

# Capturing Evolution of Research Trends in Air Pollutants and its Health Impact: A Bibliometric Approach

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## ABSTRACT

Air pollution has become one of the major problems for environment and human health. Today, both developing and developed countries are affected by air pollution, where approximately 1.1 billion people breathe unhealthy air. One out of eight deaths globally is attributed to poor quality of air. In pragmatics of development and economical advancements, the constituents responsible for poor quality of air keep on evolving, as well as have a characteristics which depends upon geographical locations and policy frameworks in that area. Consequently, the health problem associated with air pollution, also keeps on evolving with time, as new relationship are found epidemiologically, based on chronic or acute Exposure. To understand the evolution and trends of research in this field, the study analyzes scholarly publications in air pollution and its health impact with respect to evolution of pollutants and their sources using bibliometric approach; such kind of research is missing that need attention for policy formulation. Bibliometric approach has been used to study the research trends as well as contribution of authors, institutions, countries etc. This paper aims to analyze the evolution of research trend in the pollutants, its sources and the diseases over the last forty years from 1981-2020, dividing it into three phases i.e. 1981-2000, 2001-2010, 2011-2020. In the first phase the SO<sub>2</sub> was of utmost interest to public as well as researcher. Since 2001 onward focus has shifted toward particulate matter and in last decade this is more emphasized upon fine and ultra-fine particles. The presents study provides the evolution of the air pollutants along with health impacts that has moved from Asthma, pulmonary functions to COPD, and cardiovascular dysfunctions like heart rate variability and oxidative stress to eventually inflammation, blood pressure and diabetes.

**Keywords:** Air Pollution, Disease, Particulate Matter, Health Impacts, Air Pollutants.

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## INTRODUCTION

Air pollution can be described as any solid, liquid, gaseous substances are present in atmosphere in such concentration which may be injurious to human beings and other living creatures as well as harmful to property and environment.<sup>[1]</sup> Air pollution has become the leading environmental problem affecting the health of the people in both developing and developed countries. About 1.1 billion people are supposed to be exposed to bad quality of air which is unhealthy for them.<sup>[2]</sup> About 7 million deaths is being attributed to air pollution and poor air quality as per WHO(2016).<sup>[3]</sup> Air pollution is fifth highest ranking risk factor for death globally.<sup>[4]</sup> Today, the main focus remains on phasing out the fossil fuels use, which can contribute in reduction of concentration of air pollutants and mortality worldwide.<sup>[5]</sup>

Human health can have negative impacts due to air pollution on multiple organs and especially respiratory system when directly exposed to ambient air pollutants. These organs are more susceptible as they come in direct contact with outside surrounding and compared to other system in body is more vulnerable to pollutants.<sup>[6]</sup> There is a relationship established between air pollution and many respiratory diseases according to many epidemiological and mechanistic studies, which is more prevalent in patient already having morbidity like Chronic Obstructive Pulmonary Disease (COPD).<sup>[6,7]</sup> COPD is a progressive lung disease which includes characteristic symptoms of air flow limitation of respiratory track. The pollutant particle and gases along with factor such as abnormal lung development has a major association with the disease.<sup>[8]</sup> There has been a huge socio-economic burden caused by COPD, with each passing year, there is an increase in occurrence and mortality. The prevalence of the disease at global level is estimated at approximately 174 million by Global burden of disease.<sup>[4]</sup> In India, Non-Communicable Disease associated death is attributed to COPD as second most common cause which becomes more prevalent swiftly

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after 30 years of age.<sup>[9]</sup> Mahmood *et al.* studied (2017) COPD patient in Uttar Pradesh, which revealed that more than half of patient were non-smokers, indicating the role of pollution in Indo-Gangetic plain and prevalence of the disease.<sup>[10]</sup>

Exposure to high level of air pollutant particle for longer duration can increase risks of various diseases like cancer, respiratory disease and arteriosclerosis etc.<sup>[11,12]</sup> The most common accepted mechanism of health effect induced by air pollution involves inflammation and oxidative stress taking place in lungs, vascular and heart tissues.<sup>[13]</sup> Inflammation is induced as a protective mechanism as a response to injury related stimulus. The process involves production of Reactive Oxygen Species (ROS) to kill cells. Initially oxidant stress does not harm cells but induces stress defense genes which enhances resistance against any forthcoming inflammatory stress and promotes the initiations of process to repair tissues. Tissue injury is amplified by release of extra cell content.<sup>[14]</sup> The rate of ROS formation and individual antioxidant activity is unbalanced by air pollution and the oxidative stress so created leads to damage of lipids, proteins, and macromolecules in affected organs.<sup>[15]</sup>

