Growth of Literature in Pollution Control Research Output during 1985–2014: A Scientometric Study

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Abstract

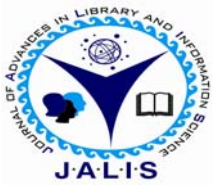
This study discusses that the literature development of the SCOPUS database in Pollution control research output during the selected period of 1985-2014. This study identified the growth of literature, publications citation, Bibliographic distribution. Further analyzed scientometric tools such as authorship pattern, Citation Index, Collaborative Coefficient, modified collaborative coefficient and block year wise Publication The Maximum number of publications in the 6th block 2010 – 2014 had 13692(25.43%) publications and had 1st ranked The block year wise average degree of collaboration was 0.72.

Keywords

Degree of Collaboration; Doubling Time; Pollution Control; Relative Growth Rate and Scientometrics.

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INTRODUCTION

Environmental pollution is more important as it was closely associated with the health issue, which can be considered as a perfect treasure in the contemporary world. It is a wider social problem as the pollution has the potential to destroy lives. Pollution problems are also closely tied to the mode of development in developing countries. Despite this, many developing countries neither improved environmental pollution control measures not implemented adequate structures to ensure that policies are effective. Modern societies face growing concern about global environmental issues; developing countries are experiencing complex, severe and fast-growing pollution problems of their own. The potent combination of industrialization, urban development, and mass consumption trends is exacerbated by foreign companies operating with little regard for the impact on the local environment. Therefore, in an intention to know the latest trend towards the research on pollution control, the SCOPUS database research output during 1985-2014. Further a few scientometric techniques such as authorship pattern, Citation Index, Collaborative Coefficient, modified collaborative coefficient and block year wise Publication were executed.

REVIEW OF LITERATURE

Vijayalakshmi S and Ambuja R (2013) reveals in their paper about the growth of remote sensing literature, 26.04% of publications were contributed in the USA. The RGR and Dt values, 82.24% of publications are in collaborative publication; the degree of collaboration was 0.85 and maximum contributions to authors, journals, institutions, subjects were found out. Ashokkumar L and Gopalakrishnan S (2013) assessed in their paper on Indian output on textile research that India was placed fourth place towards many publications; the Indian author has contributed in collaboration with 51 countries. The review includes that the Environmental Education research growth of literature, bibliographic distribution, authorship pattern and degree of collaboration were the findings of Sivasamy K and Vivekanandhan S (2015). It was also reviewed about the Authorship Trends and Collaboration pattern of the marine science literature along with the Collaboration Index, Collaboration co-efficient and the application of Lotkas Law of Elango B and Rajendram P (2012).

OBJECTIVES OF THE STUDY

The objectives of the study are as follows:

- To identify the growth of publications, citations, and CAGR
- To identify the cited and non-cited publications
- To analyze the bibliographic form of distribution
- To find out the authorship pattern, Degree of Collaboration, Citation Index, Collaborative Coefficient modified collaborative coefficient
- To examine the block year wise Degree of Collaboration
- To identify the citation of the paper, RGR and Dt.
- To find out top 20 Institutions Contribution and to determine the countries consists of more than 500 publications.

COLLECTION OF DATA

Based on the objectives as mentioned in the literature on pollution control data has been downloading from SCOPUS multidiscipline online database. A collection of 53844 number of research publications published on pollution control literature was download from 1985 to 2014.

DATA ANALYSIS

The downloaded data were segregated and tabulated by using MS-Excel spreadsheet for the further process towards the implementation of scientometric techniques.

Growth of Literature, Citations, and Rank in Pollution Control Literature, Compound Annual Growth Rate (CAGR)

The Growth rate was measured with Compound Annual Growth Rate (CAGR). The mathematical formula for calculation of CAGR is as follows:

$$CAGR = \left(\frac{Ending\ Value}{Begining\ Value}\right)^{\frac{1}{n-1}} - 1$$

Table-1 shows that the wise year growth of literature, citation, ranking, average citation per paper, cited and non-cited papers. From the period of study, a total number of 53844 publications with 581230 citations were found. During this time, 3792 publications were identified as the highest number of publications published in the year 2011, 614 publications were identified the lowest number of publications in the year 1987, the average number of publication per year was 1795 and the compound annual growth rate was 4.30. Calculation shows that the year 2000 had 2009 publication with the highest number of 42231 citations with 1st rank and the average citation per paper was 10.79. Based on the cited and non-cited publications, 30343 (56.35%) publications were cited publications and 23501(43.65%) publications were non-cited publication.

