	3.15
Portugal	6316	1.46	Portugal	6521	3.25	Poland	14315	3.13
Italy	26495	1.45	Greece	4413	3.23	Hong Kong	5671	2.51
Czech Republic	6638	1.42	Poland	13881	2.78	New Zealand	3139	2.41
Australia	20061	1.41	Italy	27123	2.37	Greece	4519	2.40
Israel	4802	1.31	Australia	20525	2.31	Italy	27764	2.36
India	45739	1.28	Czech Republic	6778	2.11	Slovakia	2250	2.27
Spain	23213	1.27	South Korea	27396	1.98	Spain	23861	1.82
France	29558	1.09	Canada	22969	1.89	Taiwan	9585	1.82
The United States	144964	1.06	Netherlands	12252	1.84	Austria	6406	1.71
Ireland	3212	0.82	Ireland	3260	1.49	Thailand	5458	1.70
Canada	22544	0.75	United Kingdom	38383	1.21	Hungary	3091	1.41
Argentina	4037	0.70	Belgium	8389	1.00	Germany	47366	1.34
Slovakia	1951	0.67	Spain	23435	0.96	Ukraine	3492	0.84
Sweden	10525	0.66	Finland	4824	0.79	Canada	23139	0.74
Japan	37895	0.51	Hungary	3048	0.33	Ireland	3281	0.64
Poland	13506	0.42	Israel	4817	0.31	Denmark	6931	-0.04
South Korea	26865	0.06	Romania	3633	0.11	Singapore	5987	-0.35
Egypt	7626	-0.05	Japan	37820	-0.20	Netherlands	12207	-0.37
Greece	4275	-0.12	Denmark	6934	-0.20	Sweden	10793	-1.22
Belgium	8306	-0.24	Germany	46738	-0.20	Israel	4739	-1.62
Finland	4786	-0.60	The United States	144405	-0.39	France	28271	-1.65
Netherlands	12031	-1.24	Norway	4553	-0.85	Argentina	4110	-1.77

Hungary	3038	-1.78	Singapore	6008	-1.17	Switzerland	11111	-1.92
Chile	2755	-1.85	Austria	6298	-1.64	Norway	4428	-2.75
Taiwan	9644	-2.87	Taiwan	9414	-2.38	United Kingdom	37299	-2.82
Turkey	10153	-3.01	France	28746	-2.75	Japan	36476	-3.55
Serbia	2307	-3.07	Switzerland	11329	-3.66	The United States	139174	-3.62
Romania	3629	-3.46	Serbia	2181	-5.46	Belgium	8077	-3.72

year-wise University wise Scifinder publication data from Pakistan.

The Scopus data about the top ten universities or organizations involved in publications is depicted in Table 10.0. While, the university wise publications data from different general, medical and engineering universities across Pakistan that have been indexed on either CALPUS or MEDLINE, the two databases of Scifinder as of July 30, 2020 is shown in table 11.

On 21st December 2018, it was reported by "Nature.com" that "Pakistan and Egypt had highest rises in research output in 2018". The said report precisely mentioned 21% rise in the research output. Herein, we reported the publications growth rate of Pakistan in chemistry publications. Pakistan did not only top the

rankings in 2017, 18 and 19, but also in 2006 and 2013. In fact it occupied 2nd position in 2015 and 3rd slot in 2005, 2007, 2010 and 2011 as well.

Before discussing the chemistry publication growth rate of Pakistan in the 21st century and the various factors affecting it, herein we also provided the chemistry publication history from 1947 to 2000.

Research output from 1947 to 1999

As per scopus data, from 1947 to 1999, only 2870 research documents were published comprising of 2749 articles, 29 notes, 24 reviews, 23 conference papers, 22 editorials, 14 letters, 4 book chapters, 3 short surveys and 2 errata. The year-wise or decade wise publications details are given in Fig. 5 and 6.

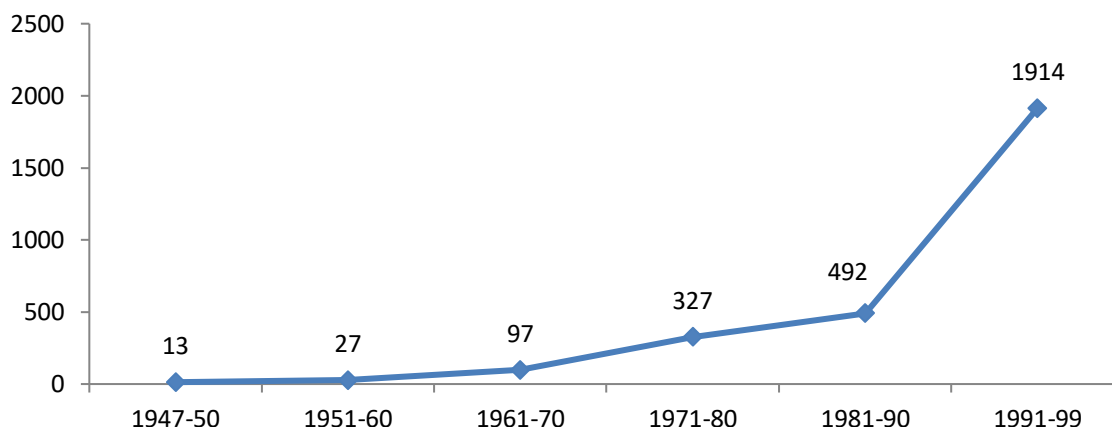


Fig. 5 List of chemistry publications in Pakistan from 1947 to 1999.

