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## Pollution Control Research Output in BRIC Countries during 2006-2015 from SCOPUS Database: A Scientometric Analysis

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### Abstract

This paper analysis the pollution control research output in BRIC countries from 2006 to 2015. A total number of 8395 data's are extracted form SCOPUS international multidisciplinary bibliographic database. The data are analyzed the year wise growth of publications, document type, Countries collaboration, language wise publications, citations and the citation ranges are identified. The statistical methods and scientometric tools such as CAGR, Average Citation per Paper (AACP), Relative Citation Index, Co-Authorship Index (CAI) and Transformative Activity Index (TAI) are used for the study. Two relative indicators are the Absolute Citation Impact (ACI) and Relative Citation Impact (RCI) has been taken up to compare the quality and impact of the Pollution Control Research in BRIC countries. Finally, the highly productive journals on pollution control publications for BRIC countries are identified and ranked.

**Keyword:** *Scientometric, Pollution Control, BRIC Countries, Co-Authorship Pattern, Co-Authorship Index, Relative Citation Index, Activity Index.*

### Introduction

BRIC countries are called as "Big Four." That is a short form of grouping to the countries of Brazil, Russia, India, and China. Emerging markets notably BRIC countries now account for a quarter of world economic activity. The BRIC acronym was first used in 2001 is economist Jim O'Neill in his paper "Building Better Global Economic BRICs"[1] predict that the Big Four economies would comprise more than 10% of the global output by the end of the decade. From the beginning of Britain's Industrial Revolution in the late 18th century until the middle of the 20th century, Europe and the United States

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shaped world history and emerged as economically dominant superpowers. Asian continent accounted for the majority of world output in 18 out of last 20 centuries. In 1950, America the architect of the post-war recovery under the Marshall Plan was responsible for 27 percent of the world's GDP. In comparison, China and India accounted for just 4.5 and 4.2 per cent respectively.[2]

One of the greatest advantages of BRIC countries is most valuable natural resources. Continuing demand from the West the ambitious plans of emerging markets are driving an insatiable appetite for these natural resources, keeping demand strong. This creates opportunities for emerging markets to trade with each other, with Brazil and Russia helping to satisfy China's hunger for agricultural and other basic commodities. Additionally, emerging markets are largely free of debt problems both on government and consumer level. Their development might be interrupted by a range of short-term threats, but the long-term drivers look promising. The global economy has changed beyond recognition in the last 30 years, and in the next 30, it will change even more. Recently research activities in BRIC countries are increased in last a number years. Particularly pollution control research activities in BRIC countries are double in the last one decade. Therefore in this research paper analyze the pollution control related research output on BRIC countries during the study period. The related analysis data's are collected from SCOPUS International multidisciplinary online database.

### Review of Related Studies

**Li-Ying Yang et. al.** (2012)<sup>3</sup> analyses to compares the disciplinary structure of the G7 countries and the BRIC countries by using bibliometric methods. His paper discusses the similarity and the balance of their disciplinary structure. They found that: High S&T level countries have a similar national disciplinary structure. In recent years the disciplinary structure of the BRIC countries has become more and more similar to that of the G7 countries. The disciplinary structure of the G7 countries is more balanced than that of the BRIC countries. In the G7 countries, more emphasis goes to the life sciences, while BRIC countries focus on physics, chemistry, mathematics and engineering.

**Mukhtiar Singh and Nabi Hasan** (2014)<sup>4</sup> identified the research output of the business group countries, known as the BRICS by research papers/articles indexed in Web of Science. A total of 2552490 records were retrieved for BRICS, which is 10.67% of the global records for the twenty years' period. Further, they analyzed the annual output of research papers growth trend of the publications, country-wise individual share, collaboration pattern with global countries and amongst/within the BRICS; top-ranked

institutions, subject dispersion, and top-ranked journals.

**Elango B, Rajendran P and Manickaraj J (2013)<sup>5</sup>** retrieved the tribology research output in BRIC countries are analyzed into document type, authorship and publication pattern, growth rate, collaboration co-efficient, co-authorship index and transformative activity index are used. Further, they identified highly productive journals and ranked based on h-index.

