

Project Completion Report

“Share of ‘*Green Chemistry*’ in Indian Chemistry Journals: A Comprehensive Bibliometric Study”

Implemented by:

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Preface

Green Chemistry, which is also known as ‘**Sustainable Chemistry**’, which enable chemists to create safe, energy efficient and non-toxic chemical products and processes, without harming human health and the environment. It is a more sophisticated way of doing chemistry, aiming at preventing pollution and health problems at the chemical design stage.

Green Chemistry is more of a ‘Chemistry **FOR** the Environment’, i.e. a more environmentally friendly Chemistry rather than **Environmental Chemistry** i.e. ‘Chemistry **OF** the Environment’, that explains nature and the impact of man on the nature.

Green Chemistry is based on a set of radical ideas (a set of **12 Scientific Principles**) that overlap with the principles of sustainability and propose a modern version of chemistry that is less toxic, less hazardous, highly efficient and non-polluting.

Being Book Series Editor of ‘**Green Chemistry for Sustainability**’ Book Series of **Springer’s UK** and associated as editorial board member and reviewer for many international research journals, Sanjay K. Sharma personally feel that the use of ‘**Green Chemistry**’ and its popularization is very much required nowadays. Publication of such researches in the chemistry journals is a very useful source of spreading this awareness among the students, research scholars and faculty actively involved in research. And a systematic study of the present data will help a lot in this regard. In Science and particularly in Chemistry there is no such comprehensive bibliometric study available **SO FAR**, which can give any idea about the share of ‘Green Chemistry’ in Chemistry journals. That’s why he found this topic of proposal quite apt and important.

Acknowledgements

Doing this project- “Share of ‘*Green Chemistry*’ in Indian Chemistry Journals: A Comprehensive Bibliometric Study”, which is one of its kind in the area of Green Chemistry is really a matter of proud as well as fulfillment. I am thankful to The Head, National Science and Technology Management Information System Division (NSTMIS), Department of Science and Technology, Technology Bhawan, New Mehrauli Road, New Delhi-110016 for approving the thought and funding this project (Ref.: DST/NSTMIS/05/283/2017-18, Dated 07.12.2018). I express my heartfelt gratitude to NSTMIS for believing on this comparatively new thought and motivated me to work on it.

Also, I extend my gratitude to all the respected members of LPAC Committee for the guidance, advices, cooperation and support without which I could not able to complete this project meaningfully.

I am grateful to the Authorities of JECRC University for giving all their support and motivation. I am thankful to all my colleagues, friends and well-wishers for their never-ending motivation.

We’d really like to thank Hilary Lafoe, Senior Editor, Chemistry and Pharmaceutical Sciences, CRC Press Routledge, Taylor & Francis Group, United Kingdom for providing us the opportunity to write a book, based on this project, which has been published with the Title-“Green Chemistry in Scientific Literature: A Bibliometric Study and Research Trends”. We appreciate that she believed in us to make this book a reality.

Last but not least, its time to express our gratitude to our family, friends, colleagues and well-wishers for extending their never-ending cooperation and support during the journey of this project.

Table of Contents

| | | |
|-----|--|-------|
| 1. | Executive Summary | 1-7 |
| | <ul style="list-style-type: none">• Importance of this Study• Objectives of the Study• Methodology Details• Results and Discussions• Policy Implication, Suggestions and Recommendations | |
| 2. | Chapter-1: Introduction, Objectives, Limitations | 8-10 |
| 3. | Chapter-2: Review of Literature | 11-18 |
| 4. | Chapter-3: Methodology | 19 |
| 5. | Chapter-4: Detailed Analysis of the Data | 20-38 |
| 6. | Chapter-5: Results and Discussion | 39-56 |
| 7. | Chapter-6: Findings/ Summary and Recommendations | 57-58 |
| 8. | Research Summary/ Annotation of Project | 59-60 |
| 9. | End Project Deliverables | 61 |
| 10. | How the Outcome of this project will be beneficial to various stakeholders | 62 |
| 11. | References | 63-65 |

Executive Summary

Importance of this study

In Science and particularly in Chemistry there is no such comprehensive bibliometric study available **SO FAR**, which can give any idea about the share of ‘Green Chemistry’ in Indian Chemistry journals. That’s why I found this topic of proposal quite apt and important. I am sure, it will be a unique type of research and very interesting results are anticipated from it.

Based on the topics mentioned by NSTMIS, DST in the invitation for proposals, we found a strong need of this study. The need of Green Chemistry and its systematic implementation and study is very important for the students, research scholars and faculty actively involved in research.

Increasing industrialization is a big threat to the sustainability of the environment. In such circumstances, such studies will motivate researchers and scientists to carry out their research as per the ‘12 principals of the Green Chemistry’ and also motivate them to publish their finding in good research journals.

Ultimately, its all related with the Sustainability of environment, the growth and well-being of the mankind.

Objectives of the Study

The following objectives will be addressed in the present study:

1. To determine the geographical distributions of contributions in the journal
2. To find out Authorship Pattern
3. To find out the degree of Collaboration
4. To find out volume wise contributions
5. To find out the statistics of distributions in various fields of ‘Green Chemistry’
6. To find out the statistics of distributions of 12 Principles of ‘Green Chemistry’
7. To find out the author self-citation ratio
8. To display volume wise dispersion of references

Methodology Details

- The Indian Journals published during **1999-2020** will be taken for this study, where pure as well as applied chemistry is involved. Since, the beginning of the ‘Green Chemistry’

(i.e. 1999) till today, whatever published in Indian journals will be covered in this study to find out the share of ‘Green Chemistry’ on the research papers published so far.

- The details regarding each published article such as title of the article, number of authors, their institutional affiliations and addresses, number of references with list, page number, number of tables and figures etc., were recorded and analyzed for making observations.
- The data has been calculated and represented in tables. The citation analysis conducted by using various statistical tools and techniques.
- Data Analysis and Interpretation will be based on detailed study of :
 - Distribution of Contributions
 - Authorship Pattern
 - Degree of Collaboration
 - Subject wise distribution
 - Geographical Distribution
 - Citation Analysis
 - Distribution of Citation (Volume wise)
 - Average Citation per Paper (ACP)
 - Author Self- Citation Analysis

Results and Discussion

On the basis of the given methodology, the study carried out comprehensively and the details have been provided in a separate Chapter.

Policy Implications, Suggestions and Recommendations

1. Green Chemistry is a very new area of chemistry and relatively not much popular in higher educational institutions, therefore its required to first make people aware about this subject and its importance. Because this subject is directly related to our environment and its sustainability, which is a topic of the global concern.
2. Secondly, from this research it has been revealed that very less number of research papers have been published in Indian journals based on green chemistry. Reason is quite obvious and mentioned in point no. 1. To overcome this situation, we should motivate people to

pursue research in the area of green chemistry and encourage them to publish their work in good Indian journals. And, if they publish, it should be rightly appraised.

3. The beauty of such studies is , that it theoretical research based on your analytical skill and approach. Therefore, such bibliometric studies open a door of interdisciplinary research as well. Such type of work should be encouraged at institution level.
4. Library science may be a great helping department in such studies. We can encourage qualified librarians available in HEIs to be associated in such studies, so that they could also improve their profile and grow in their career.
5. HEIs can take help from NGOs working in the area of Environmental sustainability for better execution.
6. Such studies may be carried out on Institutional collaborative mode. So that resources could be optimizing utilized and all the stakeholders get benefited from the outcome of the study.
7. Last but not least, outcome of such studies must be published either in form of journal's articles or in form of brief book, as we published the present study from CRC Press Taylor & Francis, UK.

Chapter-1: Introduction, Objectives, Limitations

1.1 Introduction

Green Chemistry, which is also known as ‘**Sustainable Chemistry**’, which enable chemists to create safe, energy efficient and non-toxic chemical products and processes, without harming human health and the environment. It is a more sophisticated way of doing chemistry, aiming at preventing pollution and health problems at the chemical design stage. Green Chemistry is more of a ‘Chemistry **FOR** the Environment’, i.e. a more environmentally friendly Chemistry rather than **Environmental Chemistry** i.e. ‘Chemistry **OF** the Environment’, that explains nature and the impact of man on the nature. Green Chemistry is based on a set of radical ideas (a set of **12 Scientific Principles**) that overlap with the principles of sustainability and propose a modern version of chemistry that is less toxic, less hazardous, highly efficient and non-polluting. The twelve principals are as:

- 1 Prevention
- 2 Less hazardous chemical synthesis
- 3 Designing Safer Chemicals
- 4 Atom economy
- 5 Safer solvents and auxiliaries
- 6 Design for energy efficiency
- 7 Use renewable feedstocks
- 8 Reduce derivatives
- 9 Catalysis
- 10 Design for Degradation
- 11 Real-time analysis for pollution prevention
- 12 Inherently safer chemistry for accident prevention

1.2 Motivation Behind this Project

Being Book Series Editor of ‘**Green Chemistry for Sustainability**’ Book Series of **Springer’s UK** and associated as editorial board member and reviewer for many international research journals, I personally feel that the use of ‘**Green Chemistry**’ and its popularization is very much required nowadays. Publication of such researches in the chemistry journals is a very useful source

of spreading this awareness among the students, research scholars and faculty actively involved in research.

And a systematic study of the present data will help a lot in this regard. That's why I found this topic of proposal quite apt and important.

In Science and particularly in Chemistry there is no such comprehensive bibliometric study available **SO FAR**, which can give any idea about the share of 'Green Chemistry' in Indian Chemistry journals. That's why I found this topic of proposal quite apt and important. I am sure, it will be a unique type of research and very interesting results are anticipated from it.