PM<sub>2.5</sub> is most significant pollutant which has a direct and high impact on cardiovascular disability, disorder and mortality. PM<sub>2.5</sub> has no lower threshold which means it can be lethal even in smaller dose concentration.<sup>[16]</sup> The mechanism involves disruptions of endocrine system which causes metabolic disease such as diabetes and obesity which are precursor for the cardiovascular disease.<sup>[17]</sup> In terms of reduction in life expectancy cause by PM<sub>2.5</sub>, the highly polluted countries in Asia and Africa are more affected, where there is a reduction of ~1.2–1.9 years compared to global reduction in life expectancy at birth by ~1 year. Also, population which is already have some form of morbidity is more prone to the effect of air pollution, as in many polluted low and middle-income nations, where high age specific rates of cardiovascular disease is amplified.<sup>[18]</sup>

Ozone acts a protective layer in stratosphere from UV rays but troposphere ozone is not desirable from ill impact on health aspects. Ozone forms in atmosphere when oxygen comes under an electric discharge with high voltage.<sup>[19]</sup> It is also one of strong oxidant which arise a number of chain reactions in atmosphere causing smog. Ozone exposure cause damage to skins and tear ducts and due to its low solubility cause damage to lungs due to its ability to penetrate deep inside lungs.<sup>[20]</sup> It can also leads to impaired cellular functions.<sup>[21]</sup>

Due to vast negative impact on health, the R&D efforts have taken place to identify its origin, pollutants and sources of the air pollution with impact on health to mitigate the effects of air pollution. The shift of R&D efforts with shift in the pollutants, sources and the diseases has not yet discussed. The present study presents the evolution of major sources, air pollutants

and diseases using Bibliometric approach. The study will help to understand and policy planning for decision makers.

Bibliometric analysis is used as tool for understanding and bringing forth the outputs of research and publications in library and information Science. This method is now highly established way of quantifying the growth of literature for a particular subject. This can be used to investigate data related to change amount of publications, as well as helps in identifying main authors, organizations and countries working in research in various contexts. The bibliometric analysis in this area has also shown new insights (Dhital and Rupakheti (2019),<sup>[22]</sup> Sun *et al.* (2020),<sup>[23]</sup> Li *et al.* (2017).<sup>[24]</sup> Dhital and Rupakheti (2019) published a study based on Bibliometric analysis which considered both air pollution and its relationship with health.<sup>[22]</sup> The decadal shift in the research efforts in air pollution associated with diseases is missing.

The primary objective of the study is to analyze the shift of R&D efforts along with shift in pollutants, sources, and diseases with its impact on health over the last four decades. The time period is considered 1981 to 2020 keeping in mind post implementations of Stockholm conference and Air prevention and control act in 1980 in India. This study will help in understanding the trending issues like occurring diseases and causing pollutants which are reflected in research work and subsequent publications.

## MATERIALS AND METHODS

### Data Collection

For this study, Web of Science core collection was used for retrieving the data. Easy accessibility and high coverage has been the reason of selection of Web of Science, for the use of Bibliometric analysis, compared with other databases. The search were based on two keywords “Air pollution” and “Disease\*” and then search was refined as articles and review papers only and others categories were excluded such as book, minute proceeding etc. Time scale was divided into three periods, namely 1981–2000, 2001–2010 and 2011–2020.

With the keywords “Air pollution” and “Disease”, in forty-year duration since 1981 to 2020, we obtained 17160 results. After refining we obtained 13786 articles 1998 review articles which is about 80 and 11.6 percent of the publications, respectively. The remaining publications are in the form of proceeding papers, editorial meeting, meeting abstract etc. Then in each phase was refined temporally and we obtained 1135, 3112 and 11537 results in 1981–2000, 2001–2010, 2011–2020 respectively. Then the data was downloaded in plain text format and was processed and mined with help of Bibexcel, followed by network map preparation in VOSviewer. In this study, only research articles and review articles were considered. In all three time periods research articles were

more than the review articles, indicating more problem arising with time and noble work was taken.