### **Objectives of the Study**

The main objectives of the studies are identified as the following

- to analyze the BRIC countries publications and CAGR
- to identified the document type and the impact
- to identified language wise publications
- to analyze the country wise citations and the impact
- to examined the Co–Authorship Index and Activity Index
- to identify the highly productive journals and rank

### **Methodology**

The in applied in the present study is a scientometric analysis of pollution control research publications on BRIC countries during 2006-2015 from SCOPUS international multidisciplinary indexing and abstracting database. For the present study, the following search strategy has been used in the combined field of Title, Abstractvery useand Keywords. The search key was ( (TITLE-ABS-KEY("Pollution Control")AND AFFILCOUNTRY("China") OR AFFILCOUNTRY("India") OR AFFILCOUNTRY("Russian Federation") OR AFFILCOUNTRY("Brazil") AND PUBYEAR > 2005 AND PUBYEAR < 2016)).[6]

### **Limitations**

The present study is the limit to a period of 10 years from 2006 to 2015 based on the records of pollution control research output reflected from the SCOPUS database on the BRIC countries publications.

### **Analysis and Discussion**

Year wise growth on Pollution Control Publications and CAGR on BRIC Countries

Table 1 and figure 1 shows that growth of publications and Compound Annual Growth Rate (CAGR) on BRIC countries from 2006 to 2015. The CAGR was calculated by the given below mathematical formula,[7]

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

Table 1 Year Wise Growth on BRIC countries Publications

Country →		Brazil	Russian	India	China	Total
S.No	Year					
1	2006	22	10	129	218	379
2	2007	33	9	111	253	406
3	2008	22	12	93	292	419
4	2009	34	10	104	440	588
5	2010	40	11	161	818	1030
6	2011	45	12	183	1300	1540
7	2012	36	1	166	710	913
8	2013	52	11	144	747	954
9	2014	41	15	168	906	1130
10	2015	45	19	165	807	1036
Total		370	110	1424	6491	8395
%		4.41	1.31	16.96	77.32	
CAGR %		<b>52.93</b>	<b>56.52</b>	<b>80.35</b>	<b>31.24</b>	

During the study pollution control research output in the BRIC countries, China has the highest number of 6491(77.32%) publications, followed by India 1424(16.96%), Brazil 370 (4.41%) and Russia 110(1.31%). The CAGR value on BRIC countries, India has been the highest growth rate of 80.35%, second placed in Russia (56.52%), third placed in Brazil (52.93%) and fourth placed in China (31.24%).