1. NSTMIS Strengthened My Views

- Based on the topics mentioned by NSTMIS, DST in the invitation for proposals, we found a strong need of this study. The need of Green Chemistry and its systematic implementation and study is very important for the students, research scholars and faculty actively involved in research.
- Increasing industrialization is a big threat to the sustainability of the environment. In such circumstances, such studies will motivate researchers and scientists to carry out their research as per the '12 principals of the Green Chemistry' and also motivate them to publish their finding in good research journals.
- Ultimately, its all related with the Sustainability of environment, the growth and well-being of the mankind.

1.3 Objectives of the Study

The following objectives will be addressed in the present study:

9. To determine the geographical distributions of contributions in the journal
10. To find out Authorship Pattern
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12. To find out volume wise contributions
13. To find out the statistics of distributions in various fields of 'Green Chemistry'
14. To find out the statistics of distributions of 12 Principles of 'Green Chemistry'
15. To find out the author self-citation ratio
16. To display volume wise dispersion of references

1.4 Limitations of the Study

1. If we talk about limitations of this type of studies, the biggest limitation or challenge is the data is kept on changing at daily basis. Because your study depends on number of research papers, citations, contribution of authors, geographical contribution etc, its difficult to keep on record each and every thing on daily basis. If we miss anything to record, we may conclude differently.
2. Another limitation is access of complete data available Online and offline. Every institution may not have license or subscription of every journal coming under the scope of the research. Therefore, one has to be dependent of the libraries of other institutions, which is not an easy task.

Chapter-2: Review of Literature

2.1 History of Green Chemistry

- In 1999, **Royal Society of Chemistry** started publishing the very first journal focusing 12 principles, named '**Green Chemistry**' under the Editorship of Prof. James Clark.
- Since, 1999 there are many journals started publishing from the various corners of the globe focusing Green Chemistry as a main Theme or the topic in their scope.
- In India, also chemistry journals started including manuscripts focusing Green Chemistry Principles, but no systematic statistical data is available to find out the actual share of 'Green Chemistry' in Indian Chemistry Journals.
- Keeping this need in mind, we proposed the present proposal, which is based on the bibliometric analysis of 'Green Chemistry' content published in the Indian Chemistry journals published during **1999-2020(an updated Study)**.

2.2 Global Overview

To achieve the objectives of the present study w.r.t. Indian Journals, first we have to analyze the Global Scenario with respect to the followings:

1. The geographical distributions of contributions in the journal
2. The Authorship Pattern
3. The degree of Collaboration
4. The volume wise contributions
5. The author self-citation ratio
6. The volume wise dispersion of references

The study comprehends review and bibliometric features and characteristics of the research and review papers related to green chemistry. The bibliometrics analysis of 17889 scientific papers indexing in Web of Science from 1999 to 2018 was processed according to year wise and geographical wise distribution, Authorship pattern and citation, etc.

The information in the content was constructed from the literature indexed in Science Citation Index Expanded, Journal Citation Reports and Engineering Index.

The bibliometric analysis covers a year- and geographical-wise distribution of articles, year-wise authorship pattern, degree of authorship collaboration, multidisciplinary, page distribution, degree of funding, citation, organization, scientific classification, and reference.

2.3 A Bibliometric Study of Green Chemistry in Indian Journals

In many of the areas mentioned in the introduction section, the researchers focused on converting traditional processes into greener ones. The green chemistry is reviewed, and its bibliometric features were given that reveals the characteristics of the research and review papers published in Indian journals. This study comprehends the research and review papers studied on twelve principles of green chemistry, bibliometric features, and characteristics of the research papers related. The bibliometric analysis will be performed on the literature cited in the SCOPUS from 1999 to 2019. The bibliometric analysis covers mainly year wise and geographical wise distribution, Authorship pattern and citation, etc. All these data were organized, analyzed, tabulated, and presented by using simple statistical methods.

In recent years, production, manufacturing industries, and other productive activities (mining, civil engineering, etc.) should concern and provide recycling and reduction of usage of chemicals and materials, waste minimization, and less energy consumption (Ghernaout, Ghernaout, and Naceur 2011). These attitudes correspond with the concept of green chemistry, which can be described by twelve principles; preventing waste generation, increasing conversion of reactions, designing more safe chemical syntheses, chemicals, and products, utilizing non-hazardous solvents and conditions of reaction, developing energy efficiency, utilizing renewable feedstocks, escape from chemical by-products, utilizing catalysts, designing products and chemicals to diminish after use, using real-time analysis to prevent pollution and to minimize the potential for accidents (Anastas and Eghbali 2010).

In history, some disasters such as chemical gas leakage (more than 40 tons of methyl isocyanate) accident in Bhopal, India in 1984 that resulted immediate killing of at least 3,800 people, cause to understand people the meaning of environmentally friendly technology (Broughton, 2006). This tragic disaster stimulated to produce environmentally benign synthesis, usage of non-hazardous materials, control and/or prevent the pollution, etc. (Bora et al., 2002). In Japan, TiO_2 is produced with the fixation of CO_2 and decomposition of chlorofluorocarbons. In Germany, molecular oxygen, H_2O_2 , and N_2O as known as environmentally benign oxidants are started to be utilized for the synthesis of chemicals. In the UK, the researchers invented new and efficient procedures for the production of hydroquinone, $\text{C}_6\text{H}_4\text{-1,4-(OH)}_2$ utilized in manufacturing polymeric materials. In the USA, the adipic acid $(\text{CH}_2)_4(\text{COOH})_2$ is for the first time produced using enzyme catalysis

(*Escherichia coli*) from glucose (Bora et al., 2002). The abovementioned examples are some of the examples in many cases.

The share of basic, specialty, and knowledge (pharmaceuticals, agrochemicals, and biotechnology, etc.) chemicals are about 57%, 25%, and 18%, respectively in India. (Web_page2). The pharmaceutical industry expands with an annual growth rate of around 12% and is estimated to reach \$100 billion by 2025 (Vesela et al., 2018). After the chemical disaster and rapid growth in the chemical industry, India made progress in green chemistry. The Indian University Grants Commission (UGC) established the Centre for Green Technology in 2005 (Yadav, 2006). The mission of the center can be summarized as follows:

- To increase outcomes of green products and processes
- To bring together the research outcome and industry for making environmentally friendly processes and products.
- To raise awareness in public, in scientific community and society, and industry for organizing national and international forums, publications and journals and supporting projects (Web_page1).

Vesela et al., (2018) exhibited scaling and reasons for green chemistry adoption and by the Indian pharmaceutical industry. The main motivations of green chemistry adoption in Indian pharmaceutical companies - 52 generic drug pharma and Active Pharmaceutical Ingredients (API) manufacturers - are found to be 85% due to cost-saving and 73% due to environmental regulations. The results of benchmarking studies are also showed that regulatory risk and delivery of drugs are the two most significant barriers for expanding the adoption of GC in India (Vesela et al., 2018). Bibliometrics was identified as 'the application of mathematical and statistical methods to books and other communication media' by Pritchard, A. (1969) (Velmurugan and Radhakrishnan 2016). The methods of bibliometric are used to analyze, authorship, citation and publication pattern, and the relationship within scientific domains and research communities and to structure of specific fields (Vijay and Raghavan 2007; Jermann et al. 2015; Verma, Sonkar and Gupta 2015; Demir and Sharma, 2019). The analysis of papers with various statistical methods can be directive for investigation studies, features and behavior of published pieces of knowledge for investigation of the structures of research and scientific areas, and assessment of the administration of scientific information and research activity (Velmurugan and Radhakrishnan 2016).

This study comprehends bibliometric features and characteristics of the research papers related to green chemistry. The 570 Indian journals which are indexed by SCOPUS were surveyed for research and review articles about green chemistry topics between the years 1999 and 2019. The applied query was: (TS=green AND chemistry) AND DOCUMENT TYPES: (Article & Review papers) AND PUBYEAR > 1998 AND PUBYEAR < 2020). The search was made on the 5th of June 2020. 2575 research and review papers published in 125 Indian Journals (Table-1) were found from this search. These 2575 papers were extracted from 60000 research and review papers and were examined in Bibliometrix (Aria and Cuccurullo, 2017) and MS Excel program. The bibliometrics analysis of 2575 research and review papers was processed according to year wise and geographical wise distribution, Authorship pattern and citation, etc. All these data were organized, analyzed, tabulated, and presented by using simple statistical methods in Bibliometrix and MS excel.

Table 1. List of 125 Indian Journals published 2575 research and review papers about green chemistry indexed in Scopus Database (Alphabetically arranged by Title of the Journal)

| N | Title of the Journal | N | Title of the Journal |
|----------|--|----------|---|
| 1 | Advanced Materials Letters | 31 | Indian Journal of Agricultural Sciences |
| 2 | Annals of Arid Zone | 32 | Indian Journal of Agronomy |
| 3 | Annals of Biology | 33 | Indian Journal of Animal Research |
| | Annals of Tropical Medicine and Public | | |
| 4 | Health | 34 | Indian Journal of Animal Sciences |
| | Asian Biotechnology and Development | | |
| 5 | Review | 35 | Indian Journal of Biochemistry |
| | | | Indian Journal of Biochemistry and |
| 6 | Asian Journal of Chemistry | 36 | Biophysics |
| | Asian Journal of Microbiology, | | |
| | Biotechnology, and Environmental | | |
| 7 | Sciences | 37 | Indian Journal of Biotechnology |
| | Asian Journal of Pharmaceutical and | | |
| 8 | Clinical Research | 38 | Indian Journal of Chemical Technology |
| 9 | Asian Journal of Pharmaceutics | 39 | Indian Journal of Chemistry |