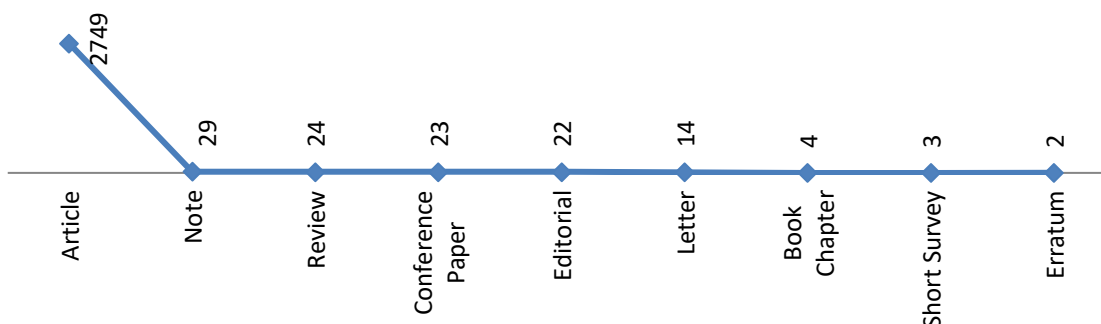


Fig. 6 Types of Chemistry publications documents in Pakistan from 1947 to 1999.

Interestingly, 13 documents were retrieved from Scopus database from the period between 1920 to 1945, that showed affiliations of three universities/colleges which are now part of Pakistan namely Department of Chemistry, D. J. Sind College, Karachi, Pakistan (n=1), Department of Chemistry/Chemical Laboratory, Government College, Punjab University, Lahore (n=11) and Department of Chemistry, Forman Christian College, Lahore (n=1). Since the number of publications in this era was only a minor proportion i.e. 0.81% of the total 73 years production therefore it was ignored for further analysis.

From 1947 to 1999, total 160 organizations or universities have directly contributed in at least three (n=3) publications. While, only six organizations or universities have produced more than one hundred (n=100) publications. University of Karachi (n=797/27.77%), Pakistan Council of Scientific and Industrial Research (n=389/13.55 %), Quaid-i-Azam University (n=384/13.38%), PCSIR Laboratories (n=253/8.82%), University of the Punjab, Lahore (n=237/8.26%) and University of Peshawar (n=130/4.53%) were top contributors

Globally the total number of publications (from 1947-1999) indexed in Scopus were found to be 3484548 with Pakistan's share of only 0.082 %. Based on the number of publications the international ranking of Pakistan was 51st (position). The top 10 countries were found to be, USA (n=1217334/34.94%), Japan (n=372448/10.69), UK (n=266954/7.66), Germany (n=260432/7.47), France (n=172552/4.95), Canada (n=141442/4.06), Italy (n=103881/2.98%), India

(n=90812/2.61), Russia (n=86760/2.49) and Netherlands (n=73755/2.12%).

Research output from 2001 to 2020

A substantial rise in the publication output is observed after the year 2000. From 2001 to March, 2020, 53054 research publications have been recorded in Pakistan. The types of documents comprised of articles (n=47311), reviews (n=3356), conference papers (n=1069), book chapters (n=747), errata (n=135), letters (n=124), editorials (n=113), short surveys (n=66), notes (n=45), books (n=35), retractions (n=11) and eleven (n=11) data papers as shown in Fig. 7 & 8. Based on Scopus record, the list of top ten (10) institutes/universities is provided in table 10. As for publication indexed in Scifinder databases, there has been a notable increase in the number of publications from virtually all universities across Pakistan which is a clear indicator of the emphasis put on chemistry research in the era. The university wise publication data in chemistry and related subject areas retrieved from Scifinder is elaborated in table 11 which clearly indicates that post 2001 there has been a remarkable increase in the number of publications from virtually all major universities across Pakistan.

However it is important to mention that the research contributions and publications indexed in Scifinder databases are not restricted to universities having a formal department of chemistry but presents an overall view of the research contribution in chemistry and related subject areas from institutions all across Pakistan.

Pak Number of Publications

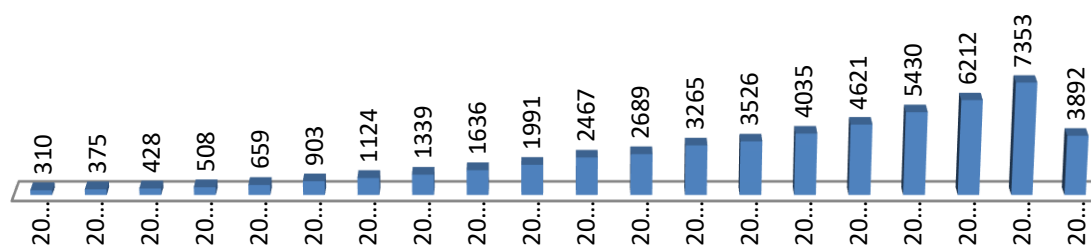


Fig. 7 List of chemistry publications in Pakistan from 2001 to March-2020.

