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Scientometric Analysis of Research on Emissions Control from 2007 to 2017

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Abstract
A scientometric analysis of the production of scientific publications on emissions control from 2007 to 2017 was carried out. HistCite was used to analyze information collected from Web of Science (WoS) on this topic during this period. The results suggest that scientific publications in this field have steadily increased over the years during the last decade. China is the country with the highest number of publications, and the Chinese Academy of Sciences represents the institution with the highest number of publications. Most of the papers and citations came from developed countries. The top three journals with highest number of papers in this field are Applied Physics Letter, Atmospheric Environment, and Environmental Science & Technology.

Keywords: Bibliometrics, emission control, visualization of analysis, research results.

INTRODUCTION

Climate change is currently one of the biggest worldwide environmental concerns, and according to some scientific estimations, it will continue to increase over the time [1], [2]. The demarcation of Emission Control Areas is an example of the strategies nowadays implemented to incentive cleaner industrial operations based on the reduction of greenhouse-effect gasses. It has stimulated maritime transport companies to develop new protocols to reduce their negative environmental impact since shipping activities generate anthropogenic pollutant emissions such as NOx, SOx, CO2, VOC and particulate matter [3], [4]. Such strategies are implemented during the designing, production and waste management and, in some cases, they have led to reductions up to 29.86% [5]–[7]. Greenhouse gases emitted from combustion processes in industrial facilities, wood processing, construction industry, among others, have been a subject of special interest [8]–[13].

Analysis of emission control is usually studied using dispersion models. Typically, emission rates of pollutants, as well as their initial distribution in a region are analyzed with a three-dimensional dispersion model [14]. A silicon carbide transistor used to detect and control gas emissions provided with a sensor of ammonium, and particulate detection alarm was used in a diesel exhaust [15]. Control emissions for ignition compression machines were studied at the University of West-Virginia (WVU) for future research [16]. Yangtze River Delta region is one of the most popular and prosperous regions in China facing problems with vehicle emissions and to enhance the quality of the air a study was conducted between 2000 and 2010 using a modeling interface, resulting in strategies to reduce total emissions by 2020 [17]. Marine diesel engines emit harmful particles to the environment so it is necessary to develop innovative strategies that permit their reduction [18]. Integrated Emission Management is an important control strategy to reduce operational costs using dynamic programming. A simulation study was performed using this kind of analysis for a Euro-VI engine A space-based analysis was also conducted to see the impact of the "blue APEC" phenomenon, due to emission reduction campaigns in China [19], [20]. 30 Due to poisoning accidents caused by toxic heavy metals, control methods (SCR + SMC + ESP/FFs + WFGD) of coal-fired power plants in China were analyzed, showing a reduction of 21-44% and 36.3-67.5% emissions by 2020 and 2030 respectively [21]. Controlling CO2 emissions and pollution in China will always be a common problem in global environmental analyses [22]. Using modified ash to control mercury emissions in coal-fired power plant applications in China, a study was conducted to reduce mercury emissions at a 300 MW plant, resulting in a reduction in mercury emissions of

up to 2,000 MW [23]. Through a Bilevel model and a Pareto analysis, a study was carried out to control emissions through carbon policies and generation of micro grids, obtaining a balance between green penetration, price and electricity consumption [24]. Nitric oxide appears in many diesel engine applications generate emissions to the environment through engine exhaust. Theoretical and experimental studies were made with urea-water mixture and cycle by cycle of NOx to reduce these emissions [25]–[27]. Fig. 1 shows the emissions of six illustrative scenarios of the Special Report of Emissions Scenarios (IE-EE). It also presents the frequency distribution of emissions from post IE-EE scenarios. Gas-F cover the gases HFC, PFC and SF6 [28].