| | | |
|----|--|---|
| | | Indian Journal of Chemistry - Section A Inorganic, Physical, Theoretical and |
| 10 | Biochemical and Cellular Archives | 40 Analytical Chemistry |
| | | Indian Journal of Chemistry - Section B |
| 11 | Biology and Medicine | 41 Organic and Medicinal Chemistry |
| 12 | Biomedical and Pharmacology Journal | 42 Indian Journal of Environmental Health Indian Journal of Environmental |
| 13 | Biomedical Journal | 43 Protection |
| 14 | Biomedical Research | 44 Indian Journal of Experimental Biology Indian Journal of Heterocyclic |
| 15 | Biomedicine Biosciences Biotechnology Research | 45 Chemistry |
| 16 | Asia | 46 Indian Journal of Microbiology Indian Journal of Natural Products and |
| 17 | BioTechnology: An Indian Journal | 47 Resources Indian Journal of Pharmaceutical |
| 18 | Bulletin of Materials Science Bulletin of Pure and Applied Sciences - | 48 Education and Research Indian Journal of Pharmaceutical |
| 19 | Section F Geological Sciences | 49 Sciences |
| 20 | Carbon - Science and Technology | 50 Indian Journal of Pharmacology |
| 21 | Chemical Engineering World | 51 Indian Journal of Physics |
| 22 | Colourage | 52 Indian journal of public health Indian Journal of Public Health |
| 23 | Current Science | 53 Research and Development |
| 24 | Defence Science Journal | 54 Indian Journal of Technology |
| 25 | Drug Invention Today Ecology, Environment and | 55 Indian Veterinary Journal International Journal of Applied |
| 26 | Conservation | 56 Chemistry International Journal of Applied |
| 27 | E-Journal of Chemistry | 57 Engineering Research |

| | | | |
|----|--------------------------|----|---|
| 28 | IETE Journal of Research | 58 | International Journal of Applied Pharmaceutics |
| 29 | IIOAB Journal | 59 | International Journal of Chemical Sciences |
| 30 | Indian Drugs | 60 | International Journal of ChemTech Research |

Table 1. Continued.

| No. | Title of the Journal | No. | Title of the Journal |
|-----|---|-----|--|
| 61 | International Journal of Drug Development and Research | 94 | Journal of Scientific and Industrial Research |
| 62 | International Journal of Engineering and Technology | 95 | Journal of Surface Science and Technology |
| 63 | International Journal of Green Pharmacy | 96 | Journal of the Indian Chemical Society |
| 64 | International Journal of Integrative Biology | 97 | Journal of the Indian Institute of Science |
| 65 | International Journal of Pharma and BioSciences | 98 | Journal of the Institution of Engineers |
| 66 | International Journal of Pharmaceutical Quality Assurance | 99 | Journal of the Textile Association |
| 67 | International Journal of Pharmaceutical Sciences | 100 | Journal of Young Pharmacists |
| 68 | International Journal of Pharmaceutical Sciences Review and Research | 101 | Man-Made Textiles in India |
| 69 | International Journal of Pharmacognosy and Phytochemical Research | 102 | Nucleus (India) |
| 70 | International Journal of Pharmacy and Pharmaceutical Sciences | 103 | Pestology |
| 71 | International Journal of Pharmacy and Technology | 104 | Pharma Times |

| | | | |
|----|---|-----|-------------------------------------|
| | International Journal of PharmTech | | |
| 72 | Research | 105 | Pharmaceutical Reviews |
| | International Journal of Plastics | | |
| 73 | Technology | 106 | Pharmacognosy Journal |
| | International Journal of Research in | | |
| 74 | Ayurveda and Pharmacy | 107 | Pharmacognosy Magazine |
| | International Journal of Research in | | |
| 75 | Pharmaceutical Sciences | 108 | Pharmacognosy Research |
| | IPPTA: Quarterly Journal of Indian Pulp | | |
| 76 | and Paper Technical Association | 109 | Pharmacognosy Reviews |
| | Journal of Advanced Pharmaceutical | | Physiology and Molecular Biology |
| 77 | Technology and Research | 110 | of Plants |
| 78 | Journal of Applied Pharmaceutical Science | 111 | Plant Archives |
| | | | Plant Cell Biotechnology and |
| 79 | Journal of Biopesticides | 112 | Molecular Biology |
| 80 | Journal of Biosciences | 113 | Plant Physiology and Biochemistry |
| | Journal of Chemical and Pharmaceutical | | |
| 81 | Research | 114 | Pollution Research |
| | Journal of Chemical and Pharmaceutical | | Proceedings of the Indian Academy |
| 82 | Sciences | 115 | of Sciences |
| 83 | Journal of Chemical Sciences | 116 | Rasayan Journal of Chemistry |
| | | | Research and Development |
| 84 | Journal of Environmental Biology | 117 | (Barrington, Illinois) |
| | Journal of Environmental Science and | | |
| 85 | Engineering | 118 | Research Journal of Biotechnology |
| | | | Research Journal of Chemistry and |
| 86 | Journal of Food Science and Technology | 119 | Environment |
| | | | Research Journal of Pharmaceutical, |
| 87 | Journal of Global Pharma Technology | 120 | Biological and Chemical Sciences |
| | Journal of Nanomedicine and | | Research Journal of Pharmacy and |
| 88 | Nanotechnology | 121 | Technology |

| | | | |
|----|--|-----|---------------------------------|
| 89 | Journal of Natural Remedies | 122 | Research on Crops |
| | Journal of Pharmaceutical Sciences and | | |
| 90 | Research | 123 | Science, Technology and Society |
| | Journal of Pharmacy and Bioallied | | |
| 91 | Sciences | 124 | Systematic Reviews in Pharmacy |
| 92 | Journal of Pharmacy Research | 125 | Trends in Carbohydrate Research |
| 93 | Journal of Polymer Materials | | |

Chapter-3: Methodology

3.1 Coverage and Methodology

- The Indian Journals published during **1999-2020** will be taken for this study, where pure as well as applied chemistry is involved. Since, the beginning of the ‘Green Chemistry’ (i.e. 1999) till today, whatever published in Indian journals will be covered in this study to find out the share of ‘Green Chemistry’ on the research papers published so far.
- The details regarding each published article such as title of the article, number of authors, their institutional affiliations and addresses, number of references with list, page number, number of tables and figures etc., were recorded and analyzed for making observations.
- The data has been calculated and represented in tables. The citation analysis conducted by using various statistical tools and techniques.

3.2 Method of Processing and Analyzing

Data Analysis and Interpretation will be based on detailed study of :

- Distribution of Contributions
- Authorship Pattern
- Degree of Collaboration
- Subject wise distribution
- Geographical Distribution
- Citation Analysis
- Distribution of Citation (Volume wise)
- Average Citation per Paper (ACP)
- Author Self- Citation Analysis

Chapter-4: Detailed Analysis of the Data

4.1 Scientific Categories

- The 17889 scientific papers are composed of 89.4% research articles and 10.6% review papers.
- Fig.-1 presents the top 20 of the diversity of research categories in a scientific manner.
- 70% of the research was published under the subject category of ‘Chemistry’.
- The “science technology” topic was observed with 12.8% of published papers.
- The “engineering”, “material science” and “biochemistry molecular biology” categories involved 10.1%, 8.6% and 5.6% of the number of published papers respectively.

4.2 Year-wise Distribution of Articles

- Figure-2 illustrates the year-wise distribution of published research and review papers. During the years between 1999 and 2018, the concepts of green chemistry have acquired growing attention.
- In 2018, 2239 research and review papers were published in journals indexed in Science Citation Index Expanded, Journal Citation Reports and Engineering Index.
- The number of published papers was only 108 in 1999.
- From 1999 to the year 2018, the number of published papers increased approximately 20 times.
- From a different point of view, the pie chart in Fig.-2 shows that 22.7% of the papers were published before 2010 and 77.3% of the papers were issued after 2010. The results reveal that concern on the concept of green chemistry has increased rapidly.

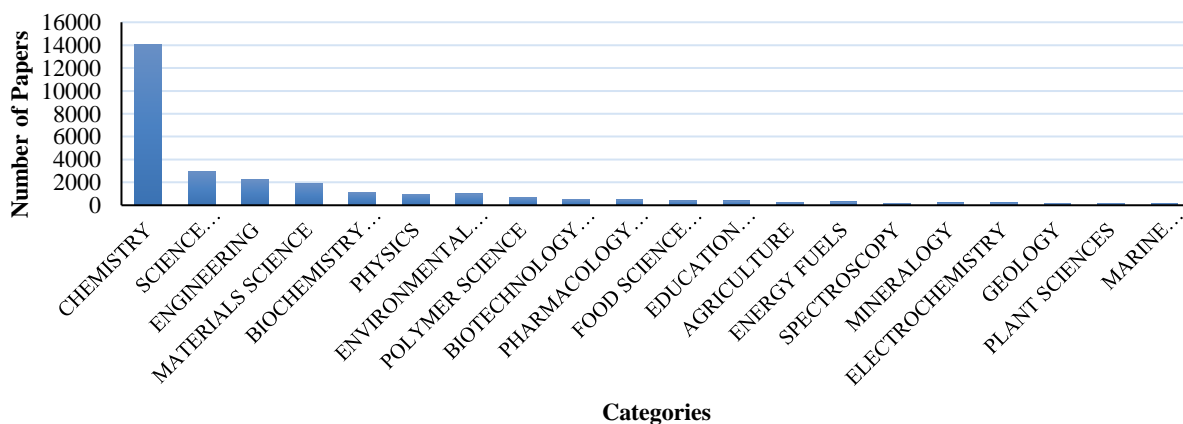


Figure-1

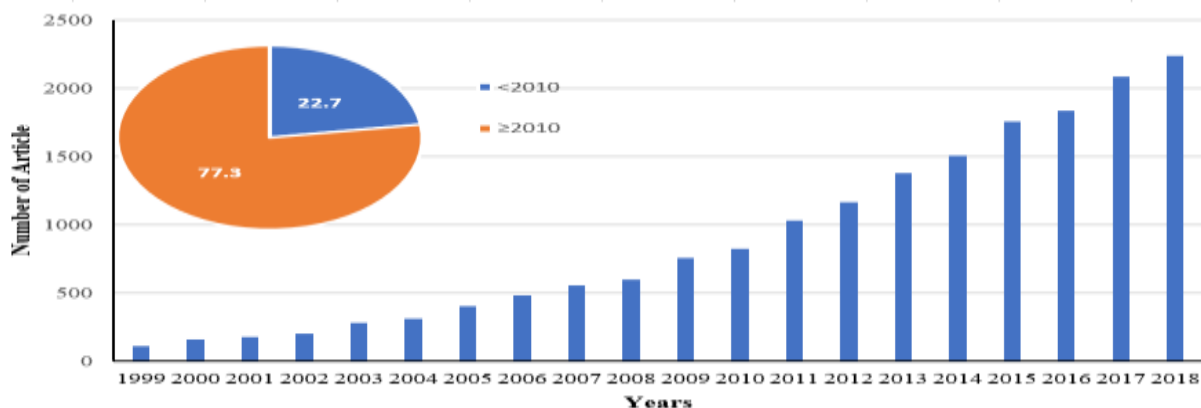


Figure-2

4.3 Geographical-wise Distribution of Green Chemistry Contributions

- 96 countries contributed to the research and review papers. The total number of contributions is 114415 involving national and international collaborations.
- The USA has made the maximum contribution to the articles with 22718 times.
- China has made 17203 contributions and India has made 7052 contributions.
- Japan and Germany are the other countries in the top five and have made 7038 and 6292 contributions, respectively.
- The total number of contributions also indicates and emphasizes that green chemistry is an interdisciplinary topic.