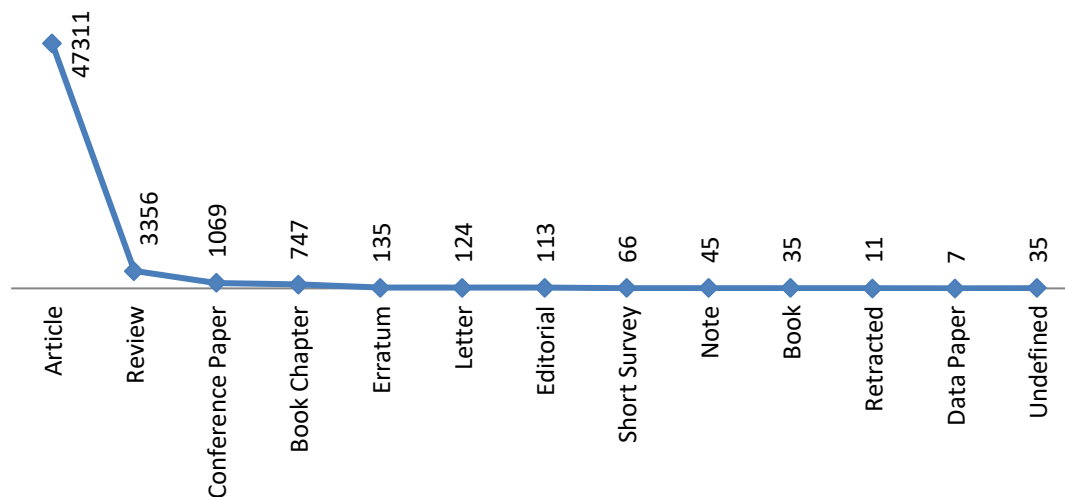


Fig. 8 Types of Chemistry publications documents in Pakistan from 2001 to March-2020.

Table-10: Scopus based list of top ten institutes involved in publications. The publications are from the year 2001 to March 2020.

S#	Name of the University	Number of Publications	Total Publications of Pakistan	%age
	Quaid-i-Azam University	6918	53054	13.03954
	University of Karachi	5917	53054	11.15279
	University of Agriculture, Faisalabad	4957	53054	9.343311
	University of the Punjab, Lahore	4491	53054	8.46496
	COMSATS University Islamabad	4203	53054	7.922117
	University of Peshawar	2768	53054	5.217326
	Government College University Faisalabad	2697	53054	5.0835
	Bahauddin Zakariya University	2628	53054	4.953444
	Government College University Lahore	2523	53054	4.755532
	University of Sargodha	2444	53054	4.606627

Table 11: University wise data of publications indexed on Scifinder from Pakistan.

University/ Institute	Total hits	2001-2020		
		total	CAPLUS	MEDLINE
Aga Khan University	9592	8576	689	7887
University of Karachi, 75270	5670	4689	3103	1586
Comsats Institute of Information Technology, Islamabad	3772	3769	1980	1789
Bahauddin Zakariya University Multan	2819	2612	1535	1077
National University of Science and Technology	2637	2635	1479	1156
Islamia University of Bahawalpur	2282	2043	1078	965
Dow University of Health Sciences	2105	2096	199	1897
University of the Punjab, Lahore, Pakistan	2028	1971	10	1961
University of Peshawar, Peshawar, Pakistan	2015	1972	21	1951
University of Agriculture Faisalabad Pakistan	1889	1863	18	1845
University of Sargodha	1786	1785	1020	765
Government College University Faisalabad Pakistan	1429	1429	3	1426
Abdul Wali khan University Mardan	1393	1391	522	869
Hazara university	1057	1055	590	465
Pakistan Institute of Engineering and Applied Sciences	1015	983	592	391
International islamic university islamabad	982	982	498	484
University of Malakand	970	970	539	431
Gomal University	953	799	483	312
Lahore College for Women University	843	843	569	274
Kohat University of Science and Technology	805	805	396	409
University of Sindh, Jamshoro, Pakistan	624	611	6	605
Government College University, Lahore, Pakistan	366	366	0	366
University of Gujrat, Pakistan	358	358	1	357
NED University of Engineering and Technology	309	300	213	87
University of Balochistan	300	288	1	287
University of Science and Technology Bannu	278	278	139	139
University of Haripur	206	204	86	118
Bacha Khan University	164	164	90	74

The university wise data of the publications indexed on Scifinder is shown in Table-11. It is obvious from the data that research output from all universities across Pakistan underwent a remarkable increase in the last two decades (2001 to 2020). In fact many institutions which only started maturing during the first decade of the century also excelled in research realm and made a significant contribution in terms of publications. In fact both new and old institutes excelled in research contributions that confirmed a place in Scifinder. It is also noteworthy that the increase in research output has been observed from universities in all four provinces of Pakistan. The Scopus data about the top ten universities or organizations involved in publications is depicted in Table 10.0

Viewed together, both Scopus and Scifinder data indicate some of the top universities which include Quaid i Azam University, University of Karachi and Comsats institute of Information Technology, Islamabad. Their exact record and %age is given in tables 10 and 11.

We further extended the idea and provided details of the list of top 10 countries with exact number and %age of publication (in Table 12.0). Based on the number of publications, Pakistan was on 40th Position. The authors would however like to mention that the ranking that arise from different databases are inevitably different because of varying algorithms and structure (of these databases).

Some ground rationales for increase in publication output

The evident increase in research output in the last two decades could be explained by considering several vital factors, which are usually involved in research development. Since the number of publications before 1974 was comparatively negligible therefore we only focused after 1974-75 publication data for drawing a comparison.