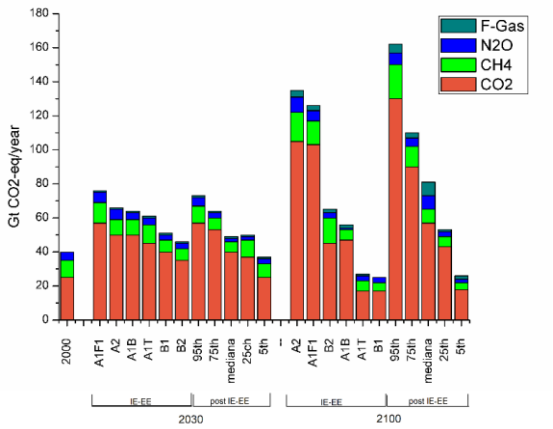

Figure 1. Global greenhouse gas emissions for 2000 and baseline emissions for 2030 and 2100 taken from the IPCC EI-EE scenarios.

Citations and research are analyzed using the HistCite tool to evaluate the trends and current status of published works in this field.

DATA SOURCES AND METHODOLOGY

Papers related to emission control were collected using Web of Science (WoS). The search was done using “emissions and control”, “emissions”, “field emission” and “spontaneous emission”. It was collected 1993 documents including journal papers, conferences, reviews, editorial material, and letters.

The information was imported into HistCite and analyzed. Data such as citations for each year, country, institution, and journal were also taken into account. High impact papers, high-impact authors, and research trends were analyzed. The software UCINET 6 with the NetDraw tool were used to create a network to visualize the citation analysis.

RESULTS AND DISCUSSIONS

Document type and language

Eight types of documents were identified in the 1993 publications. Most of these documents were papers (86.95%) indicating that this is the main model for scientific communication involving emission control. Proceedings and reviews were two important models for publishing academic achievements in this field of research.

The papers were written in 8 languages, where English had the highest percentage 98.99%. It happens because most of the papers indexed by WoS are published in English. Besides, English is accepted as the international language for all papers, proceedings, reviews, among others.

Annual research output

Figure 2 shows the production of research in each year from 2007 to 2017, according to data collected on November 8,2017. Over this period, an increasing trend has been observed, although the results between 2010 and 2012 decreased slightly. This shows a continuous concern of the scientific community on this topic throughout the last decade.

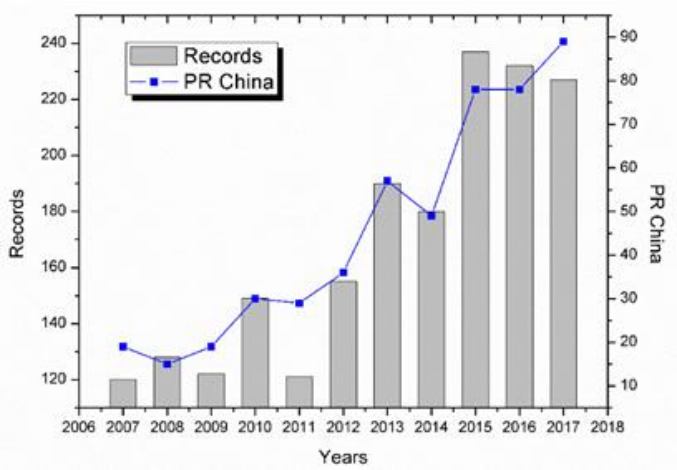

Figure 2. Annual emissions control research product from 2007 to 2017.

Analysis of the research-based distribution can help to understand a country's capacity and explore the capacity gap between several countries. A total of 73 countries have contributed to research on emissions and monitoring, indicating that this issue is attractive worldwide. From Table 1, it can be observed that the five countries that contribute the most are the following United States of America, Republic of China, Japan, Germany and the United Kingdom, whose publications represents the 71.30% of the total scientific production on this topic.

Using the local score of local citations (TLCS) it was found that China has the higher number of publications, and also the higher number of citations (42.7%). U. S. A. has 487 publications and 189 citations. Japan, United Kingdom, Germany and Canada, present 191, 133, 125 and 92 citations respectively.