Table 1: Growth of Literature, Citation, Cited and Un-cited Papers in Pollution Control Output

S.No	Year	TP	TC	TC %	Rank with Citation	ACP	Cited Pub.	CP %	Non CitedPub.	UP %
1	1985	705	2306	0.40	29	3.27	213	0.70	492	2.09
2	1986	653	2015	0.35	30	3.09	195	0.64	458	1.95
3	1987	614	2877	0.49	28	4.69	182	0.60	432	1.84
4	1988	683	3222	0.55	26	4.72	244	0.80	439	1.87
5	1989	856	4730	0.81	24	5.53	322	1.06	534	2.27
6	1990	677	3447	0.59	25	5.09	273	0.90	404	1.72
7	1991	791	8977	1.54	22	11.35	398	1.31	393	1.67
8	1992	1142	11439	1.97	21	10.02	620	2.04	522	2.22
9	1993	1573	16691	2.87	18	10.61	853	2.81	720	3.06
10	1994	1942	16649	2.86	19	8.57	1000	3.30	942	4.01
11	1995	1767	16969	2.92	17	9.60	1000	3.30	767	3.26
12	1996	2093	21567	3.71	16	10.30	1052	3.47	1041	4.43
13	1997	2313	23595	4.06	13	10.20	1152	3.80	1161	4.94
14	1998	2652	37973	6.53	2	14.32	1505	4.96	1147	4.88
15	1999	1973	34794	5.99	4	17.64	1345	4.43	628	2.67
16	2000	2009	42221	7.26	1	21.02	1305	4.30	704	3.00
17	2001	1457	23701	4.08	12	16.27	922	3.04	535	2.28
18	2002	1609	21672	3.73	15	13.47	894	2.95	715	3.04

19	2003	1802	26530	4.56	10	14.72	986	3.25	816	3.47
20	2004	2184	27661	4.76	9	12.67	1207	3.98	977	4.16
21	2005	2364	28492	4.90	8	12.05	1242	4.09	1122	4.77
22	2006	2002	31311	5.39	6	15.64	1301	4.29	701	2.98
23	2007	2245	37193	6.40	3	16.57	1554	5.12	691	2.94
24	2008	1858	31401	5.40	5	16.90	1348	4.44	510	2.17
25	2009	2188	30825	5.30	7	14.09	1537	5.07	651	2.77
26	2010	2615	22084	3.80	14	8.45	1625	5.36	990	4.21
27	2011	3792	25793	4.44	11	6.80	2302	7.59	1490	6.34
28	2012	2564	14395	2.48	20	5.61	1496	4.93	1068	4.54
29	2013	2331	7651	1.32	23	3.28	1322	4.36	1009	4.29
30	2014	2390	3049	0.52	27	1.28	948	3.12	1442	6.14
Total		53844	581230	100.00		10.79	30343	100.00	23501	100.00
CAGR%		4.30				%	56.35	%	43.65	

Bibliographic distribution of Pollution Control Output

Table 2 reflects that the bibliographic distribution of pollution control research output during the selected period of 1985-2014. From this study the highest number of 32303 (59.99%) publications are published as an article which has been followed by 13065(24.26%) papers published in the conference paper, 2844(5.28%) and the third place was the publications published in review followed by another type of bibliographic distribution.