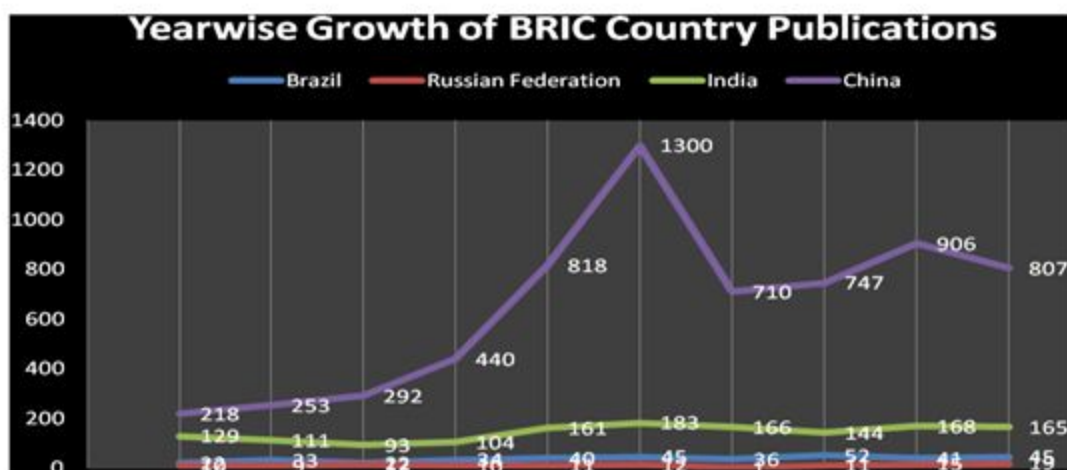


Figure 1 Year Wise Growth on BRIC Publications

### Year wise collaborated countries with BRIC countries

Table 2 Year Wise Collaborated Publications with BRIC

S. No	Year	Brazil	Russian	India	China	Total	%	TP
1	2006	8	5	11	39	63	3.04	379
2	2007	28	6	20	75	129	6.23	406
3	2008	7	7	35	93	142	6.85	419
4	2009	8	15	17	82	122	5.89	588
5	2010	11	9	28	145	193	9.31	1030
6	2011	7	15	40	186	248	11.97	1540
7	2012	19	1	43	148	211	10.18	913
8	2013	35	8	47	165	255	12.31	954
9	2014	31	32	87	228	378	18.24	1130
10	2015	17	10	51	253	331	15.97	1036
Total		171	108	379	1414	2072	100.00	8395
%		8.25	5.21	18.29	68.24	100.00	24.68	

Table 2 shows that the year wise collaborated with BRIC countries. During the study out of 8395

publications, 2072(24.68%) publications collaborate with other countries. China is the highest number of 1414(68.24%) collaborated publications, followed by India has 379(18.29%), Brazil 171 (8.25%) and Russia 108(5.21%).

### Top ten Collaborated Countries with BRIC

Top ten collaborated countries with BRIC are shows in Table 3. From the study identified the United States is the highest number of 621 collaborated publications. Followed by the United Kingdom is a 2<sup>nd</sup> placed collaborating countries on Brazil and India, Germany is a second placed on Russia and Canada is the second placed on China.[8]

Table 3 Top 10 Collaborated Countries with BRIC Publications

S. No	Brazil		Russian		India		China	
	CC	Pub.	CC	Pub.	CC	Pub.	CC	Pub.
1	United States	32	United States	11	United States	77	United States	501
2	United Kingdom	12	Germany	11	United Kingdom	31	Canada	134
3	Spain	11	United Kingdom	11	China	24	Hong Kong	124
4	Canada	10	France	7	South Korea	22	Japan	84
5	France	10	Canada	6	Germany	20	United Kingdom	78
6	Italy	9	China	5	Japan	18	Australia	72
7	Portugal	9	India	4	Canada	15	Germany	43
8	Sweden	8	Norway	4	Australia	14	Taiwan	41
9	Germany	7	Austria	3	Portugal	12	South Korea	25
10	Mexico	5	Japan	3	South Africa	9	India	24
	Others	58	Others	43	Others	137	Others	288
	<b>Total</b>	<b>171</b>		<b>108</b>		<b>379</b>		<b>1414</b>

CC = Collaborated Country, Pub. = Publications

### Bibliographic form on BRIC Countries

Table 4 Bibliographic form of BRIC Publications

S.No	Document	Brazil	Russian	India	China	TP	%	TC	%	ACI
1	Article	284	79	1100	4192	5655	67.36	56643	84.68	10.02
2	Conference Paper	65	27	197	2066	2355	28.05	1776	2.65	0.75
3	Review	14	3	91	180	288	3.43	7970	11.91	27.67
4	Note	3	0	1	12	16	0.19	154	0.23	9.63
5	Letter	2	0	4	2	8	0.10	43	0.06	5.38
6	Abstract Report	1	0	0	1	2	0.02	0	0.00	0.00
7	Editorial	1	0	12	14	27	0.32	61	0.09	2.26
8	Book	0	1	3	2	6	0.07	16	0.02	2.67
9	Book Chapter	0	0	14	14	28	0.33	6	0.01	0.21
10	Erratum	0	0	1	0	1	0.01	0	0.00	0.00
11	Short Survey	0	0	1	8	9	0.11	224	0.33	24.89
<b>Total</b>		<b>370</b>	<b>110</b>	<b>1424</b>	<b>6491</b>	<b>8395</b>	<b>100.00</b>	66893	100.00	7.97