## Methods

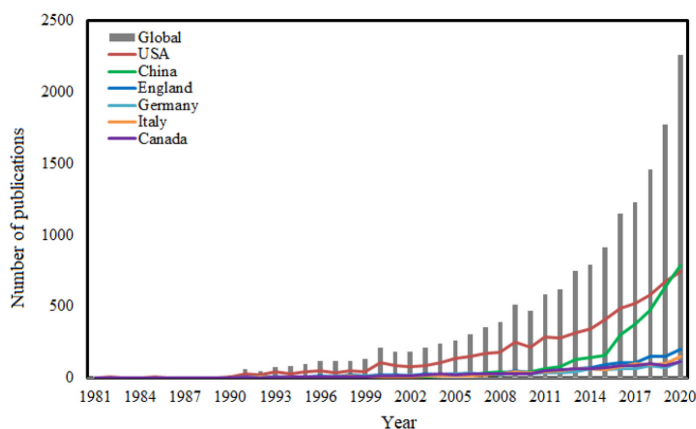
The data was exported from Web of Science, as plain text that included all the Bibliometric information including title, abstract, authors, keywords, references, and citation data which are needed for analysis. Bibexcel software was used for the data mining and preparing the data set. The data set was prepared for all three time periods. MS excel was used to prepare tables and pivot charts from the data obtained from Bibexcel. The visualization maps were prepared using VOSviewer. The network files and maps coordinates were prepared in Bibexcel and visualized using VOSviewer.

## RESULTS

### Publications Trends

Pattern of year-wise distribution of publication related to air pollution and associated diseases of the world as well as of the major leading countries have shown in Figure 1. The increasing trend in publication shows the severity of the problem and the importance of the R&D efforts due to its large impact of human health as well as other sectors like environment and economy of the countries. USA and China are major contributor in the field of air pollution and its effects on human health. The USA was the major contributor in this field till 2018 and then China has taken lead in research in this field and published highest in the year 2019 and 2020. The R&D efforts of the China has boosted after the year 2015 (Figure 1).

Overall there is an increasing trend in number of publications over the last 40 years. Since in this study, time periods is divided into three phases, as expected the maximum increase is observed in third phase (2011–2020), which contributes for almost 73.1 % research output in this field, suggesting



**Figure 1:** Publications trends on air pollution and associated disease related research for the period 1981–2020. The data is adopted from Web of Science, extracted on February 2021.

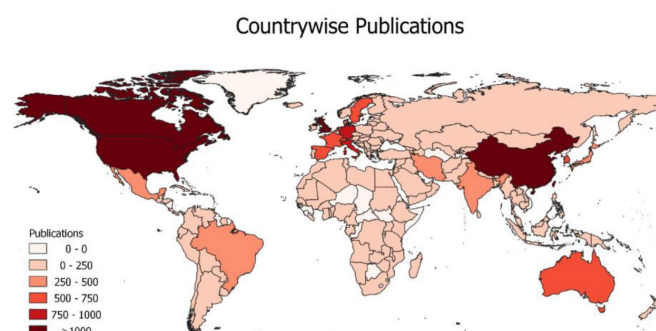
with every passing year, air pollution is becoming a major threat for human life. In year 2020, the peak production was observed, with 2263 publications which is a contribution of 14.34 percent in whole duration of study and 19.62 percent in third phase. In the early twenty years, i.e. during first phase from 1981 to 2000 less than one percent of overall research productivity was found related to air pollution and associated diseases. Research productivity was low because it was still emerging as a problem in developing countries and well as a research field. There was some fluctuation observed during 1983, 1986, 1988, 1992, and 1998, when fewer publications were produced than previous year, which can be attributed to nascent stage of research in this field. In the second phase (2001–2010), there was a steady increase in productivity apart from minor fluctuation during 2001 and 2010.