Establishment of Higher Education Commission

On September 11, 2002, the Higher Education Commission (HEC), Islamabad was established with the

aim to facilitate the institutes of Higher Learning in Pakistan. HEC directed its policies towards facilitating research activities and improving the overall research culture and also created an increased motivation among researchers to excel in producing high quality research. Consequently, an extensive progress in research output can be noticed in this era.

Number of universities, teachers, students and thesis production

The data collected about the number of universities, teachers & students is given in Table 13. The increase in research manpower may provide some valid justification for increase in publication output. In 1974-75, there were ten (10) universities with 2455 faculty and 21000 students in all. In 2001-02, a substantial increase in the number of universities (n=74), faculty (n=5160) and students (n=276000) was observed. After 2002, the higher education system astonishingly improved. In 2017-18, the number of universities further increased to 186 with 56885 teachers, and 1575000 thousand students. In 2019-20 the total number of universities is 211. Presently in Pakistan there are 317,323 institutions accommodating 50,292,570 students and 1,836,584 teachers as per the data retrieved from National Education Management Information System, Academy of Educational Planning and Management, Ministry of Federal Education and Professional Training, Government of Pakistan/ March 2018.

In the same vein, we collected data from Pakistan research repository (PRR) about the total number of thesis produced from 1933. The data is presented in Fig. 9. From 1947 to 1974 only seventeen thesis records was obtained from PRR. Precisely, from 1947 to 1949, one from 1950-1959, four from 1960 to 1969, two and from 1970 to 1974, ten thesis were reposted. From 1970 to 1999, in all subjects only 1034 thesis were produced with less than 400 in chemistry. While, from 2000 to Jan 2020, 10,096 thesis in all subjects and 3281 in chemistry are archived in (PRR) Fig. 10

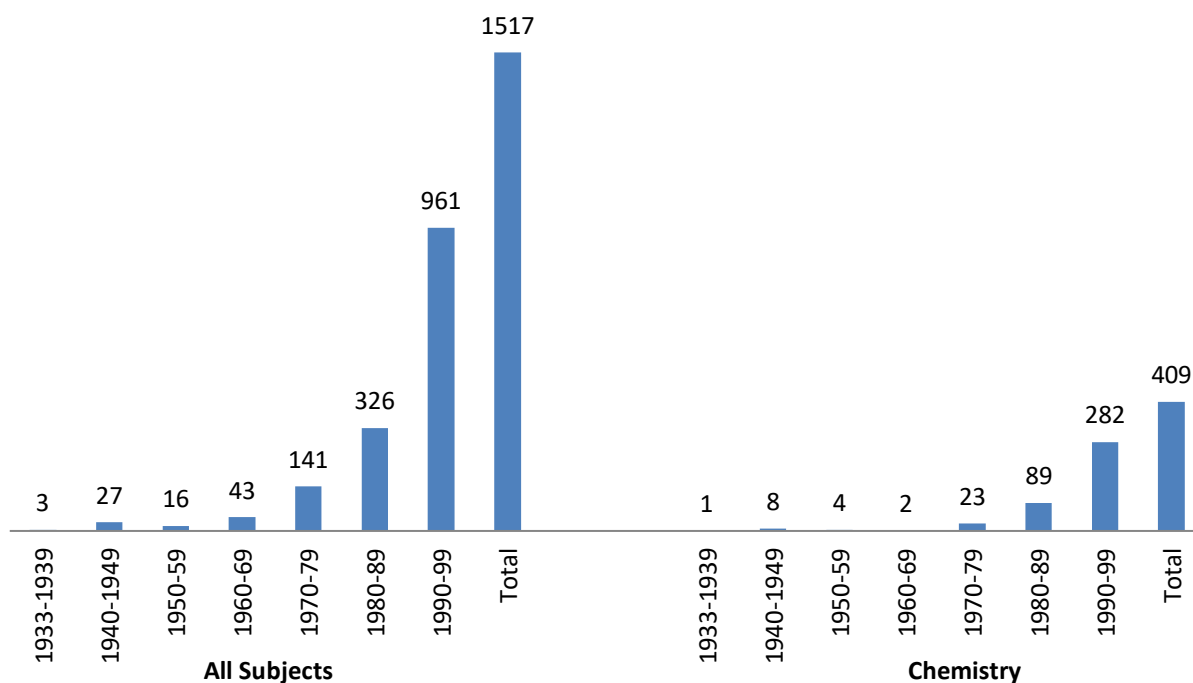


Fig. 9 Total number of thesis archived in general subjects and chemistry from 1933-1999.

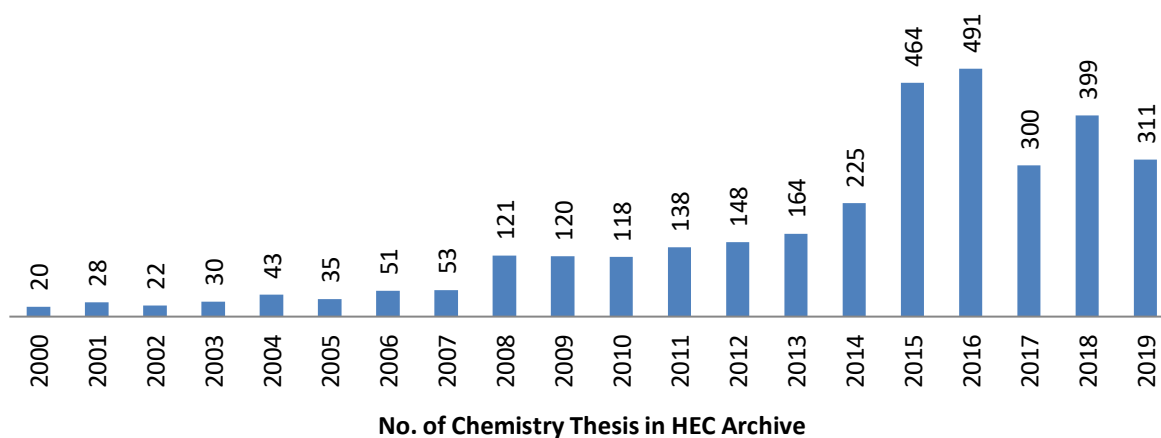


Fig. 10 List of year-wise chemistry thesis from 2000 to 2020.