Table-2

| S. No. | Country | Papers |
|----------|--------------------------|-------------|
| 1 | United States of America | 22718 |
| 2 | China | 17203 |
| 3 | India | 7052 |
| 4 | Japan | 7038 |
| 5 | Germany | 6292 |
| 6 | France | 3963 |

| | | |
|----|-------------|------|
| 7 | Italy | 3172 |
| 8 | Spain | 3102 |
| 9 | Canada | 3029 |
| 10 | South Korea | 2905 |

4.4 Continent wise Distribution

- Figure-3 reveals the distribution of the number of contributions over continents.
- The highest contribution was done with 38.3% from countries in Asia. Europe provided 31.5% contribution. 23.2% contribution was made by North America.

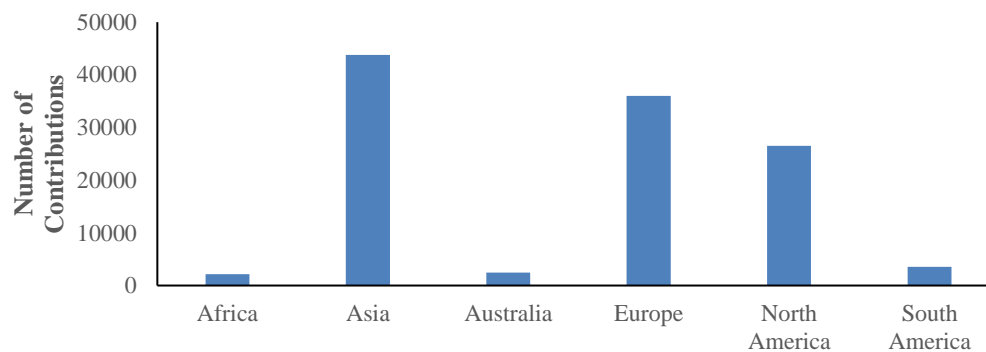


Figure-3

4.5 Authorship Pattern

- Authorship pattern of contributions is presented in Fig.-4. The single-authored paper has a minimum percentage with 5.5% that can be interpreted that the authors tend to research in collaboration.
- The maximum percentage was observed as 25.9% (4626 papers) with more than 5 authors.
- 3490 papers were studied by three authors having a 19.5% share.
- The number of four and five authors collaborations was 18.5% (3315 papers) and 15.1% (2705 papers), respectively.

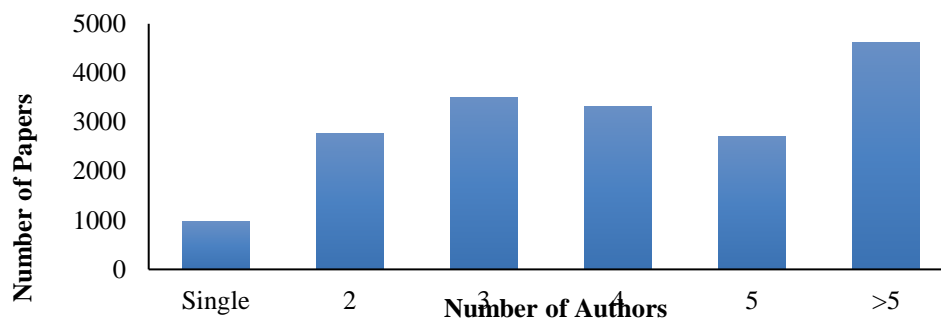


Figure-4

4.6 International Collaborations

- 42.3% of papers were researched by a single country.
- 29% of papers were made by the collaboration of two countries.
- 15.5% of papers were made by the collaboration of three countries.
- 13.2% papers were made by the collaboration of more than three countries.

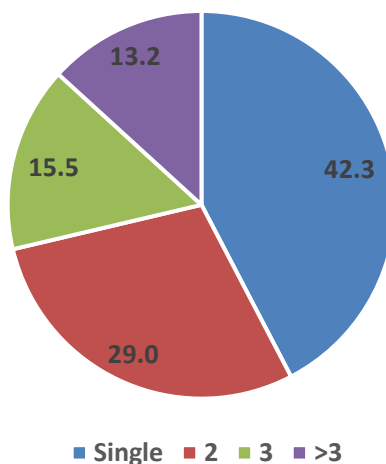


Figure-5

- As it is seen in Fig.-6, the collaboration increases sharply after 2002.
- After 2007, at least 50% of published papers were studied with collaboration. The presented results in this section reveal and prove the multidisciplinary nature of green chemistry.
- The highest collaboration percentage (65.7%) was obtained in 2018.

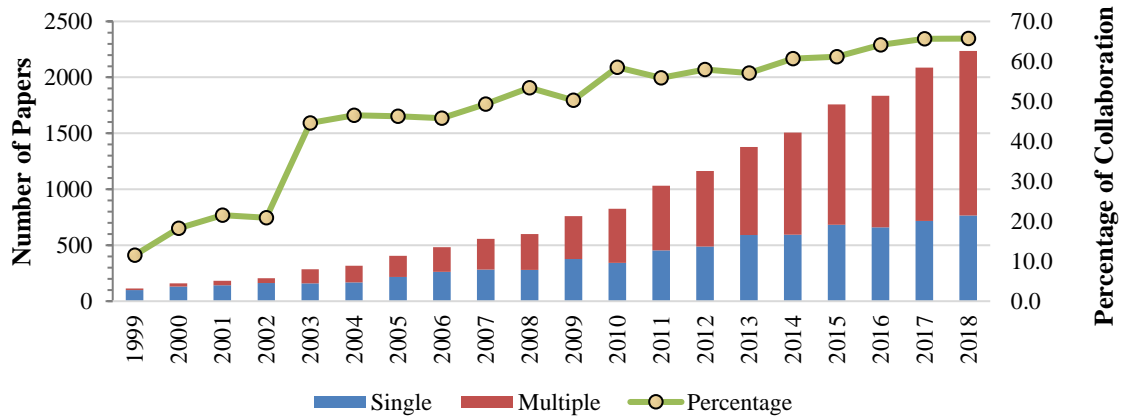


Figure-6

4.7 The Number of Pages, Citations, and References Distributions

- Figure-7 shows the distribution of a number of pages in each research and review papers.
- Most of research articles' length (8865 papers) was varied from 5-10 pages.
- 3892 papers have a length between 1-5 pages.
- and the number of papers, having the length of between 10 and 15 pages, was 3251.

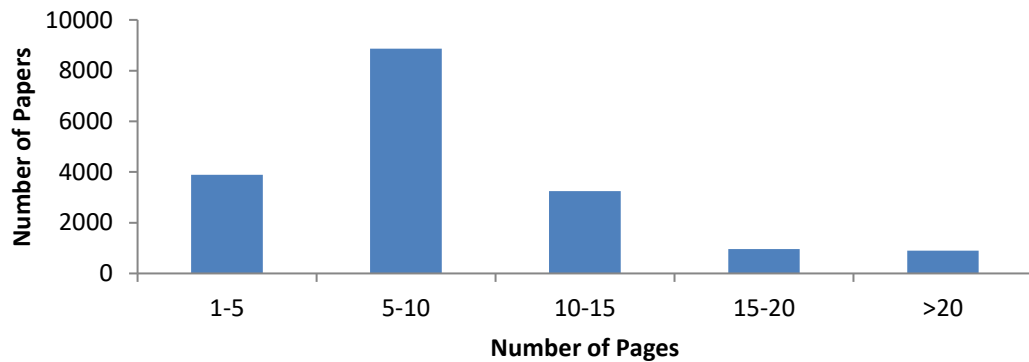


Figure-7

4.8 Number of Citations Over the Years

Figure-8 presents the number of citations over the years. The years between 2006 and 2015, the number of citations exceeds 25000 per year. The number of citations can be described as alive data which means that these data continue to increase.

4.9 Number of Papers Vs Number of Citations

- The number of papers versus the number of citation distribution was presented in Fig.-9.
- 8170 research and review papers were cited below 10 times which can be expressed as 45.7% percentage.
- The 1812 papers were not cited even once.
- 1130 papers were cited between 50 and 100 times as 6.3% percentage.
- The 824 papers were cited more than 100 times as percentage it can be defined as 4.6%.

High citation quantity can reflect the quality of research.