Table 4 shows that the Bibliographic form on BRIC countries publications. During the study maximum number of 5655 (67.36%) publications are published article, followed by Conference Paper 2355(28.05%), remaining 4.59% of publications are contributed in the review, note, letter, abstract report, editorial, book, book chapter, erratum and short survey.[9]

### Language wise Publications on BRIC Countries

Table 5 shows that language wise publications on BRIC countries during the study period. Total no of 10 languages are adopted for BRIC countries publications during the 10 year study period. A maximum number of 6889 (81.89%) of publications of BRIC countries are published in the English Language, followed by 2<sup>nd</sup> position in the Chinese language has 1488(17.69%) publications. Remaining 0.42% of publications are occupied in another language like Portuguese 0.24%, French, German, Russia are each

0.04% and Spanish, Japanese are in 0.02%, Croatian and Romanian has 0.01%.

Table 5 Language wise BRIC Publications

Country →		Brazil	Russian	India	China	Total	%
S.No	Language						
1	English	355	103	1423	5008	6889	81.89
2	Portuguese	20	0	0	0	20	0.24
3	French	2	0	1	0	3	0.04
4	Spanish	2	0	0	0	2	0.02
5	German	0	3	0	0	3	0.04
6	Russian	0	3	0	0	3	0.04
7	Chinese	0	1	0	1487	1488	17.69
8	Croatian	0	1	0	0	1	0.01
9	Japanese	0	0	0	2	2	0.02
10	Romanian	0	0	0	1	1	0.01
<b>Total</b>		<b>379</b>	<b>111</b>	<b>1424</b>	<b>6498</b>	<b>8412</b>	<b>100.00</b>

### Year wise Citations Impact and Relative Citation Index on BRIC

The impacts of scientific publications are analyzed by two relative indicators namely Absolute Citation Impact and Relative Citation Impact. The Absolute Citation Impact is called as CPP, which is calculated by the average number of citations per publication. This is the most common and frequently used indicator. ACI use to compare the quality of the research on BRIC countries. On the other hand, Thomson Reuters developed RCI to calculate Science and Engineering Indicators. Chitra V studied in the field of Lung Cancer research in G7 and BRIC countries.[7]

$$RCI = \frac{\text{A Country share of total citations}}{\text{A Country share of total publications}}$$

RCI = 1 indicates that a country's citation rate equal to world citation rate.

RCI < 1 indicates a country's citation rate less than world citation rate and also reflects



RCI > 1 indicates a country's citation rate higher than world citation rate

Table 6 Year Vs Citations and RCI on BRIC Publications

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	TC	TP	ACI	RCI
<b>Brazil</b>	690	717	623	391	576	389	226	395	103	26	4136	370	<b>11.2</b>	<b>1.4</b>
<b>Russia</b>	560	42	74	169	61	56	0	70	57	8	1097	110	<b>9.97</b>	<b>1.3</b>
<b>India</b>	2655	2443	1515	2196	1309	1327	998	791	753	151	14138	1424	<b>9.93</b>	<b>1.3</b>
<b>China</b>	3590	4662	4855	6116	7065	8081	5464	3684	2972	1033	47522	6491	<b>7.32</b>	<b>0.9</b>
<b>Total</b>	7495	7864	7067	8872	9011	9853	6688	4940	3885	1218	66893	8395	<b>9.6</b>	<b>1.2</b>

Table 6 shows that year wise citations, average citation per paper and relative citation index on BRIC countries. During the study, a total number of 8395 publications are received 66893 citations. China has the highest number of 47522(71.04%) citations, followed by India 14138(21.14%) citations, Brazil 4136(6.18%) citations and Russia 1097(1.64%) citations.

From the study, Brazil has been the highest number of 11.18 Average Citation per Paper, followed by Russia 9.97, India 9.93 and China 7.32. Average Citation per paper on BRIC countries are 9.60. The Relative Citation Index on Brazil has the highest no of 1.4, Russia, and India are higher than the world average and China has been the RCI values are below the world average. The average RCI values on BRIC countries are 1.20.