Table 2: Bibliographic Distribution of Pollution Control Output

S. No	**Document Type**	**TP**	**TP %**	**Cum.**	**%**
1	Article	32303	59.99	32303	59.99
2	Conference Paper	13065	24.26	45368	84.26
3	Review	2844	5.28	48212	89.54
4	Note	2086	3.87	50298	93.41
5	Conference Review	802	1.49	51100	94.90
6	Short Survey	494	0.92	51594	95.82
7	Editorial	407	0.76	52001	96.58
8	Book Chapter	185	0.34	52186	96.92
9	Letter	179	0.33	52365	97.25
10	Book	110	0.20	52475	97.46
11	Report	94	0.17	52569	97.63
12	Business Article	41	0.08	52610	97.71
13	Erratum	8	0.01	52618	97.72
14	Abstract Report	6	0.01	52624	97.73
15	Undefined	1220	2.27	53844	100.00
Total		**53844**	**100.00**		

Year Vs Authorship Pattern in Pollution Control Literature

Table-3 shows that year wise authorship pattern degree of collaboration, Co-authorship Index, Collaborative coefficient, Multi-author collaborative coefficient. From the table highest no of 14827 papers are contributed by the single author, followed by 11144 papers in two authors, 9475 papers in 3 authors, etc. From the study, a total no of 53843 articles are published in 151523 authors. It is very clear that the table No.3 indicates that the multi-authored papers play a predominant role in the single author contributions.

Table 3: Year wise Authorship Pattern, Degree of Collaboration, Collaborative Coefficient

S. No	Year	Ann.	1 Au	2 Au	3 Au.	4 Au.	5 Au.	>5 Au.	Total	Total Au.	DC	CI	CC	MCC
1	1985	17	332	172	113	42	15	14	705	1369	0.52	1.965	0.315	0.316
2	1986	20	337	153	94	35	8	6	653	1175	0.47	1.825	0.280	0.280
3	1987	14	340	125	84	32	10	9	614	1105	0.43	1.818	0.264	0.265
4	1988	21	364	139	89	39	16	15	683	1269	0.45	1.885	0.277	0.278
5	1989	18	481	186	98	50	13	10	856	1494	0.43	1.761	0.256	0.257

6	1990	39	360	143	78	38	14	5	677	1174	0.44	1.779	0.262	0.263
7	1991	27	370	197	113	49	19	16	791	1518	0.52	1.952	0.313	0.313
8	1992	38	462	286	197	78	43	38	1142	2461	0.58	2.195	0.362	0.362
9	1993	56	645	374	247	129	66	56	1573	3432	0.57	2.226	0.362	0.362
10	1994	87	926	439	264	119	58	49	1942	3789	0.50	1.996	0.309	0.309
11	1995	59	801	343	276	142	71	75	1767	3855	0.53	2.213	0.341	0.341
12	1996	72	888	533	318	146	79	57	2093	4355	0.56	2.125	0.347	0.347
13	1997	62	889	581	369	210	107	95	2313	5278	0.61	2.317	0.382	0.382
14	1998	75	969	644	465	274	111	114	2652	6199	0.62	2.370	0.397	0.397
15	1999	47	681	438	372	197	115	123	1973	4961	0.65	2.551	0.421	0.422
16	2000	139	609	475	330	214	119	122	2009	5079	0.67	2.643	0.438	0.438
17	2001	134	414	330	230	175	96	78	1457	3686	0.69	2.685	0.449	0.449
18	2002	165	458	334	276	176	90	110	1609	4091	0.68	2.719	0.450	0.450
19	2003	180	578	375	275	180	99	115	1802	4449	0.64	2.633	0.422	0.422
20	2004	185	583	435	345	269	163	204	2184	6117	0.71	2.969	0.477	0.478
21	2005	212	641	512	416	261	133	189	2364	6312	0.70	2.836	0.464	0.464
22	2006	143	431	373	406	267	173	209	2002	5980	0.77	3.140	0.524	0.525
23	2007	119	402	437	430	344	240	273	2245	7321	0.81	3.373	0.559	0.560
24	2008	79	269	346	392	324	179	269	1858	6438	0.85	3.576	0.591	0.591
25	2009	114	329	422	417	325	250	331	2188	7628	0.84	3.626	0.587	0.587
26	2010	126	305	504	564	488	291	337	2615	9039	0.88	3.580	0.609	0.609
27	2011	206	359	707	843	720	428	529	3792	13489	0.90	3.699	0.628	0.628
28	2012	249	260	382	483	461	277	452	2564	9388	0.89	3.948	0.634	0.635
29	2013	148	185	378	423	431	307	459	2331	9165	0.92	4.123	0.657	0.657
30	2014	81	159	381	468	432	323	546	2390	9907	0.93	4.293	0.674	0.674
Total		2932	14827	11144	9475	6647	3913	4905	53843	151523	0.71	2.694	0.435	0.435