Of the 73 countries analyzed, has a TLCS of 910, where 34 countries are developed and the remaining 39 are developing countries. The 34 developed countries have a total value of TLCS of 1633, at least 4 times more than developing countries.

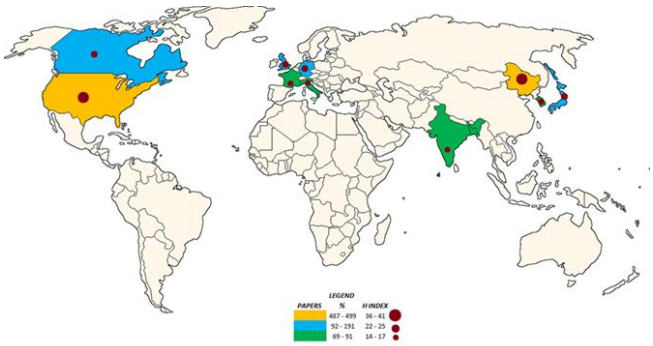

Figure 3. Worldwide distribution of countries with the highest number of papers.

TLCS represents a country's total academic influence, but cannot indicate the individual influence of a published papers. Therefore, the average number of papers citations is used as an indicator for analyzing the influence of a papers. In appreciation for and the academic impact, countries with more than 50 papers, a total of 13 countries, were chosen to calculate the average number of citations per papers.

Selected countries were ranked according to average papers citations in descending order. Table 1 shows that the top five countries are Norway, China, Denmark, Japan and Sweden. Their average citations per papers are 1.37,0.55,0.48,0.476 and 0.475 respectively. Compared to the other countries, papers from the first five countries showed a good academic impact, influencing research studies on this topic.

Table I. Ranking of results, citation score (TLCS) and TLCS/results for each country.

COUNTRY	TLCS	COUNTRY	TLCS/RECORDS
P.R. CHINA	276	NORWAY	1.37
USA	189	R.P. CHINA	0.55
JAPAN	91	DENMARK	0.48
UK	40	JAPAN	0.476
CANADA	24	SWEDEN	0.475
INDIA	22	GREECE	0.43
TAIWAN	22	NETHERLANDS	0.41
NORWAY	22	TAIWAN	0.39
GERMANY	21	USA	0.388
NETHRLANDS	19	UK	0.3

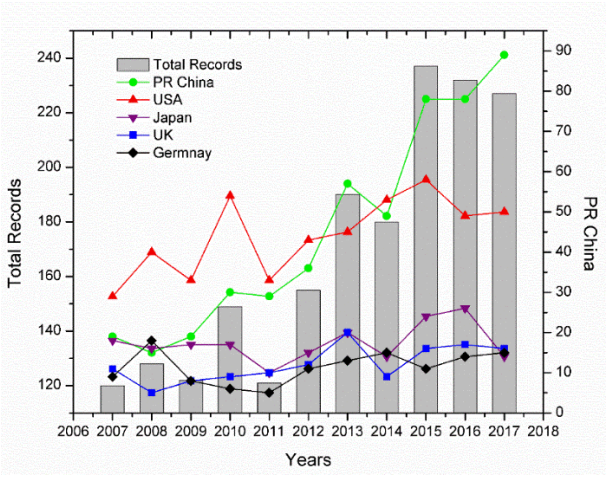

Figure 4. Total publications by country from 2007 to 2017

Distribution based on the institution of research results and citations

Institution-based distribution of research results and citations can help us to understand the research capacity and activity of institutions worldwide. It can also help us to identify each institution's research in emission control, as Table 2 shows, the institution with the most research was the Chinese Academy of Sciences, from which 72 papers were found. The following four institutions located in China and Tokyo, where Tsinghua University, Unregistered Universities and Zhejiang University, have a large number of papers related to emission control. The reason may be that China, Japan and the United States of America, being industrial countries, have a lot of scope for research on emissions and emission control.