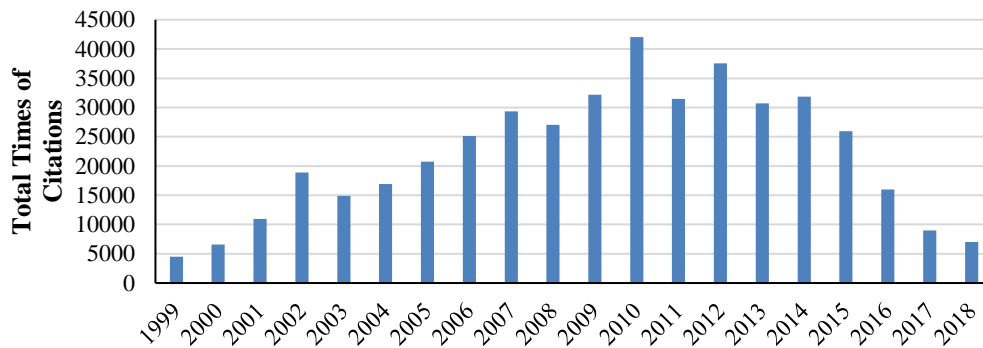


Figure-8

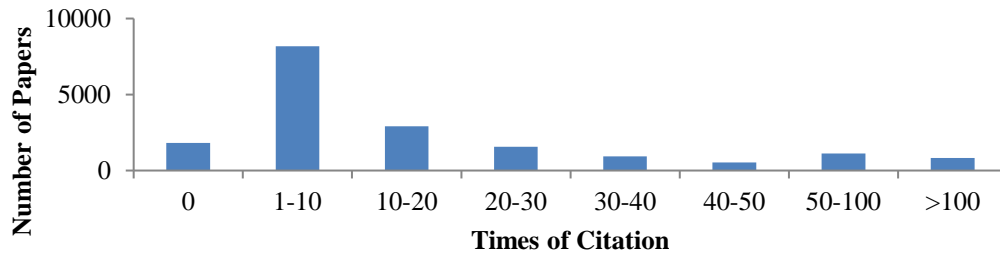


Figure-9

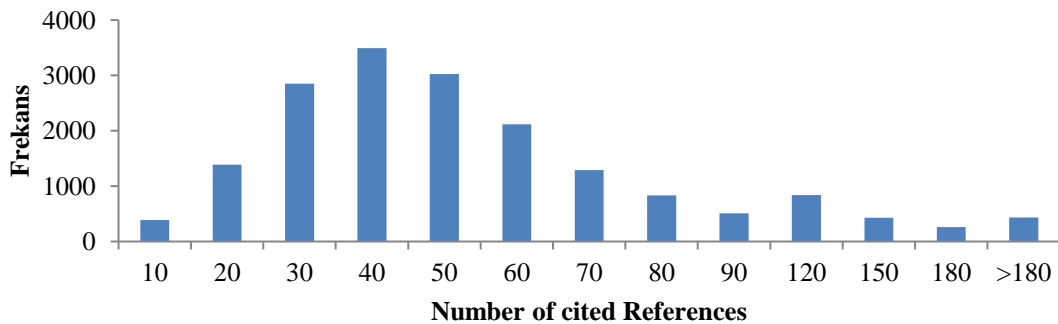


Figure-10

The histogram of the number of cited references in each paper was shown in Fig.-10. The histogram of the number of cited references distributed bimodally since the data was obtained from two different sources which are the number of research papers and review papers. As well known, the review papers were written using a high number of references. The papers were studied and/or written using between 30 and 40 cited references approximately on average. The second peak can be seen between 90 and 120 cited references.

4.10 Analysis of Organizations, Journals, Funding, and Foundation Organizations

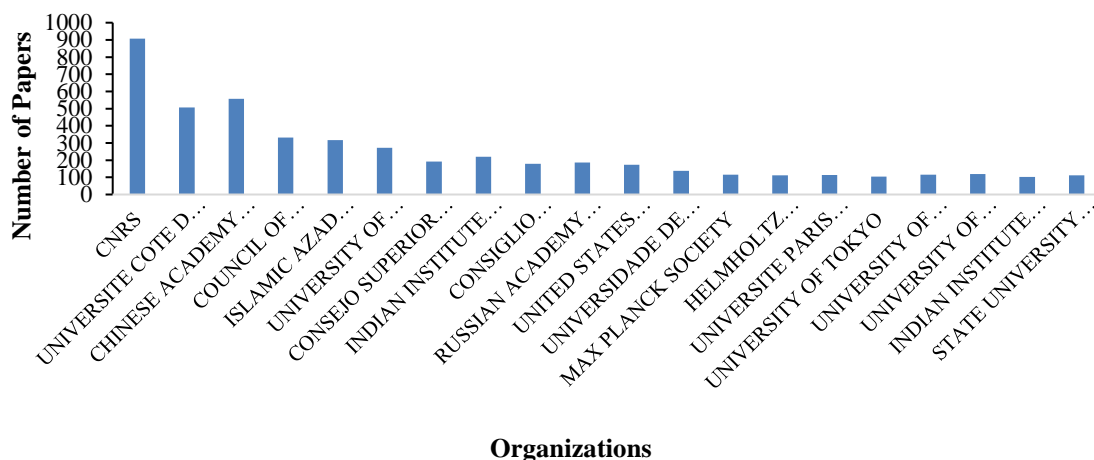


Figure-11

- Figure-11 reveals top 20 research organizations contributed to green chemistry.
- 908 published papers were studied by the contribution of CNRS (France), followed by The Chinese Academy of Sciences with 557 published papers.
- The Université Côte d'Azur (France) published 507 research and/or review papers.
- **Council of Scientific Industrial Research - CSIR (India)**, Islamic Azad University (Iran) and University of California System (USA) contribute with **331**, 217 and 272 papers, respectively.
- Figure-12 illustrates the top 20 journals that published papers related to **Green Chemistry**. The number of published papers in the top 20 journals as shown in Fig.-12 was 26.2% of the total number of published papers. In another word, every one of four papers was printed in these journals.
- This phenomenon may be because these journals reach more readers. The journal 'Green Chemistry' published 646 articles at this time. 410 papers were issued by the Royal Society of Chemistry Advances. The Tetrahedron Letters, Chemistry A European Journal and ACS

Sustainable Chemistry Engineering have printed 357, 291 and 281 research and/or review papers, respectively.

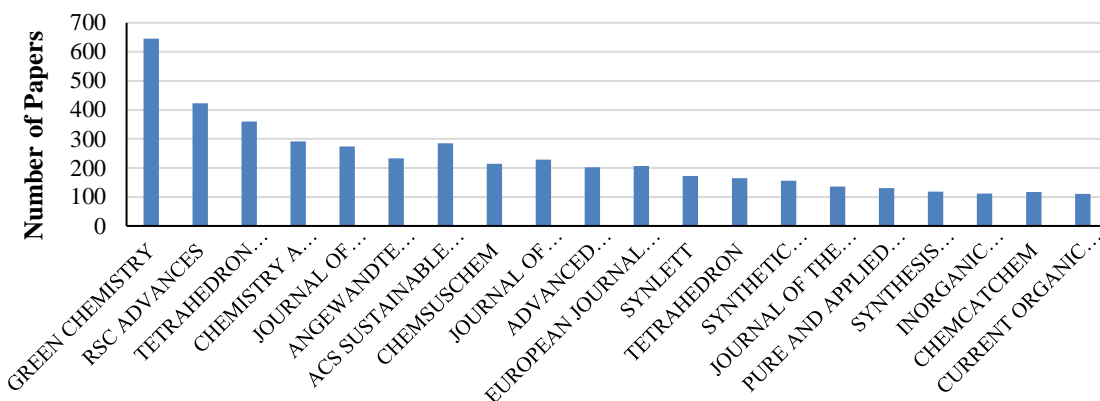


Figure-12

4.11 General Information and Year-wise Distributions

Figure- 13 presents the distribution of 2575 published research and review papers according to the years from 1999 to 2019. 2389 papers are research articles and 186 papers are review articles. 125 different Indian journals published 2575 papers and the average published papers per year is 128.75. In the last decade, the importance of green chemistry was understood by those concerned (researchers, scientists, and manufacturers, etc.). This phenomenon can be predicted by pie charts in Fig.1. 90% of published articles were published in the last decades. The number of papers increases with increasing years. The maximum number of papers (332) was published in 2015.

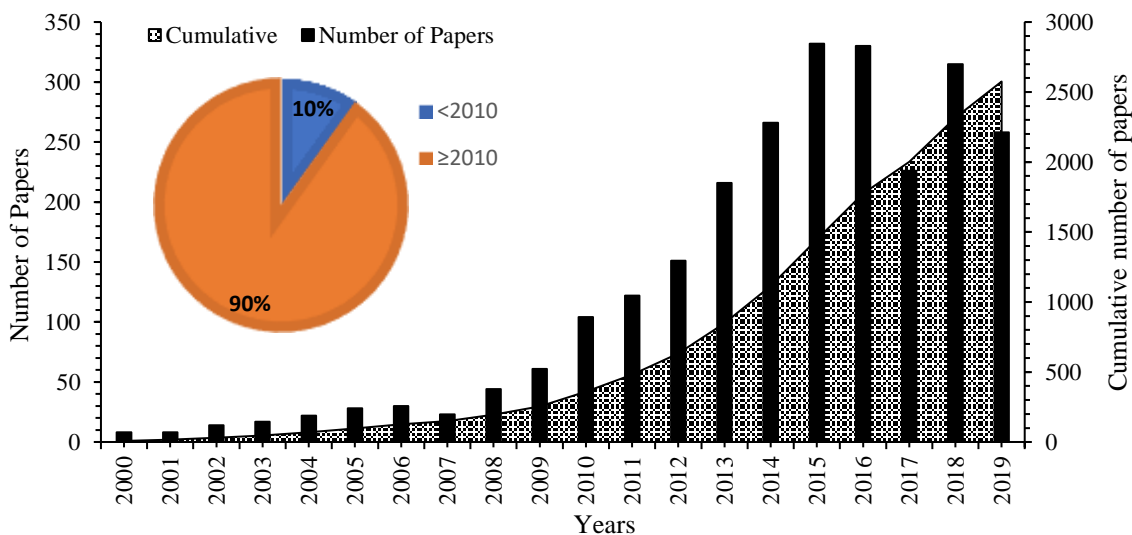


Figure-13. Year-wise distribution of the number of articles

4.12 The Frequency of Citations

The distribution of the year-wise citation score of research and review papers was shown in Fig.-14. The maximum citation scores were observed in 2015 and 2010 as 2953 and 2936 citations, respectively. The total number of citations during these years was 31381. The cumulative number of citations inherently increases with increment in years. The citation score is alive data and time needs for understanding papers' quality and published new research which cited old articles. The cumulative citation score increases with increasing years.