The average degree of collaboration is 0.71, Co-authorship Index is 2.694, Collaborative Coefficient is 0.435 and Multi-author collaborative coefficient is 0.435.

Block Year Wise Growth of Literature, Rank, Authorship and Degree of Collaboration in Pollution Control Literature

Table 4: Block Year Wise Growth of Literature, Rank and Degree of Collaboration in Pollution Control Literature

S. No	Year	Publications	%	Cum.	Cum %	Rank	Single Author Ns	Multi-Author Nm	DC = Nm/(Nm+Ns)
1	1985-1989	3511	6.52	3511	6.52	6	1854	1567	0.46
2	1990-1994	6125	11.38	9636	17.90	5	2763	3115	0.53
3	1995-1999	10798	20.05	20434	37.95	2	4228	6255	0.60
4	2000-2004	9061	16.83	29495	54.78	4	2642	5615	0.68
5	2005-2009	10657	19.79	40152	74.57	3	2072	7919	0.79
6	2010-2014	13692	25.43	53844	100.00	1	1268	11614	0.90
		53844	100.00				14827	36085	0.71

Table-4 shows that the 30 years study period divided into six block years and each block year into five years. A maximum number of publications in the 6th block 2010 – 2014 had 13692(25.43%) publications and had 1st ranked and followed by 2nd ranked for the block year 1995-1999 had 10798 (20.05%) publications. From this study, a total number of 14827 single author papers and 36085 multi-author

papers are found. The degree of collaboration in the six block year was 0.46 to o.90. The average degree of collaboration was 0.71
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Citation Analysis of Pollution Control Research Output

Table 5: Citation Analysis of Pollution Control Research Output

S. No	Citations	No of Cited Paper	Cited Paper %	No of Citations	Citation %
1	0	23503	43.65	0	0.00
2	1	4958	9.21	4958	0.85
3	2	2939	5.46	5878	1.01
4	3	2166	4.02	6498	1.12
5	4	1752	3.25	7008	1.21
6	5	1497	2.78	7485	1.29
7	6	1216	2.26	7296	1.26
8	7	1085	2.02	7595	1.31
9	8	947	1.76	7576	1.31
10	9	810	1.50	7290	1.26
11	10	791	1.47	7910	1.36
12	11 – 50	9697	18.01	222976	38.44
13	51-100	1603	2.98	110603	19.07
14	101-200	634	1.18	85811	14.80
15	201-500	206	0.38	60342	10.40
16	501-1000	35	0.07	23873	4.12
17	>1000	5	0.01	6894	1.19
Total Papers		**53844**	**100.00**	**579993**	**100.00**
Cited paper		**30341**	**56.35%**		
UnCited Paper		**23503**	**43.65%**		

Table-5 shows that the citation among the pollution control research literature output during the selected period of 1985-2014. During the period, a total number of 53844 publications consists of 579993 citations. Single citation papers are 4958(9.21%). A maximum number of 9697(18.01%) papers had the total number of 222976(38.44%) citations, and the ranges were 11-50 citations, followed by 1603(2.98%) papers with a range of 51-100 citations and the total number of citations were 110603(19.07%). Out of the total number of 53844 publications, 30341(56.35%) were the cited publications and 23503(43.65%) were the publications without citation.