The institution-based distribution of citations was different from the results shown in Table 1. Using TLCS as an example, the first five institutions are Tsighua University, Kyoto University, Harvard University, the Chinese Academy of Science and Huazhong University of Science and Technology, with 81, 38, 37, 35 y 28 citations respectively. Furthermore, the Chinese Research Institute Environment Sciences has only 10 published articles, even though it is not the first ten institutions with more papers, this institution has shown great academic influence in this field.

Average citations value was used in papers to explore institutions with high citations per papers. Results still differed from previous research results and dating analysis. With regard to research output and academic impact, institutions with more than 15 papers were chosen to calculate the average quote value of papers, the first five institutions were the Chinese Academy of Environmental Science Research, Beijing Technology Institution, Harvard University, Tsing Hua National University and Tsinghua University. The papers averaged by these institutions show more influence than other universities on the issue of emissions and control.

Table II. Classification of the top 10 countries of published papers, TLCS y TLCS by papers.

INSTITUTION	RECORDS	INSTITUTION	TLCS	INSTITUTION	TLCS/RECORDS
CHINESE ACAD. SCI.	72	TSINGHUA UNIV.	81	CHINESE RES. INST. ENVIRONM. SCI.	2
TSINGHUA UNIV.	50	KYOTO UNIV.	38	BEIJING INST. TECHNOL.	1.875
UNKNOWN INST.	45	HARVARD UNIV.	37	HARVARD UNIV.	1.76
ZHEJIANG UNIV.	26	CHINESE ACAD. SCI.	35	NATL TSING HUA UNIV.	1.636
KYOTO UNIV.	25	HUAZHONG UNIV. SCI. & TECHNOL.	28	TSINGHUA UNIV.	1.62
PEKING UNIV.	23	US EPA	21	KYOTO UNIV.	1.52
HUAZHONG UNIV. SCI. & TECHNOL.	22	CHINESE RES. INST. ENVIRONM. SCI.	20	HUAZHONG UNIV. SCI. & TECHNOL.	1.27
HARVARD UNIV.	21	NATL TSING HUA UNIV.	18	US EPA	1
US EPA	21	NANJING UNIV.	16	NANJING UNIV.	0.941
CNRS	20	ZHEJIANG UNIV.	16	ZHEJIANG UNIV.	0.615

Distribution of central journals and quotations

1993 papers have been published in 726 leading journals in the area of emissions and control. All journals were organized in descending order with their respective number of published papers. In terms of published papers, Applied Physics Letters papers has a total of 55 publications, with a percentage of 2.8% of the total number of journals. In reference to the TGCS, the overall total citation score, Advanced Functional Materials papers, has a score of 1329, with a percentage of 4.9% of the overall citation score.

Papers that publish more papers do not necessarily guarantee a great TLCS. For example, Applied Physics Letter papers has the largest number of published papers, but does not have a local total citation score (TLCS), such as Atmospheric Environmental papers, which has 53 published papers and a TLCS of 56, which is the second most published papers and has the largest TLCS. Along with these two journals, Environmental Science & Technology was the third with the highest TLCS score of 50. These journals, with high TLCS scores, have a greater influence on the development of research on emissions and control.

Table III. Classification of the top 6 journals of published papers, TLCS y TLCS by papers

JOURNAL	RECORDS	TLCS	TGCS
APPLIED PHYSICS LETTERS	55	0	1328
ATMOSPHERIC ENVIRONMENT	53	56	799
ENVIRONMENTAL SCIENCE & TECHONOLOGY	45	50	1080
OPTICS EXPRESS	23	10	466
ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL SOCIETY	22	0	0
ENERGY & FUELS	22	5	107

The highest average citation score per papers is in Nature Photonics papers, which produces 7 citations per papers, followed by Advanced Materials and Atmospheric Chemistry and Physics, whose average citations per papers are 2 and 1.84, respectively

Table IV. Classification of the first ten journals with average citations by papers.