#### Citations Range on Pollution Control Research Publications on BRIC Countries

Table 7 shows that, citation ranges on BRIC countries for the period of ten years. During the period, total numbers of 8395 publications with 66893 citations. Out of 8395 publications, 3476(41.30%) publications have not received any citations and remaining 4919(58.70%) publications are received different ranges of citations. The highest number of 996 publications are received a single citation, followed by 772

Table 7 Citations Range on BRIC Countries Publications

Citation Range	Number of Papers				
	Brazil	Russia	India	China	Total
0	96	49	567	2764	3476
1	46	11	155	784	996
2	29	4	80	485	598
3	21	5	66	298	390
4	13	4	61	231	309
5	13	3	47	199	262
6-10	46	16	140	570	772
11-20	50	6	128	515	699
21-50	38	10	124	450	622
51-100	11	0	37	149	197
>100	7	2	19	46	74
Total Publications	370	110	1424	6491	8395
Total Citations	4136	1097	14138	47522	66893
<b>ACPP</b>	<b>11.18</b>	<b>9.97</b>	<b>9.93</b>	<b>7.32</b>	<b>7.97</b>
<b>More than 20 citations</b>	<b>56</b>	<b>12</b>	<b>180</b>	<b>645</b>	<b>893</b>

publications are received 6-10 times citations range, 699 publications are received 11-20 times citations range, 622 publications are received 21-50 times citations range, etc. The average citations per paper are 7.97 and Brazil, Russia and India publications are received a more than average citations. [10]

### Co-authorship Pattern

The Authorship pattern and Co-Authorship Index (CAI) values are calculated by the following formula suggested by Garg and Padhi, [11,12]

$$CAI = \frac{(N_{ij} / N_{io})}{(N_{oj} / N_{oo})} \times 100$$

Where,  $N_{ij}$  = Number of publications for the particular authorship pattern for a particular country

$N_{io}$  = Total output for the particular authorship pattern

$N_{oj}$  = Total output of the particular country,  $N_{oo}$  = Total output of all the countries

CAI = 100 reveal that the number of publications corresponds to the world average,

CAI > 100 reveal higher than the world average and CAI < 100 reveal that lower than the world average.

Table 8 Co-Authorship Index on BRIC Country Publications

Authorship → Country ↓	Single	CAI	Two	CAI	Multi	CAI	Mega	CAI	Total
Brazil	9	47.05	68	112.13	65	81.80	228	108.18	370
Russian	7	123.09	13	72.10	21	88.89	69	110.12	110
India	156	211.91	434	185.94	347	113.46	487	60.04	1424
China	262	78.08	861	80.93	1370	98.27	3998	108.13	6491
<b>Total</b>	<b>434</b>		<b>1376</b>		<b>1803</b>		<b>4782</b>		<b>8395</b>

Table 8 shows that authorship pattern and Co-authorship Index (CAI) on BRIC countries. During the study, Indian authors contributions of single, two and multi authors CAI values are more than the world average & mega authors contributions 487(60.04) has been below the world average. But the mega author's publications of BRIC, expect India the CAI values are more than the world average. The same time multi authors publications of BRIC countries, expect India the CAI values are the below the world average.

### Transformative Activity Index

To identify the development of pollution control research activities among the BRIC Countries during 2006–2015. The Transformative Activity Index (TAI) recommended by Guan and Ma [13]. Mathematically

$$TAI = \frac{(C_i/C_o)}{(W_i/W_o)} \times 100$$

Here,

$C_i$  = Number of publications for a particular country in a particular year

$C_o$  = Total output for a particular country

$W_i$  = Number of publications for all countries in a particular year

$W_o$  = Total output for all countries during the study period

Table 9 shows that the TAI values on BRIC countries. During the study, the year 2006 and 2015 have been considering for analysis. From the analysis, the TAI values are increased for Brazil and China at the same time TAI values are decreased for Russia and India from 2006 to 2015. The highest TAI values for China with 8.7 and the lowest in India has -9.5. The TAI values are nearly equal to all BRIC countries on 2006 and 2015.