Relative Growth Rate and Doubling time in Global Pollution Control Literature

Relative Growth Rate and Doubling Time of Pollution Control research outputs are shown in Table-6. The (RGR) Relative Growth Rate is increased in a number of publications per unit of time. If the number of articles is doubled during the selected period of pollution control publication then the difference between the logarithms number of beginning and end of this period. The Doubling time is directly related to the RGR. From the table, the RGR and DT values are found to negative and positive. The RGR values are -0.39 in the year 2012 to 0.37 in the year 1992 and the Doubling time was negative in linear with -11.25 in the year 1987 to 38.33 in the year 2000.

Table 6: RGR and Dt in Pollution Control Literature

S.No	Year	TP	TP %	W1	W2	RGR	Dt
1	1985	705	1.31	0.00	0.00	0.00	0.00
2	1986	653	1.21	6.56	6.48	-0.08	-9.04
3	1987	614	1.14	6.48	6.42	-0.06	-11.25
4	1988	683	1.27	6.42	6.53	0.11	6.51
5	1989	856	1.59	6.53	6.75	0.23	3.07
6	1990	677	1.26	6.75	6.52	-0.23	-2.95
7	1991	791	1.47	6.52	6.67	0.16	4.45
8	1992	1142	2.12	6.67	7.04	0.37	1.89
9	1993	1573	2.92	7.04	7.36	0.32	2.16
10	1994	1942	3.61	7.36	7.57	0.21	3.29
11	1995	1767	3.28	7.57	7.48	-0.09	-7.34
12	1996	2093	3.89	7.48	7.65	0.17	4.09
13	1997	2313	4.30	7.65	7.75	0.10	6.93
14	1998	2652	4.93	7.75	7.88	0.14	5.07
15	1999	1973	3.66	7.88	7.59	-0.30	-2.34
16	2000	2009	3.73	7.59	7.61	0.02	38.33
17	2001	1457	2.71	7.61	7.28	-0.32	-2.16
18	2002	1609	2.99	7.28	7.38	0.10	6.98
19	2003	1802	3.35	7.38	7.50	0.11	6.12
20	2004	2184	4.06	7.50	7.69	0.19	3.60
21	2005	2364	4.39	7.69	7.77	0.08	8.75
22	2006	2002	3.72	7.77	7.60	-0.17	-4.17
23	2007	2245	4.17	7.60	7.72	0.11	6.05
24	2008	1858	3.45	7.72	7.53	-0.19	-3.66
25	2009	2188	4.06	7.53	7.69	0.16	4.24
26	2010	2615	4.86	7.69	7.87	0.18	3.89
27	2011	3792	7.04	7.87	8.24	0.37	1.86
28	2012	2564	4.76	8.24	7.85	-0.39	-1.77
29	2013	2331	4.33	7.85	7.75	-0.10	-7.27
30	2014	2390	4.44	7.75	7.78	0.02	27.72
Total		**53844**	**100.00**				

Top 20 Most Productive Institutions in Pollution Control Publication

Table 7: Most Top 20 Institution Contribution in Pollution Control Literature

S.No	Name of the Institution/R&D/University	TP	%	Country
1	The United States Environmental Protection Agency	688	15.68	USA
2	Tsinghua University	434	9.89	China
3	Chinese Academy of Sciences	300	6.84	China
4	Zhejiang University	232	5.29	China
5	North Carolina State University	193	4.40	USA
6	Tongji University	191	4.35	China
7	UC Berkeley	188	4.29	USA
8	Research Center for Eco-Environmental Sciences Chinese Academy of Sciences	187	4.26	China

9	Peking University	180	4.10	China
10	Beijing Normal University	179	4.08	China
11	UC Davis	177	4.03	USA
12	Imperial College London	174	3.97	UK
13	Danmarks Tekniske Universitet	165	3.76	Denmark
14	National Cheng Kung University	164	3.74	Taiwan
15	Wageningen University and Research Centre	163	3.72	Netherlands
16	Chinese Research Academy of Environmental Sciences	161	3.67	China
17	Harbin Institute of Technology	159	3.62	China
18	National Taiwan University	158	3.60	Taiwan
19	University of California, Riverside	151	3.44	USA
20	Pennsylvania State University	143	3.26	USA
Total		**4387**	**100.00**	

Table-7 shows the contributions of the top 20 institutions were identified. From this study 4387(8.15%) publications were contributed by top 20 institutions. The top 20 institutions come from 5 countries; the most prolific countries were China – 9, USA – 6, Taiwan – 2 and each one in the UK, Denmark and Netherland. The top level contributions of institutions are the United States Environmental Protection Agency with a publication count of 688(15.68%) publications, followed by Tsinghua University 434(9.89%), Chinese Academy of Sciences 300(6.84%) of China.