JOURNAL	TLCS/RECORDS	RECORDS	TLCS
NATURE PHOTONICS	7	3	21
ADVANCED MATERIALS	2	6	12
ATMOSPHERIC CHEMESTRY AND PHYSICS	1.84	19	35
APPLIED CATALYSIS B-ENVIRONMENTAL	1.67	9	15
ADVANCED FUNCTIONAL MATERIALS	1.33	9	12
ENVIRONMENTAL SCIENCE & TECHNOLOGY	1.11	45	50
ATMOSPHERIC ENVIRONMENTAL	1.05	53	56
NANO LETTERS	1	17	17
TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	0.86	15	13
JOURNAL OF THE AIR & WASTE MANAGEMENT ASSOCIATION OPTICS	0.66	18	12

High-impact papers and authors

High-impact items are selected using TLCS. From Table 5, it can be seen that they were written by 35 authors, of which Li JH wrote two by himself [29], [30]. High-impact papers were published in 8 different journals. Considering that Atmospheric Environmental has published 53 papers, while International Journal of Engine Research has published only 4 papers, it is concluded that to be a high level journal an important factor is with respect to the impact of a papers. Note that most of the high impact papers were published between 2007 and 2010, indicating that focused research needs a long time to gain acceptance and visibility.

Table V. Classification of the first eicght high impact articles.

AUTHOR	TITLE	JOURNAL	YEAR	TLCS
NODA S, FUJITA M, ASANO T	SPONTANEOUS-EMISSION CONTROL BY PHOTONIC CRYSTALS AND NANOCAVITIES	NATURE PHOTONICS	2007	21
TWIGG MV	PROGRESS AND FUTURE CHALLENGES IN CONTROLLING AUTOMOTIVE EXHAUST GAS EMISSIONS	APPLIED CATALYSIS B-ENVIRONMENTAL	2007	10
WU Y, ZHANG SJ, LI ML, GE YS, SHU JW, ET AL.	THE CHALLENGE TO NOX EMISSION CONTROL FOR HEAVY-DUTY DIESEL VEHICLES IN CHINA	ATMOSPHERIC CHEMISTRY AND PHYSICS	2007	10
WANG XD, ZHOU J, LAO CS, SONG JH, XU NS, ET AL.	IN SITU FIELD EMISSION OF DENSITY-CONTROLLED ZNO NANOWIRE ARRAYS	ADVANCED MATERIALS	2007	9
JOHNSON TV	REVIEW OF DIESEL EMISSIONS AND CONTROL	INTERNATIONAL JOURNAL OF ENGINE RESEARCH.	2009	9
ZHAO Y, DUAN L, XING J, LARSSEN T, NIELSEN CP, ET AL.	SOIL ACIDIFICATION IN CHINA: IS CONTROLLING SO2 EMISSIONS ENOUGH?	ENVIRONMENTAL SCIENCE & TECHNOLOGY	2009	9
HOLMES MJ, CHOI K, KAKO S, ARITA M, ARAKAWA Y	ROOM-TEMPERATURE TRIGGERED SINGLE PHOTON EMISSION FROM A III-NITRIDE SITE-CONTROLLED NANOWIRE QUANTUM DOT	NANO LETTERS	2014	8
LI JH	CONTROL OF SPONTANEOUS EMISSION SPECTRA VIA AN EXTERNAL COHERENT MAGNETIC FIELD IN A CYCLE-CONFIGURATION ATOMIC MEDIUM	EUROPEAN PHYSICAL JOURNAL D.	2007	8

High-impact authors were chosen using TLCS. As Table 6 shows, the author with the largest TLCS is Hao JM, who has 22 papers and a TLCS value of 66. Second and third place where He KB and Wu Y with TLCS values of 49 respectively.