Table-12: Scopus based list of top 10 countries with total number and %age of publications. Pakistan is included only to describe its total publications with % share.

S#	Country	Number of Publications	Total Publications	% Age
1.	The United States	2403235	10013057	24.00101
2.	China	1929345	10013057	19.26829
3.	Germany	727246	10013057	7.262977
4.	Japan	708947	10013057	7.080225
5.	United Kingdom	589025	10013057	5.882569
6.	India	561305	10013057	5.605731
7.	France	473626	10013057	4.730084
8.	Italy	387566	10013057	3.870606
9.	Canada	356076	10013057	3.556117
10.	South Korea	352348	10013057	3.518885
11.	Pakistan	51480	10013057	0.514129

Table 13: List of year-wise (1975-2020), the number of universities, number of teachers and enrolments (in Thousands)

Year	No of Universities	Number of Teachers	Enrolments (in Thousands)
1974-5	10	2455	21
1975-6	12	2726	23
1976-7	12	2916	38
1977-8	15	3265	41
1978-9	15	3573	39
1979-80	15	3068	42
1980-1	19	3183	43
1981-2	20	3357	48
1982-3	20	3322	49
1983-4	20	3490	50
1984-5	21	3589	54
1985-6	22	3740	60
1986-7	22	3878	61
1987-8	22	4020	65
1988-9	22	4162	69
1989-90	22	4304	73
1990-1	22	4744	62
1991-2	23	4926	66
1992-3	27	5728	68
1993-4	28	5217	77
1994-5	34	5316	81
1995-6	38	5417	83
1996-7	41	5162	92
1997-8	45	5515	94
1998-9	46	4911	92
1999-2000	54	5914	114
2000-1	59	5988	125
2001-2	74	5160	276
2002-3	96	6180	332
2003-4	106	37,428	423
2004-5	108	37,469	472
2005-6	111	37,509	521
2006-7	120	44,537	606
2007-8	124	46,893	741
2008-9	129	52,833	804
2009-2010	132	57,780	936
2010-11	135	63,557	1108
2011-12	139	70,053	1320
2012-13	147	77,557	1595
2013-14	161	77,557	1595
2014-15	163	88,288	1299
2015-16	163	83,375	1356
2016-17	185	58,733	1463
2017-18 *	186	56,885	1575
20018-19 **	-	53853	1572
2019-2020	211	-	-

* (Provisional)

** (Estimated or Provisional)

For Universities, enrolments and teachers numbers the data was taken from

1. Pakistan Economic Survey for the year 1974-75 to 1991-92 And
2. Pakistan Education Statistics for the year 1992-93 to 2016-17
3. Higher education commission for year 2017-2019

Table-14: Details of year-wise HEC budget.

Development and Non Development Expenditure on Higher Education (Million Rs.)													
	2005-06		2006-07		2007-08		2008-09		2009-10				
Released Recurring	10,493.412		14,332.521		12,536.498		15,766.425		21,500.000				
Released Development	10,890.877		14,409.156		15,390.455		16,420.408		22,500.000				
Released Total	21,384.289		28,741.677		27,926.953		132,186.833		44,000.000				
For the years 2012-19 (Rs. Billions)													
	2012-13		2013-14		2014-15		2015-16		2016-17		2017-18		2018-19
	Alloc.	Exp	Alloc.	Exp	Alloc.	Exp	Alloc.	Exp	Alloc.	Exp	Allo	Exp	Allo
Current/ Recurring	32.755	36.278	39.000	43.118	43.000	43.050	51.000	51.000	58.000	58.000	62.183	65.520	65.000
Development	15.800	15.800	18.490	18.490	20.000	27.809	20.000	20.207	21.486	25.110	35.663	22.280	35.829
Total	48.555	52.078	57.490	61.608	63.000	70.859	71.000	71.207	79.486	83.11	97.846	87.800	100.829
Source: "HEC" and "Academy of Educational Planning and Management Ministry of Federal Education and Professional Training Islamabad".													

Source: "HEC" and "Academy of Educational Planning and Management Ministry of Federal Education and Professional Training Islamabad".