### Prolific Countries

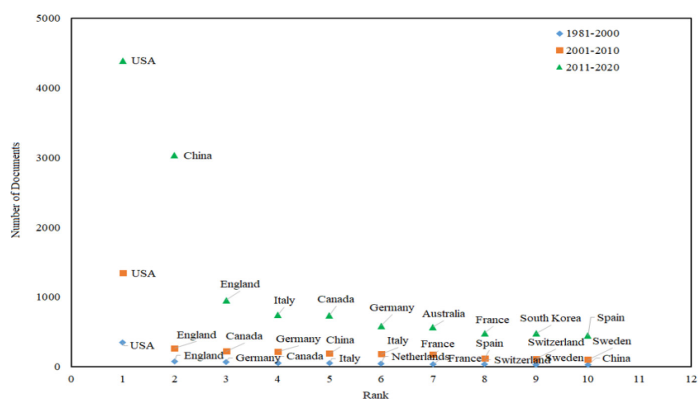
The worldwide distribution of publication is not uniform, while North America and Europe is still leading the research output, the countries from Africa, Asia Minor, Central Asia is lagging far behind despite the prospects of globalisation and exchange of information in recent times (Figure 2). The research output in the field of air pollution and its impact are very few, which is starkly low, except the exception of south Africa, Ethiopia and Egypt.

The reason for the low output is due to presence of mostly developing countries in Africa (prominently in Saharan and central Africa) lacking in infrastructure and required scientific skills. Another region which is lagging behind is central Asia, mostly those countries which were once the part of USSR, this is due to these countries are still creating the infrastructure and development in field of science as in USSR regime most of the scientific infrastructure were concentrated in Western USSR.

Figure 3 shows the ranking of top 10 major contributing countries in terms of research publications in the field of air pollution and associated diseases for three time scales 1981–



**Figure 2:** Country-wise distribution of research publications from 1981–2020.



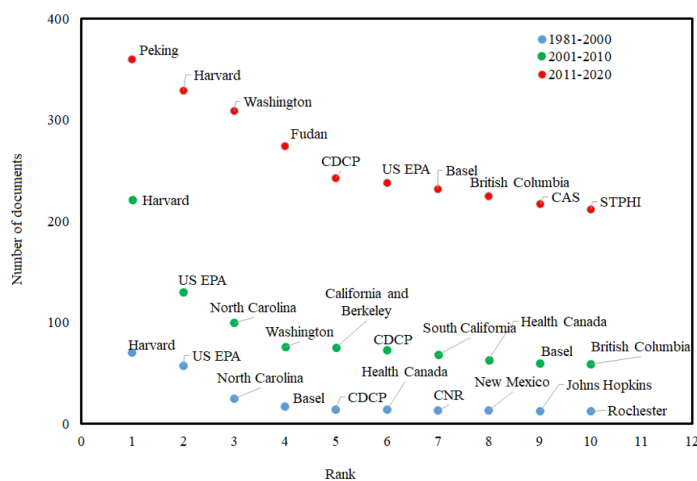
**Figure 3:** Ranking of top 10 contributing countries during the time scales 1981-2000, 2001-2010 and 2011-2020.

2000, 2001–2010 and 2011–2020. USA was leading in the production during all the three time phases. It contributed about 30.4% in early phase during 1981–2000, 43.16% of total publication during ten years between 2001 and 2010, and approx. 38% during 2011–2020. Conventionally, the developed countries have contributed more to the production of publications. The list of top countries in research production in this field is dominated by European nations in each three time period, such as England, Germany, Spain, Netherlands, France and Sweden. Other developed nations like Canada and Australia also feature in this list. The reason behind this domination is that these countries possess better quality of infrastructure as well as funding needed for conducting the research.

The most contrasting finding is the rise of People's Republic of China, whose share in research production increased from 2.25% in first phase to 6.14% in second phase and eventually to 26.31 percent in third phase during 2011–2020 (Figure 3). This supplements that in recent time China economy has become one of the largest in world and the expenditure on research and development has increased immensely. There is more focus on science technology development in the country, at the same time problems of air pollution in China has been reported more due to rapid development and urbanization and industrialization. The pollution problem in Beijing is well known and there are also some success stories of combating the problem of air pollution. This explains the increased research in this field in China. South Korea in another country from Asia which features among top ten contributors, with 4.14% share during 2011–2020.

### Prolific Institutions

The analysis of contribution of institutions in this field shows that Harvard University was one of the leading institutions in the period 1981–2000 and 2001–2010, while US EPA was second largest contributing institutions during this period (Figure 4). The USA was prominent country in first two



**Figure 4:** Ranking of top 10 contributing Institutions in terms of number of published documents for the period 1981-2000, 2001-2010 and 2011-2020.

phases with six out of top ten institutions situated there. Harvard University, US EPA and University of Carolina, were the top three institutions in both the phases. Canada, Italy, Switzerland and china had one institution each in first phase among top ten institutions contributing in the production of research publications. In second phase, Canada has two institutions namely Health Canada and University of British Columbia, while Switzerland has one, Basel University and China was represented with Centre of Disease Control and Prevention Organization.