Table 9 TAI values on BRIC Countries

Year →	2006	TAI	2015	TAI	Change in TAI	Total
Country ↓						
<b>Brazil</b>	22	17.7	45	18.3	0.6	370
<b>Russia</b>	10	27.0	19	26.0	-1.0	110
<b>India</b>	129	26.9	165	17.5	-9.5	1424
<b>China</b>	218	10.0	807	18.7	8.7	6491
Total	379		1036			8395

Highly preferred Journals on BRIC countries publications and citations

Table 10 Highly preferred Journals on BRIC countries publications and citations

Name of the Journal	TP	Rank	TC	Rank
Advanced Materials Research	414	1	83	16
Journal of Hazardous Materials	268	2	8524	1
Applied Mechanics and Materials	214	3	32	19
Atmospheric Environment	206	4	4925	3
Environmental Science and Technology	150	5	4417	2

Environmental Monitoring and Assessment	149	6	1887	7
Chemosphere	134	7	2800	4
Science of the Total Environment	127	8	2355	4
Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering	97	9	322	12
Environmental Pollution	91	10	2072	6
Huanjing Kexue Xuebao/Acta Scientiae Circumstantiae	89	11	128	14
Journal of Cleaner Production	89	11	892	10
Water, Air, and Soil Pollution	67	12	657	11
Water Science and Technology	66	13	290	13
Research of Environmental Sciences	65	14	62	17
Huanjing Kexue/Environmental Science	63	15	98	15
Journal of Environmental Management	57	16	1083	8
Proceedings of SPIE - The International Society for Optical Engineering	56	17	4	20
Bioresource Technology	55	18	2092	5
Zhongguo Huanjing Kexue/China Environmental Science	55	18	41	18
Journal of Environmental Sciences	51	19	1000	9

Table 10 shows that highly preferred journals contributions with more than 50 publications in all BRIC countries during 2006 – 2015 has been analyzed the journals publications, citations and rank. A total no of 2563 (30.53%) publications are contributed in top 21 journals by the authors from BRIC countries have been published. A total of 33764 (50.48%) citations are received in the top 21 journals during the study period. The journals Advanced Materials Research, Journal of Hazardous Materials and Applied Mechanics and Materials are the ranked first, second and third respectively regarding a number of publications while they ranked twelve, 16,1,19 ranked based on citations.

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## Findings and Conclusion

- Pollution control research output in the BRIC countries, China has the highest number of 6491(77.32%) publications. The CAGR value on BRIC countries, India has been the highest growth rate of 80.35%.
- Out of 8395 publications, 2072(24.68%) publications collaborate with other countries. China is the highest number of 1414(68.24%) collaborated publications.
- United States is the highest number of 621 collaborating publications on BRIC countries. During the study maximum number of 5655 (67.36%) publications are published in article,
- Maximum number of 6889 (81.89%) of publications of BRIC countries are published in the English Language
- A total number of 8395 publications are received 66893 citations. China has a highest number of 47522(71.04%) citations. Brazil has been highest number of 11.18 ACI. The average RCI values on BRIC countries are 1.20.
- Out of 8395 publications, 3476(41.30%) publications have not received any citations and remaining 4919(58.70%) publications are received different ranges of citations. Highest numbers of 996 publications are received single citations.
- During the study, Indian authors contributions of single, two and multi authors CAI values are more than the world average. But the mega author's publications of BRIC, expect India the CAI values are more than the world average. The same time multi authors publications of BRIC countries, expect India the CAI values are the below the world average.
- The TAI values are increased for Brazil and China at the same time TAI values are decreased for Russia and India from 2006 to 2015. The highest TAI values for Chain with 8.7
- A total no of 2563 (30.53%) publications are contributed in top 21 journals by the authors from BRIC countries have been published. A total of 33764 (50.48%) citations are received in the top 21 journals during the study period.
- Further, the same study to be continued from the web of science, Indian Citation Index database used for various scientometric tools and compare with the present study. The comparison results are very useful for scientist and researchers to contribute more research about pollution control research and save the human live.

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