*Financial Resources**Government of Pakistan Education Expenditure*

In Pakistan, the public expenditure on education from the year 1975 to 2017-18 is listed in Fig. 11. The data was retrieved from the World Bank and it appears that the various governments have been more or less committed to enhance financial resources for education. There is gradual and consistent rise in budgets. The public budget on education was 11.3 billion in 1975 and increased to 72.3 billion in 2001. As apparent from Fig. 11, the budget allocation astonishingly increased after 2002 era. This covered financial assistance and support from primary to tertiary education. Precisely, the budget augmented from 83.2 billion in 2003 to 315 billion in 2018. The data for only tertiary education budget is depicted in Fig 12. From 1971 to 1979, the yearly budget ranged from 153 to 826 million. From

1980 to 1990, it increased from 1.0 billion to 2.8 billion. A further increase from 3.5 billion to 8.72 billion was observed from 1991 to 1997. The year wise data for tertiary education could not be obtained for the years 1998-2012. However, in the years following the establishment of the HEC (in 2002), the funding has immensely increased. The total development and non development expenditure on higher education for the years (2005-06, 2006-07, 2007-08, 2008-9 and 2009-10) was 21.38, 28.74, 27.92, 32.18 and 44.00 billion respectively. The budgetary data (current/recurring and development) for the years 2012-2019 is presented in Table 14. The total (current/recurring and development) budget increased from 48.55 billion to 100.82 billion in 2018-19. The data about the HEC budget was obtained from the Academy of Educational Planning and Management, Ministry of Federal Education and Professional Training Islamabad (Table-14).

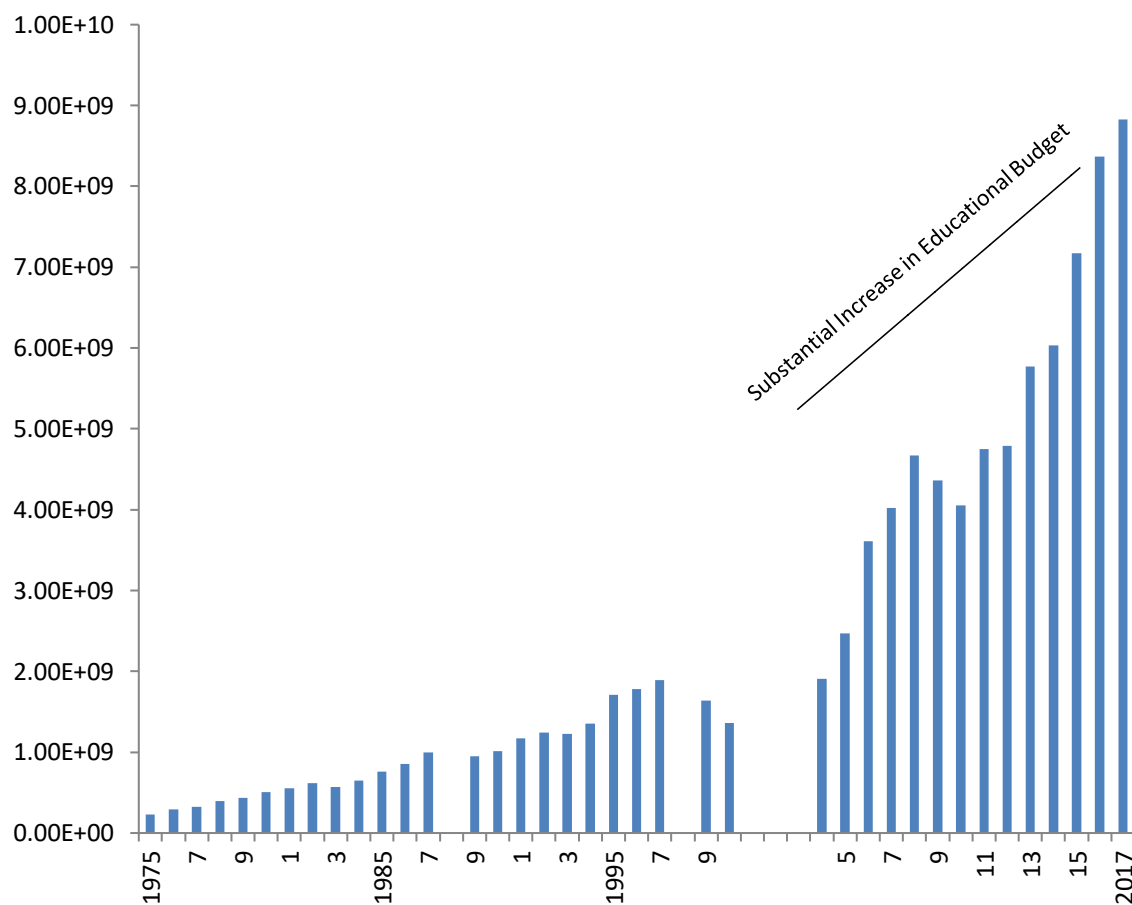


Fig. 11 Educational budget from 1975-2020.