Table V. Ranking of the first ten authors with high values of TLCS

AUTHOR	RECORDS	TLCS
HAO JM	22	66
HE KB	13	49
WU Y	14	49
ZHOU Y	10	38
FU LX	6	36
LIU H	14	32
NIELSEN CP	8	30
ZHAO Y	8	30
ASANO T	4	25
NODA S	4	22

Citation Visualization Analysis

HistCite was used to generate a chronological citation chart display for papers related to emission control research. As shown in Figure 5, the first 50 papers with GCS citations were selected to generate the chronological citation chart.

From Figure 5 it can be seen that the papers written by Li Zr, Behnke K., Monson and Ghirardo have a high correlation factor, compared to other papers such as those written by Sharkey, Rasulov, Hallouist, which have a low correlation factor. The article written by Monson has a greater correlation factor than many other articles, relating to articles from 2013 and beyond, such as those written by authors Li Zr, Calfapietra in 2013 and Morfopoulus in 2014. The papers published between 2007 and 2009 have a greater correlation between them, the most recent papers (2011-2016), in addition to being related to each other, retain a relationship with the papers of the aforementioned period.

In the visualization analysis of citations, institutions such as Plant Physiology and Biochemistry, their published papers are related to each other, whereas institutions such as Atmospheric Chemistry and Physics and Annals of Botany, are only related to journals that do not have many correlations, such as Geoscientific Model Development and Biology Controls Model.

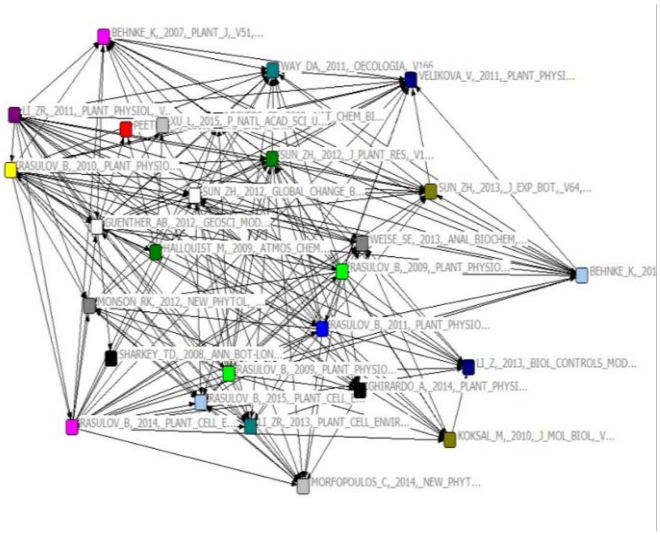

Figure 5. Chronological citation chart for emission control research.

CONCLUSIONS

In general, the trend in emission control research has increased from 2007 to 2017, which increased considerably between 2015 and 2017. These results imply that the issue of emission control plays an important role in climate change research. As the problem of climate change remains, research on emissions and emission control is expected to increase in the future.

With the exception of China and India, research was concentrated in developed countries such as United States of America, Japan, United Kingdom, Germany and Canada; however, a total of 74 countries around the world contributed to emissions control research, showing that climate change is a global problem. Many papers were published in journals with specific disciplines such as energy, environment, fuel, chemistry, although the papers accepted by these journals had more citations. Papers with high TLCS scores published in 2007 had a major impact over the next ten years on research into emission control of these.

The research had three areas of interest between 2007 and 2017. The first, focused on the impact of pollutant emissions on the problem of climate change such as pesticides, vehicle leaks, chemical waste, among others. The second, concerning pollutants, the research focused on emission control strategies, applying it to many industrial and residential applications. The latter branch focused on statistical and predictive analysis of the impact of current pollutants on external factors such as the environment, humans, among others, and innovation of emission control strategies. Research on emissions control showed an advanced understanding of the relationship between emissions control and climate change, yet many researchers do not reach consensus on certain issues.

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