The domination of institutions from USA was taken over by China in third phase during 2011–2020 (Figure 4). Among top ten institutions, four were from china. Peking University was at the first place with 3.12 percent of overall productivity during this time. It was followed by Harvard University and University of Washington, from USA. Overall, USA has three representations in the list. Two institutions from Switzerland and one from Canada completed the list of top ten institutions (Figure 4).

### Prolific Authors

Joel Schwartz has published the most number of documents in the field of air pollution and disease over the whole study period between 1981 and 2020. He has worked on epidemiology with major focus on consequences of exposure to pollutants. Also, he has garnered most citations which means his work is highly referred by other researcher in this field. Haidong Kan, from Fudan university is second most prolific author, his major focus is air pollution and associated carcinogenicity. Christian Schindler from Columbia University is third most published author his work majorly focus on exposure assessment of air pollution and epidemiology Table 1.

Temporal analysis of performance of author show that's apart from authors who were active during all three phases like

Schwartz and Schindler, who occupies first and third overall rank, there are new author too, who have climbed the ladder quickly like Haidong Kan, who is second on the overall list, first published only during the second phase. The overall growth of new author are quite swift in most recent phase.

### Prolific Journals

The journal Environmental Health Perspectives has published most number of documents in this research field, publications from this journal are in environmental health science domain. Also, it has gathered the most number of citation over its publications. Environmental research is the second most prolific journal in this field, however its scope are including all form of environmental issues like air pollution, water

pollution and waste management. Most of the journals are publishing work in discipline of public health, environmental health, environmental and atmospheric science.

Table 2 depicts the evolution of journals in this field, the rank wise evolution of overall top ten publishing journals, shows that from 1981 to 2020 there is considerable change taken place. 4 journals were not existing in 1981–2000 phase but by 2010–2020 phase they were leading Journals, which is evident from rise of International Journal of Environmental Research and Public Health, which published most documents in 2011–2020 phase. Similarly, Plos One, a multidisciplinary journal, was not having any publication in first phase and was ranked 125 in 2001–2010 phase, emerged 7<sup>th</sup> most prominent journal. However, some the older journals have maintained their relevance like, Environmental Health Perspectives and Environmental Research remained among top 10 leading journals. The evolution, gives the notion that this field is emerging quickly and new journals are spreading from newer places.

**Table 1: Temporal analysis of author performance. The N represents the number of publications for the respective period and respective author.**

Over-All Rank	Author	Documents	1981-2000 Rank (N)	2001-2010 Rank (N)	2011-2020 Rank (N)
1	Joel Schwartz	307	1(48)	1(96)	1(163)
2	Haidong Kan	142	-	25(14)	2(128)
3	Christian Schindler	138	10(14)	2(45)	8(79)
4	Yuming Guo	101	-	1439(2)	4(99)
5	Michael Brauer,	130	881(1)	5(23)	3(106)
6	Annette Peters,	118	104(5)	3(43)	15(70)
7	Brent Coull	105	351(2)	6(25)	9(78)
8	Joel Kaufman	103	1704(1)	4(27)	10(75)
9	Petros Koutrakis	99	71(6)	259(5)	5(88)
10	Renjie Chen	87	-	272(5)	7(82)

### Evolution of Air Pollutants

The co-occurrence analysis of keywords helps us in deciphering the focal point of research over the years. In this study, the analysis will bring forth the pollutants and disease which are evolved in research trends over the years as an impact of air pollution on health. Figure 5, tabulates the most occurred pollutants in three time period namely, 1981–2000 (early phase), 2001–2010 (mid phase) and 2011–2020 (current phase) (Figure 6). Ozone was most frequent pollutant term mentioned during early phase and with time it's shifted downward in research trend, with its rank being second and third, in mid and current phase. Sulphur Dioxide is getting

**Table 2: Top 10 journals with highest number of publications and rank-wise evolution. N represents the number of documents and IF represents the impact factor.**