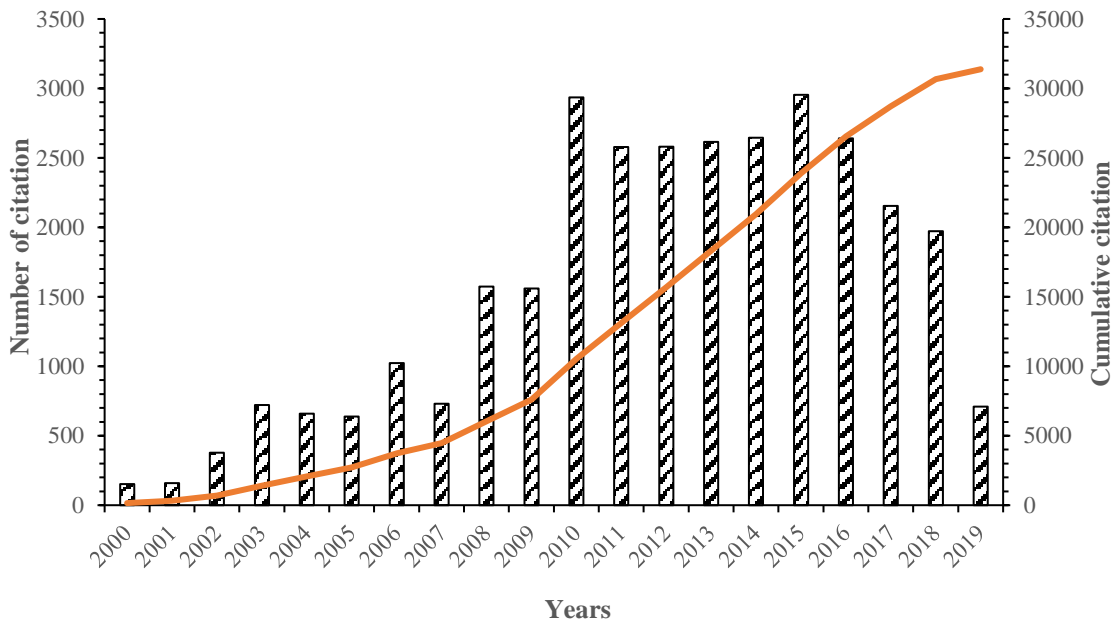


Figure-14. Year-wise citation score of papers

Figure-15 presents the distribution of the number of citations per paper (C/P) and the ratio of C/P per citable years. The citable years mean that the paper published in 2000 having 20 years till present chance for taking citation. An average citation per paper was 12.19 and the average citations per year were 1.8. The papers published in 2003 get highest the number of citations per paper with 42.5. The papers published in the last 6 years have lower the number of C/P than the average C/P. However, recently published papers have a high ratio of C/P per year which means that they obtained a high number of citations in a short time. Recent papers are promising that will obtain more and higher the number of citations than old papers.

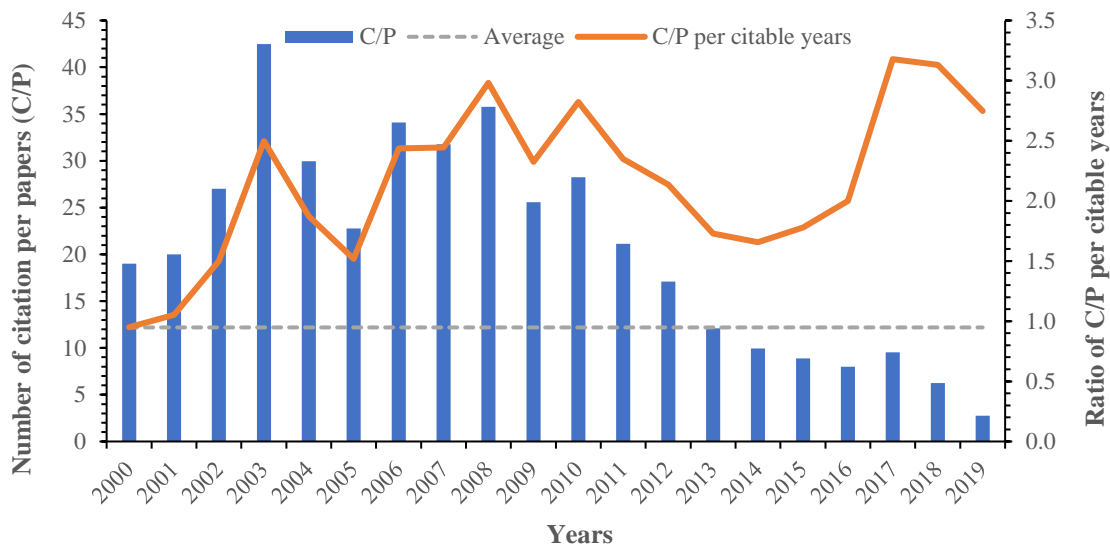


Figure-15. The number of citations per paper and ratio of C/P per citable years

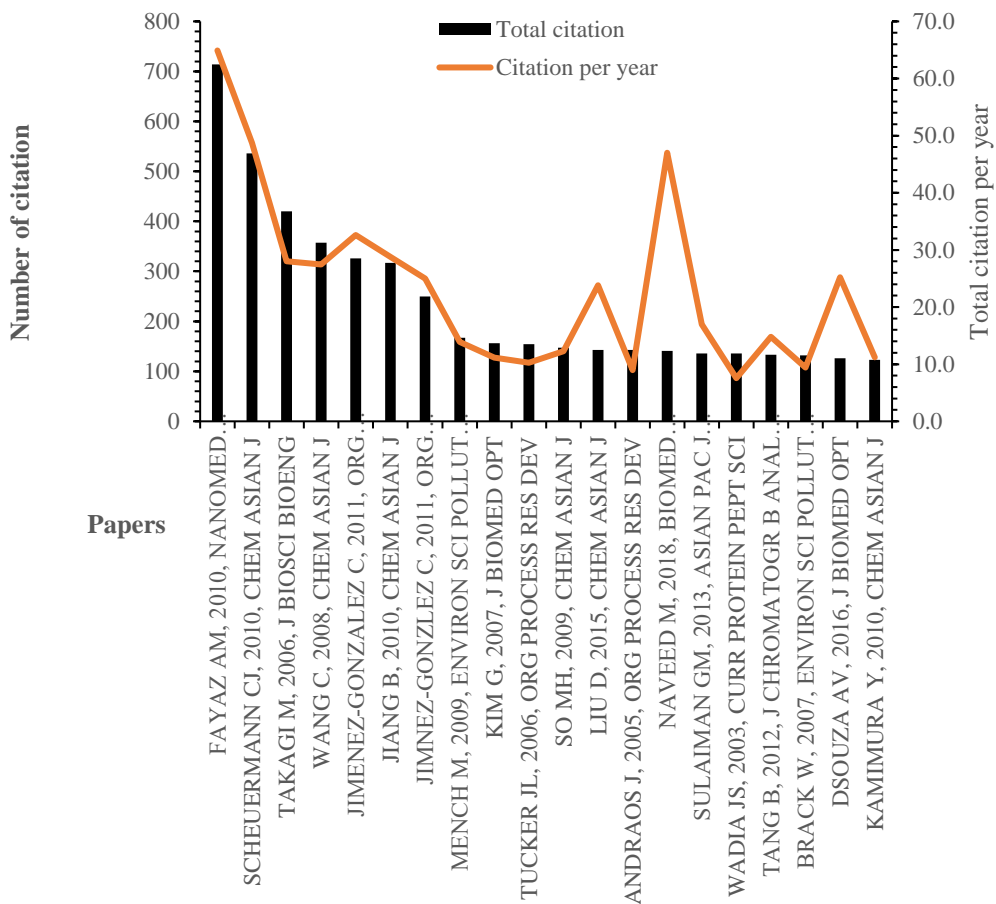


Figure-16. Top 20 most cited papers

Figure-16 reveals the most cited 20 papers and total citation per year value of these papers. The most cited article belongs to Fayaz A.M. with 714 citations published in 2010. Total citation per year values can be indicated the potential citation score of articles in the future. The total citation per year values of Fayaz (2010, research paper), Scheuermann (2010, review paper), and Naveed (2018, review paper) were observed as 64.9, 48.7, and 47.0, respectively. Article of Naveed M. published in 2018 and its total citation per year score is third-highest score among most cited 20 articles which indicates that would increase its number of citations in near future.

4.13 Authorship Pattern

Figure-17 represents the Authorship pattern of research and review papers. The 11363 Authors including repeating of some Authors studied and published 2575 research and review papers. The exact number of Authors was 7722 without any repetition. The ratio of paper per Author was 0.33. 117 research and review papers were published by 81 single Authors. The percentages of papers authored by 2, 3, and 4 Authors were 18%, 21%, and 19%, respectively. 2458 papers were written by a collaboration of 7641 Authors. A ratio of Authors per paper can give a collaboration index which was 3.11 in this case. As is abovementioned, the green chemistry topic is interdisciplinary, for that reason, 96% of papers were studied by multiple Authors.