More than 500 publications countries Vs Citations in Pollution Control

Table-8 shows that 16 countries published more than 500 publications all over the world. The contribution amounts to a total number of 40081(74.5%) papers. From this study, it is analyzed that United States contributed 1/4th of publications with 14689(27.28%) publications and 231590(38.03%) citations. Followed by China with 6564(12.19%) publications and 49833(8.18%) citations, United Kingdom 2961(5.5%) publications and 59764(9.81%) citations. The growth ratio was compared with the USA, and identified China with 0.45, the UK with 0.20 and Germany with 0.15.

Table 8: Countries published more than 500 Publications on Pollution Control

S. No	Country	TP	%	Citations	%	ROG with the USA
1	United States	14689	27.28	231590	38.03	1.00
2	China	6564	12.19	49833	8.18	0.45
3	United Kingdom	2961	5.50	59764	9.81	0.20
4	Germany	2210	4.10	31550	5.18	0.15
5	India	2062	3.83	23227	3.81	0.14
6	Canada	1986	3.69	39679	6.52	0.14
7	Japan	1494	2.77	19824	3.26	0.10
8	France	1309	2.43	21706	3.56	0.09
9	Italy	1228	2.28	19312	3.17	0.08
10	Spain	1064	1.98	21961	3.61	0.07
11	Australia	925	1.72	16166	2.65	0.06
12	Netherlands	911	1.69	20559	3.38	0.06
13	Taiwan	900	1.67	14182	2.33	0.06
14	Sweden	639	1.19	14712	2.42	0.04
15	South Korea	638	1.18	8640	1.42	0.04
16	Switzerland	501	0.93	16218	2.66	0.03
17	Others	13765	25.56			
	Total	53844	100.00			

FINDINGS AND CONCLUSION

- During the period of study, a total number of 53844 publications with 581230 citations were found. The average number of publication per year was 1795, and the compound annual growth rate was 4.30.

- It is found that 30343(56.35%) publications are cited publication and 23501(43.65%) publications were not cited.

- Based on the bibliographic analysis, a maximum of 32303 (59.99%) papers were published as an article.

- The highest no of 14827 papers are contributed by the single author. From the study, a total no of 53843 articles are published in 151523 authors. It is very clear that the multi-authored papers play a predominant role in the single author contributions. The average degree of collaboration is 0.71, Co-authorship Index is 2.694, Collaborative Coefficient is 0.435 and Multi-author collaborative coefficient is 0.435.

- A maximum number of publications were published in the 6th block 2010 – 2014 with a record count of 13692(25.43%) and place in the 1st rank. The block year wise average degree of collaboration was 0.72.

- During the study period, a total number of 53844 publications consist of 579993 citations. A maximum number of 9697(18.01%) papers had a total number of 222976(38.44%) citations and the ranges are 11-50 citations per papers.

- The RGR values are -0.39 in the year 2012 to 0.37 in the year 1992 and the Doubling time values are -11.25 in the year 1987 to 38.33 in the year 2000.

- During the selected study period 4387(8.15%) publications were contributed by top 20 institutions and that too all the institutions comes from 5 countries. Out of that, the most prolific countries are China–9 and USA–6. The United States Environmental Protection Agency contributed a maximum number of publications.

- It was identified from the study that more than 500 publications were published by 16 countries with a total number of 40081(74.5%) publications. It was further identified that 1/4th of publications were contributed by the United States with a publication count of 14689 (27.28%) and 231590(38.03%) citations.

- Much more research should encourage to the control of the pollution to developing a healthy environment at the global level to make the living beings have a pleasant atmosphere.

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