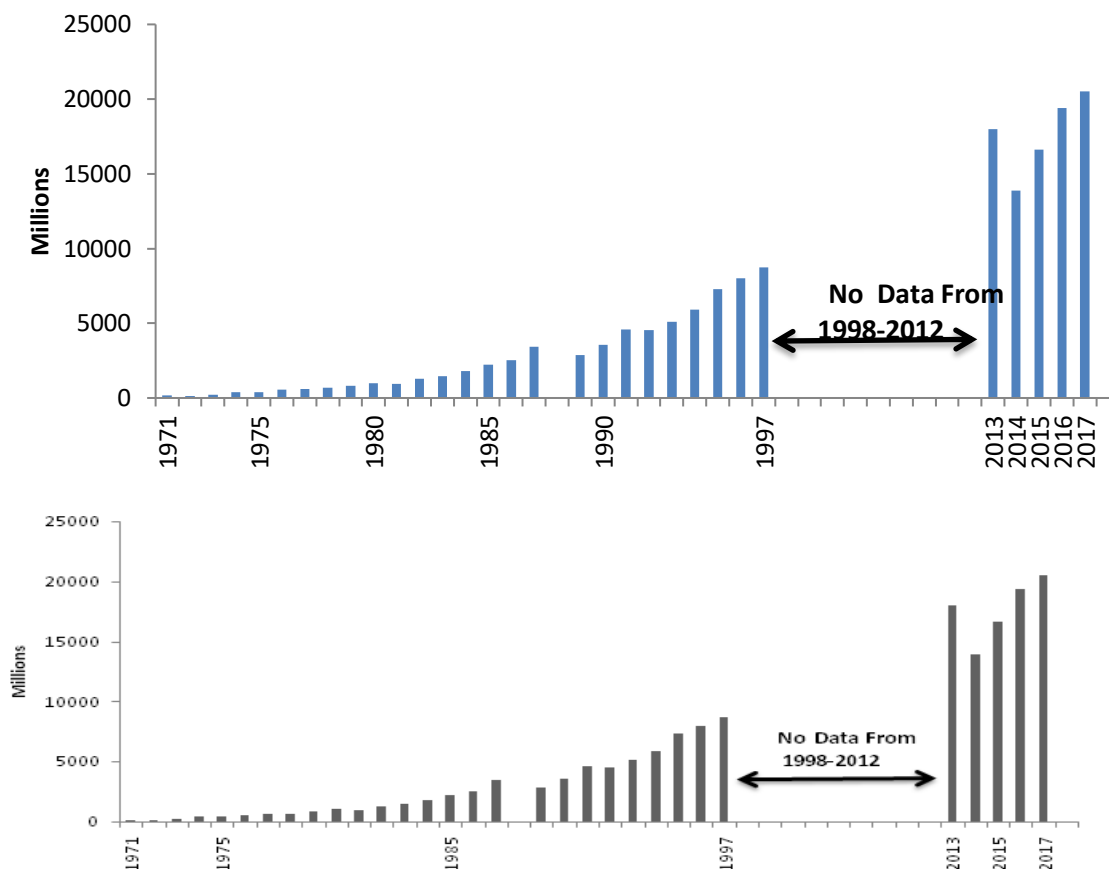


Fig. 12 Tertiary education budget from 1971-2018.

Foreign Assistance

Pakistan is a notable recipient of education aid from international community. A substantial increase can be noticed from US\$ 20 million to US\$ 432 million in 2012. Moreover, Pakistan is amongst the top 10 countries receiving aid for education (OECD DAC). Similarly, World Bank (WB), Asian Development Bank (ADB), Australian Agency for International Development (AusAID), Islamic Development Bank (IDB), United Nations Development Programme (UNDP), United Nations Educational, Scientific and Cultural Organization (UNESCO), Canadian International Development Agency (CIDA), Department for International Development (DFID), Deutsche Gesellschaft Fur Technische Zusammenarbeit (GTZ), Deutscher Akademischer Austausch Dienst (DAAD), Canadian International Development Agency (CIDA), Japan International Cooperation Agency (JICA), Norwegian Agency for Development Cooperation

(NORAD), U.S. Agency For International Development, European Union (EU) and Third World Academy of Sciences (TWAS) to name a few, renowned world donor agencies, banks or organizations that are providing massive financial assistance or grants in promoting science and education.

National and International Financial Resources in Chemistry Publications

It is worthy to note that from 1947 to 1999, limited numbers of publications have acknowledged the funding details. In fact, only five national or international organizations have financially supported at least ten research publications. Pakistan Science Foundation (n=33), Pakistan Atomic Energy Commission (n=21), Quaid-i-Azam University (n=14), Deutscher Akademischer Austauschdienst, Germany (n=12) and National Institutes of Health have funded 11 publications. And, 2659 research

publications did not define or acknowledge any financial support.

While, from 2001-2019, more than 75 organizations, have financially supported at least 50 publications, 34 organizations have sponsored more than 100 publications, 22 have sponsored more than 150, 16 have sponsored more than 200, 10 have sponsored more than 300, 8 have sponsored more than 400, 4 have sponsored more than 1500 while 3 organizations have sponsored more than 2000 research publications. The record for sponsoring 2nd highest number of publications is held by Alabama Commission on Higher Education (n=2590), followed by National Natural Science Foundation of China (n=2560) and National Research Foundation of Korea (n=485).

Some of the other renowned organizations funding Chemistry research in Pakistan include but are not limited to Fundamental Research Funds for the Central Universities, Deanship of Scientific Research, King Saud University, National Basic Research Program of China (973 Program), Quaid-i-Azam University, King Saud University, Chinese Academy of Sciences, Pakistan Science Foundation, National Institutes of Health, University of Karachi, University of the Punjab and China Postdoctoral Science Foundation etc...

Last but not the least; the major grant contributor has been HEC with 3675 sponsored publication. HEC has launched various funding programs to promote science and technology. The list include Grand Challenge Fund (GCF), Local Challenge Fund (LCF), Technology Transfer Support Fund (TTSF), Innovative & Collaborative Research Grant (ICRG), National Research Programme for Universities (NRPU), Technology Development Fund (TDF), Problem Based Applied Interdisciplinary Research Programme (PBAIRP), RAPID Research & Innovation Initiative (RRII), Pak-FRANCE Peridot Research Program, PAK-TURK Researchers' Mobility Grant Programme, Pakistan Program For Collaborative Research (PPCR), Pak-US Joint Research Program (with USA) and establishment of Offices of Research Innovation & Commercialization (ORICS) etc..