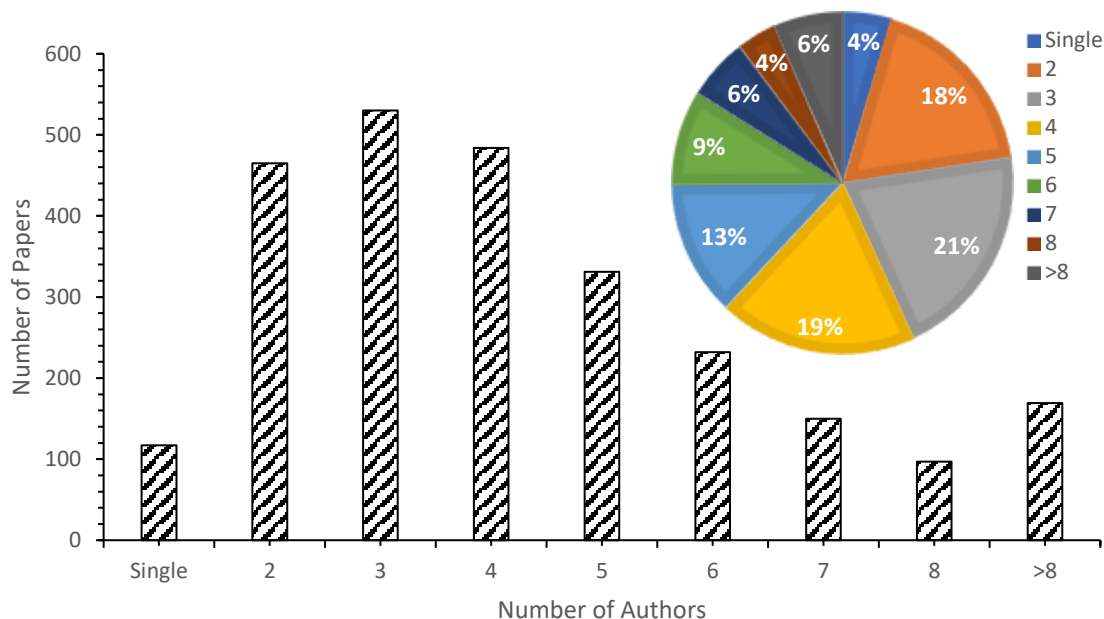


Figure-17. Authorship pattern of papers

Figure-18 illustrates the year wise collaboration index distribution and variation of authorship of papers against years. The collaboration index fluctuated before 2010 due to the low number of papers. After 2010, the collaboration index was almost steady and goes between 1.0 and 1.1.

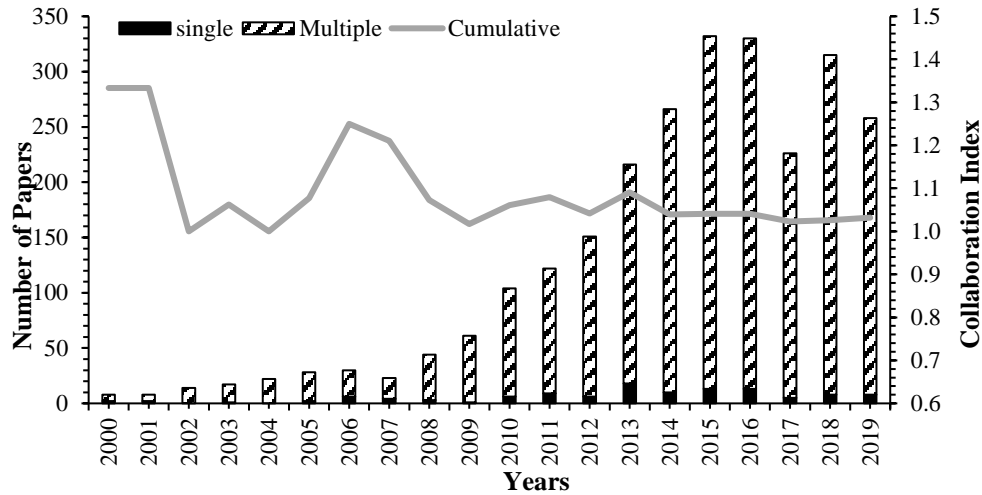


Figure-18. Year wise collaboration index and authorship of papers

Figure-19 illustrates the top 10 Authors' published research and review papers over time. Kumar S. published 46 research and review papers between 2006 and 2019 years and his papers got 452 citations during these years. Following Author is Zhang Y. published 24 papers and got 270 citations. Li J. got 202 citations with 32 published research and review papers.

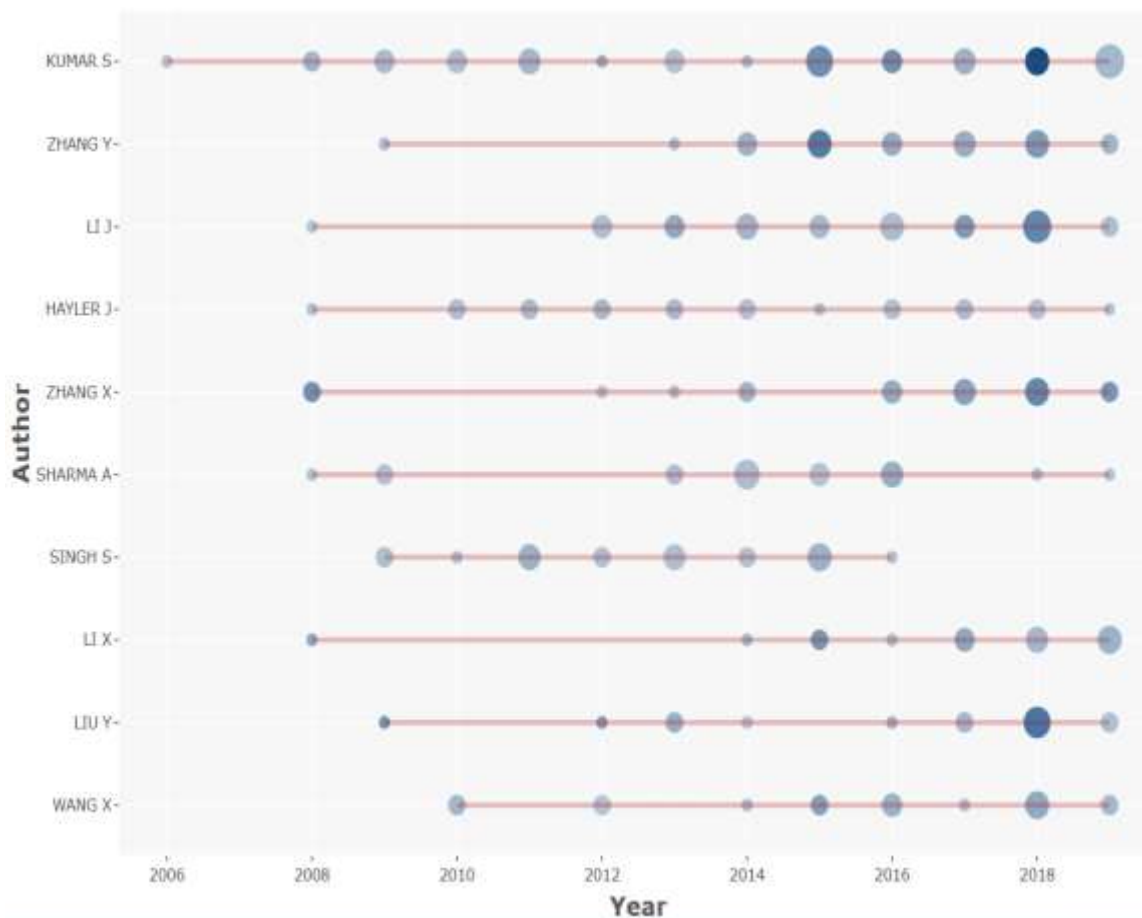


Figure-19. Top 10 Authors' production against years

4.14 Scientific Categories and Trend Topics

Figure-20 indicates trend topics as well as scientific categories of published papers. The titles of 2575 published papers were analyzed and at least 20 times repeated words were plotted against years. This analysis can give information about research trends of green chemistry. The concept of green chemistry, as well as most of its twelve principles, directly related to “chemistry”. In the year between 2011 and 2013, researchers focused on utilizing microwave and irradiation techniques, solvent-free and oxidation reactions. In recent years, the extraction method becomes prominent. Nanoparticles, oxides, and algae were trend materials that researchers mostly studied.