Overall Rank	Journals	Total documents	1981-2000 Rank (N)	2001-2010 Rank (N)	2011-2020 Rank (N)	Discipline	IF
1	Environmental Health Perspectives	665	1(84)	1(250)	5(331)	Environmental health	9.0
2	Environmental Research	555	7(26)	3(72)	2(457)	Environmental science, Environmental health	6.5
3	Science of the Total Environment	514	18(16)	10(43)	3(455)	Environmental science	7.9
4	International Journal of Environmental Research and Public Health	513	-	69(8)	1(505)	Public Health	3.4
5	Environment International	447	31(8)	41(15)	4(424)	Environmental science, Environmental health	9.6
6	Environmental Pollution	327	19(14)	34(17)	6(296)	Environmental science	8.1
7	Plos One	297	-	125(5)	7(292)	Multidisciplinary	3.7
8	Environmental Science and Pollution Research	289	-	117(6)	8(283)	Environmental science and related subject	4.2
9	Atmospheric Environment	262	30(8)	11(41)	9(213)	Atmospheric science, Environmental science	4.0
10	Environmental Health	249	-	12(37)	10(212)	Public Health	4.7



outdoor air pollution. For this study, both these types of air pollution are considered. Air pollution has been a problem emanating from beginning of 20<sup>th</sup> century, till the times of 1970s before the meeting of Stockholm conference in 1972, only when an episode like London smog of 1956, it would get due attention as need for development would overrule the policies to manage or curb it. The acceptance of air pollution as a potential health risk began in right earnest only after the 1972 meet, when countries over the world, made guidelines for prevention of air pollution. In recent time, the episodes of air pollution associated problems has increased manifold, as seen from example of china and India. In the context of growth of industrialization, urbanization, and also population, air pollution has become more prevalent in the developing countries which are experiencing the impacts on large scale. World Health Organization (WHO) recognized air pollution being one of the health emergencies. In Conference of the Parties (COP) Paris meeting held during 2015, mitigating impacts on health due to air pollution is taken as one of the goal of Sustainable development. Between 2008 and 2013, air pollution increased manifold approximated at 8 percent increase worldwide. The maximum level of urban pollution was experienced in the developing countries which are beyond the threshold by about 5-10 times limit prescribed by WHO (2016).<sup>[3]</sup> This trend analysis show that about three fourth publications has been produced 2011 onwards. This result is in sync with the study done on PM<sub>2.5</sub> trends, which reflects upon the problems of increasing pollution worldwide. In that study, it was found that problem of air pollution is not given the same focus and weight age in developing countries compared to developed ones.<sup>[25]</sup> The analysis includes 63 countries in 1981-2000 phases, when 63 countries published a minimum of one article having 18 publications on an average. Similarly 95 countries published a minimum of one article during 2001-2010 having 33 publications on average. The number of countries publishing at one article increase further to 157 during 2011-2020 publishing on average 73 articles. Indian subcontinent contribution was meager in first phase as only India had any publication during that time. Since the beginning of the new century other subcontinent nations has started to work in this field, at total of 72 documents (about 0.24 percent) in 2001-2010 phase were published while 632 documents (about 0.54 percent) in 2011-2020 phase. This is far behind the USA and China, which also indicates about the available scientific infrastructure, research and development funding as well as willingness of government to play a pivotal role.

The study of publications effectiveness in the field of research is known as citation analysis. For the estimation of this effectiveness of publications, citation analysis is considered a customary tool, despite the drawbacks of self-citations. It was found that during the citation analysis of first and second phase,

publications from USA and England were cited most number of times. While during third phase, publications from USA and China were cited most. There was strong collaboration found between the publications from USA, England and China who are among countries with highest number of citations for their publications. When institutions were considered, a total of 867 institutes were there which published at least one article during 1981-2000 and the average number of publications per institute was 1.3 publications. This means in early phase collaboration was not as strong as in later phases and also research in this area was majorly scattered around developed countries. The Harvard University carried the most research in this time period while US EPA and University of North Carolina followed. During 2001-2020, the number of institution engaged were 2865, with each publishing at least one article and on average 1.09 articles. Harvard University, US EPA and University of North Carolina leading the vast research during this phase as well. The average publication per institution fell down to 1.03, during 2011-2020 when 1110 institutes published at least one article. There has been strong links and collaboration among the top institute in this phase, with Peking University, Harvard and University of Washington leading the research.