The international collaboration can also be observed in all chemistry categories.

From 1947 to 1999, a limited number of international affiliations are observed in research publications. Only 17 countries are reported to be involved in more than 10 research publications. The

highest international affiliation was noticed for USA (n=236/8.22%), followed by UK (n=191/6.65%) and Germany (n=134/4.66%).

While from 2001 to 2019, total 160 countries are reported to be involved in affiliations (14). Precisely, 126 countries have collaborated or affiliation with at least 10 publications. The highest publications are recorded with China (n=7445/1403%), followed by KSA (n=4590/8.65%), USA (n=3570/6.73%), UK (n=2871/5.411%), Malaysia (n=2631/4.95%), Germany (n=2383/4.49%) and South Korea (n=2141/4.03%) indicating that the tendency to collaborate internationally also increased during the era.

There are several reasons for increase in international collaborations/affiliations. HEC has introduced multiple programs to facilitate international affiliations. Herein, it must be mentioned that HEC has sponsored more than 4500 scholars to pursue higher education in foreign countries. Overseas scholarships for MS/M.Phil leading to PhD or direct PhD program, faculty development program (FDP), split PhD and postdoctoral fellowship program, US-Pakistan Knowledge Corridor PhD Scholarship Program, Cultural Exchange Program, Common Wealth Scholarships, partial support program and postdoctoral fellowship program are a few highlights of HEC's incentives to facilitate scholars for studying abroad (15). Furthermore, HEC has signed memorandum of understanding (MOU) with various international agencies (in more than 15 countries e.g. UK, China, Germany, Holland, France etc) and universities for educational purposes and mutual exchange of scholars.

Similarly, various international ministries, organizations and foundations are offering grants or fellowships to pursue higher education. According to a statement issued by China's Ministry of Education, there are approximately 28000 Pakistani students all over China. Where 6156 Pakistani students are pursuing PhD degrees, 3600 are pursuing Masters degrees, 11100 are pursuing bachelor's degrees and 3000 students are enrolled in Short Term Exchange Program across China. Since the inception of USEFP in 1950, more than 7500 Pakistani scholars/students have participated in this program. This is playing a fundamental role in increasing the number of foreign graduates and ultimately the research output. After analyzing the data retrieved from Web of Science, several global agencies have been acknowledged.

A recent report also highlighted the research performed in Islamabad based Higher Education Institutes, where the author concluded a massive rise in publication output (16). The increasing tendency (after 2001/02) in publication output has been described in several other studies. For example, Samina et al., reported the publication record in the area of, pharmacology. One of the salient feature noticed was that globally Pakistan lag behind the developed world (17). However, it ranks on 13th Position as compared with 100 publishing Asian countries (in the area of Pharmacy). In the same vein, research progress in the field of biotechnology also increased. Comparatively this area is new and started in 1980. The output stated from only 15 publications in 1980 which increased to 3273 for 2011. 22% was the recorded annual growth (18).

Similarly, a rapid publication growth is also reported by M. Bashir (2013). Based on the number of articles, the Pakistan's productivity increased more than five-fold after 2001. The growth was noticed across all major scientific fields. The Multidisciplinary area showed the highest (1471.43%) growth from 2001-2005 to 2006-2010. Furthermore, the increasing tendency (in the range of 220 to 550 %) was also noted in Mathematics, Computer Science, Biochemistry, Physics, Chemical Engineering and Materials Science, Agricultural, Biological, Sciences and Environmental Sciences (19).

Conclusion

This is perhaps the first study assessing the Pakistan productivity in the field of Chemistry since independence. The impact of the reforms introduced since the establishment of HEC have been found to exceed the cumulative impact of almost 50 years of existence of the country. In the general subject areas, the performance was very impressive with more than 10 times the number of PhDs thesis produced from 2002–2019, as compared to the 1947–2002 period. Chemistry also saw impressive progress (8 times higher thesis production). Thomson Reuter's Science Watch regularly characterized and in fact analyzed Pakistan as a rising star. Between 2003 and 2010, the publications rate from Pakistan increased by more than 320%, only behind Malaysia, Iran and China. While, in 2012, the Pakistan's normalized citation impact was higher than all BRIC countries (Brazil, Russia, India and China). While a recent report compiled by Clarivate for Nature, Pakistan topped the list with a rise of 21% in research output. The report focused on 40 countries with at least 10000

papers in the Web of Science database. Although there is a substantial and rapid growth rate in research output from 2002 onwards, but the contribution of Pakistan to world scientific knowledge is still modest (only 0.2 to 0.4 %). Apart from collaborative efforts to further increase the research output, there also exists an immense need improve coordination between Academia and industry hence moving science from Bench to bedside and ensuring its impact (20). Additionally researchers must be encouraged to think innovatively and come up with novel ideas to solve indigenous problems of Pakistan.

Also diverse concrete measures like international growth policy, appropriate funding for advance research, good research management, fair incentives for research production, appropriate recognition by the government and strong support from the development community are desperately needed to improve the global share and ranking.

Limitations

As is the case with all bibliometric studies, this study also suffers from some inevitable limitations. The search data bases have some inherent issues such as variations in subject breadth, subject depth, low precision and recall (21) that create complete and total relevant data retrieval rather difficult. Also affiliation information mistakes made by authors or even slightly varying affiliation information about the same institute can result in inaccurate or low visibility of the institutions in the citation indexes (22, 23).

Conflicts of interest

The authors declare no conflict of interest.

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