Keywords contemplate the major ideas of authors and their work in paper, which gives basic information about trends in research areas. Whenever keywords occur together, depending on the number of publication in which they appear, a network of co-occurrence of keywords is created. Air pollution, Ozone and Asthma were the most frequent keywords during 1981-2000 ;air pollution, asthma, particulate matter during 2001-2010; air pollution, particulate matter and PM 2.5 during 2011-2020. Particulate matters include carbonaceous particles component along with associated adsorbed chemical of organic nature as well as reactive species. Nitrates, sulphates, PAC, metals like iron, copper, nickel, zinc and vanadium are included in Particulate matter.<sup>[26]</sup> Whenever there is chronic as well as acute exposure to high PM<sub>2.5</sub>, there is high risk of ischemic-cardiac disease, heart failure, as well of cerebrovascular disease. Existing morbidity like hearts disorder is further deteriorated by air pollution and its plays role in disease development.<sup>[27]</sup>

This study comes up with a fundamental outline on global research related to air pollution and its associated disease and it reflects inadequacy of publications in the region's most affected by air pollution threat. Also this study contemplate the evolving trends of diseases, till now the major focus has been on respiratory disease in early phase and cardio-vascular diseases in later phase but intermediate stage which eventually leads to cardio-vascular disease need to be studied in greater detail, for example diabetes under controlled experimental study. Also, some undisclosed knowledge and information

can be deciphered from doing a cause specific Bibliometric study. BIB excel is a software tool used for preparing the data for Bibliometric study from database file by processing and mining files. For preparation of mapping and visualization different software is used, most often VOSviewer and PAJEK. These show the relationship between the units of analysis.

### Strength and Limitations

In this analysis of data for last forty years, Web of Science core collection is utilized. Since the data has a sample size of 17160, manual review would take a lot of time, is not time efficient. Also, there may be some data which is not listed in the Web of Science, which otherwise would not be identified and corrected. Additionally, data related to authors, institutions and countries were cross-verified in Bibexcel, VOSviewer and web of science. Moreover, while analyzing author's data, author full name only was considered to minimize any fallacy. Still, we acknowledge despite best efforts, obtained result may not include each articles, in case full name of author is not displayed in any publication. At last, only articles published in English language are considered for this study and thus it's not able to reflect the quality work done in other languages.

### CONCLUSION

In this study, we have tried to come up with a fundamental outline of the research publications related to air pollution and its associated diseases over the last forty years. The overall sums of 15784 documents were included in all three time periods of the study, i.e. 1981–2000, 2001–2010, and 2011–2020. The trends in publication were slow and gradual increase in first phase, rapid increase in second phase and almost exponential increase in third phase. We can interpret after this bibliometric analysis that threat of air pollution has taken over the world and research related to air pollution and associated disease is still inadequate for developing countries as their contribution share is very few considering the level of pollution at places, for example the Indian subcontinent is one of the most affected region by air pollution in world but apart from India, research output is negligible in other member countries. Secondly the evolving natures of types of pollutants which are reflection of the level development of any place, the associated disease have also changes over the period of time, in the first two phases the major focus was on the asthma and respiratory disease, when SO<sub>2</sub>, NO<sub>2</sub>, Ozone were pollutant in major focus which reflect from the fact that coal use was major air pollution causing issue. In the third phase cardio vascular disease is highly associated with air pollution impacts on health as pollutant in major focus has

shifted to particulate matter especially fine particulate PM<sub>2.5</sub>. Along with cardiovascular disease, the intermediate stages like inflammation, diabetes and heart rate variability's have also increased and are reflected in co-occurrence analysis of keywords in this Bibliometric study.

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### CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

### REFERENCES

1. Central Pollution Control Board [Internet]. CPCB. [cited 2022Feb23]. Available from: <https://cpcb.nic.in/>
2. About air [Internet]. UNEP. [cited 2022Feb13]. Available from: <https://www.unep.org/explore-topics/air/about-air#:~:text=Air%20pollution%2C%20which%20kills%20an>
3. Health Organization W. Ambient air pollution: A global assessment of exposure and burden of disease. *Clean Air Journal*. 2016;26(2):6.
4. Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2019. Institute for Health Metrics and Evaluation. 2019
5. Lelieveld J, Klingmüller K, Pozzer A, Pöschl U, Fnais M, Daiber A, *et al.* Cardiovascular disease burden from ambient air pollution in Europe reassessed using novel hazard ratio functions. *European Heart Journal*. 2019;40(20):1590-6.
6. Loxham M, Davies DE, Holgate ST. The health effects of Fine Particulate Air Pollution. *BMJ*. 2019; i6609.
7. Duan R, Hao K, Yang T. Air pollution and chronic obstructive pulmonary disease. *Chronic Diseases and Translational Medicine*. 2020;6(4):260-9.
8. Vestbo J, Hurd SS, Agustí AG, Jones PW, Vogelmeier C, Anzueto A, *et al.* Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease. *American Journal of Respiratory and Critical Care Medicine*. 2013;187(4):347-65.
9. India State-level Disease Burden Initiative CRD Collaborators. The burden of chronic respiratory diseases and their heterogeneity across the states of India: The Global Burden of Disease Study 1990–2016. *The Lancet Global Health*. 2018;6(12):1363-74.
10. Mahmood T, Singh RK, Kant S, Shukla AD, Chandra A, Srivastava RK. Prevalence and etiological profile of chronic obstructive pulmonary disease in nonsmokers. *Lung India*. 2017; 34(2):122.
11. Dockery DW, Pope CA, Xu X, Spengler JD, Ware JH, Fay ME, *et al.* An association between air pollution and mortality in six U.S. cities. *New England Journal of Medicine*. 1993; 329(24):1753-9.
12. Brunekreef B, Holgate ST. Air Pollution and health. *The Lancet*. 2002;360(9341):1233-42.
13. Ghio AJ, Kim C, Devlin RB. Concentrated ambient air particles induce mild pulmonary inflammation in healthy human volunteers. *American Journal of Respiratory and Critical Care Medicine*. 2000;162(3):981-8.
14. Jaeschke H. Reactive oxygen and mechanisms of inflammatory liver injury: Present concepts. *Journal of Gastroenterology and Hepatology*. 2011;26:173-9.
15. Risom L, Møller P, Loft S. Oxidative stress-induced DNA damage by Particulate Air Pollution. *Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis*. 2005;592(1-2):119-37.
16. Rajagopalan S, Al-Kindi SG, Brook RD. Air pollution and cardiovascular disease. *Journal of the American College of Cardiology*. 2018;72(17):2054-70.
17. Hamanaka RB, Mutlu GM. Particulate matter air pollution: Effects on the cardiovascular system. *Frontiers in Endocrinology*. 2018;9.
18. Apte JS, Pant P. Toward cleaner air for a billion Indians. *Proceedings of the National Academy of Sciences*. 2019;116(22):10614-6.

19. Bezirtzoglou E, Alexopoulos A. Ozone history and ecosystems: A goliath from impacts to advance industrial benefits and interests, to environmental and therapeutical strategies. Ozone depletion, chemistry and impacts. 2009;135-45.
20. Thiele JJ, Traber MG, Tsang K, Cross CE, Packer L. *In vivo* exposure to ozone depletes Vitamins C and E and induces lipid peroxidation in epidermal layers of murine skin. *Free Radical Biology and Medicine*. 1997;23(3):385-91.
21. Hatch GE, Slade R, Harris LP, McDonnell WF, Devlin RB, Koren HS, *et al.* Ozone dose and effect in humans and rats. A comparison using oxygen-18 labeling and bronchoalveolar lavage. *American Journal of Respiratory and Critical Care Medicine*. 1994;150(3):676-83.
22. Dhital, S, Rupakheti, D. Bibliometric analysis of global research on air pollution and human health: 1998-2017. *Environmental Science and Pollution Research*. 2019;26(13):13103-14.
23. Sun J, Zhou Z, Huang J, Li G. A Bibliometric Analysis of the Impacts of Air Pollution on Children. *International Journal of Environmental Research and Public Health*. 2020.17;17(4):1277.
24. Li Y, Wang Y, Rui X, *et al.* Sources of atmospheric pollution: A bibliometric analysis. *Scientometrics*. 2017;112:1025-45
25. Yang S, Sui J, Liu T, Wu W, Xu S, Yin L, *et al.* Trends on PM2.5 research, 1997–2016: A bibliometric study. *Environmental Science and Pollution Research*. 2018;25(13):12284-98.
26. Newby DE, Mannucci PM, Tell GS, Baccarelli AA, Brook RD, Donaldson K, *et al.* Expert position paper on air pollution and cardiovascular disease. *European Heart Journal*. 2014; 36(2):83-93.
27. Xie W, Li G, Zhao D, Xie X, Wei Z, Wang W, *et al.* Relationship between fine particulate air pollution and ischaemic heart disease morbidity and mortality. *Heart*. 2014;101(4):257-63.