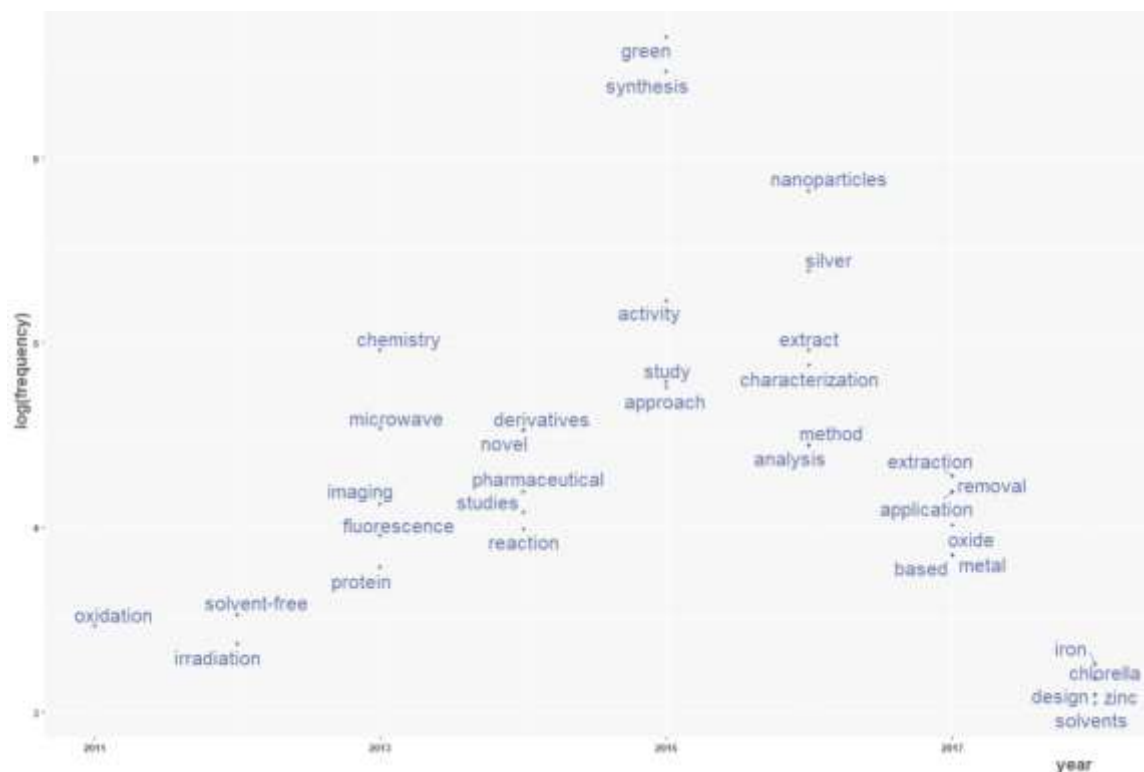


Figure-20. Trends of science categories of published papers

4.15 Top Journals and h-index

Figure-21 depicts the name of the top 10 journals that published research and review papers related to the green chemistry topic. 388 research papers were published in Environmental Science and Pollution Research journal. The top 10 journals as shown in Fig.-21 published 43.0% of all research and review papers. The research journal of pharmaceutical biological and chemical sciences journals published 220 research and review papers with 8.5% of all papers. The Journal of biomedical optics published 4.3% of 2575 that is equal to 111 papers.

Figure-22 illustrates the H index of journals publishing most articles. The *h-index* indicates that the published *h* papers have been cited at least *h* times (Hirsch, 2005). Environmental Science and Pollution Research journal have 33 *h-index*. The *h-index* of the journal of biomedical optics, chemistry and Asian journal, and organic process research and development were 31, 27, and 26, respectively.

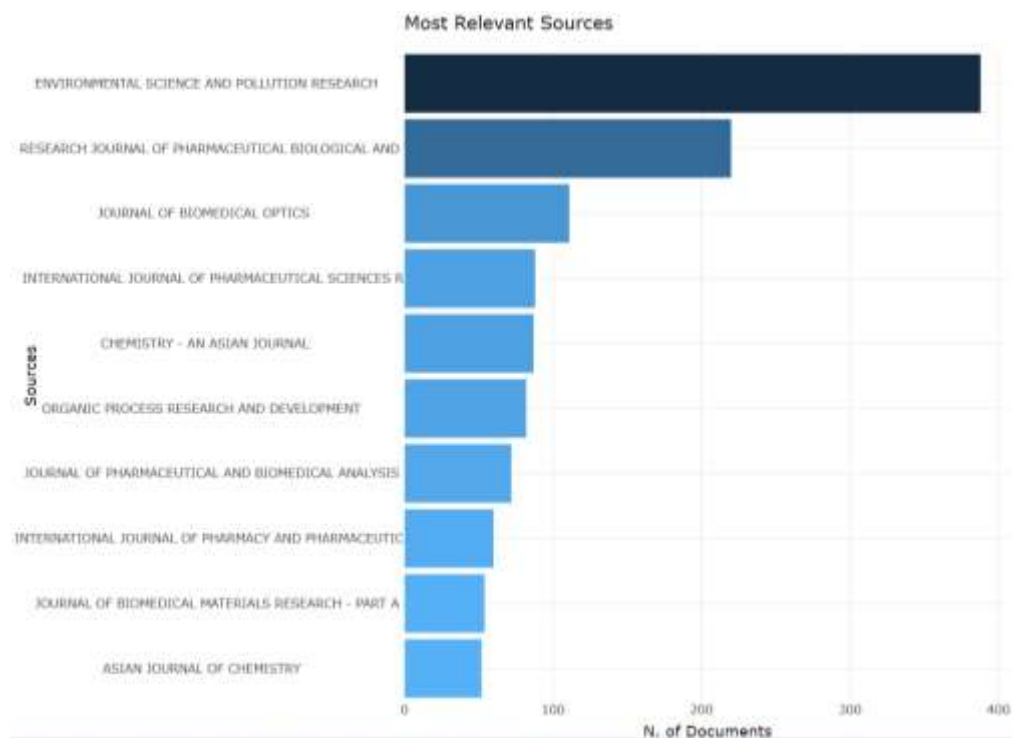


Figure-21. Top 10 journals and number of published papers

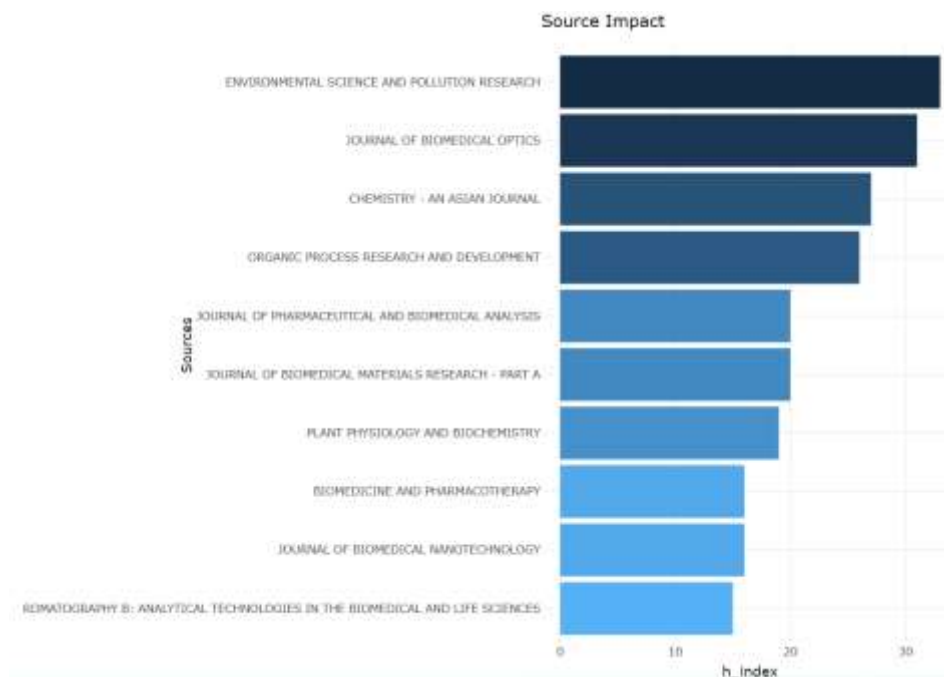


Figure-22. The H index of journals publishing most articles

4.16 Country-wise Distribution of Contributions and Affiliations

Figure-23 illustrates the distribution of contributions made by countries. The maximum contributions were made by India (1825). Following India, the contributions of Iran, the USA, and

China were 246, 555, and 763, respectively. The 76 countries in the world contributed these 2575 research and review papers in Indian journals.

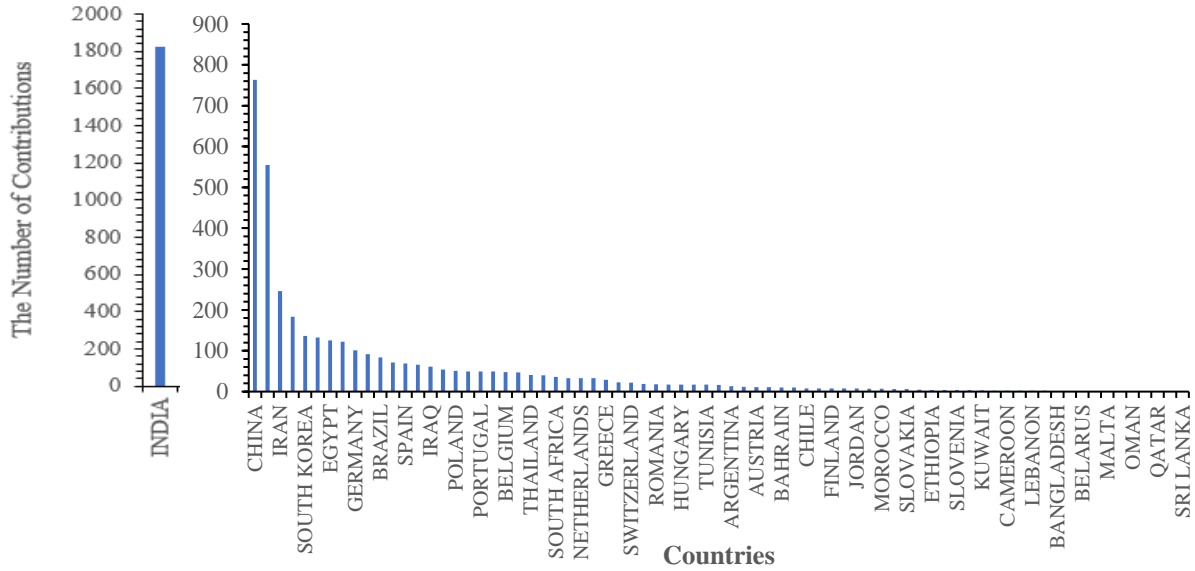


Figure-23. Country-wise distribution of contributions

The geographical-wise distribution of contributions was represented on the Earth map as shown in Fig.-24. The intensity of published research and review papers was shown from dark to light color. 76 countries were spread around the seven countries. The red lines indicate the international collaborations.

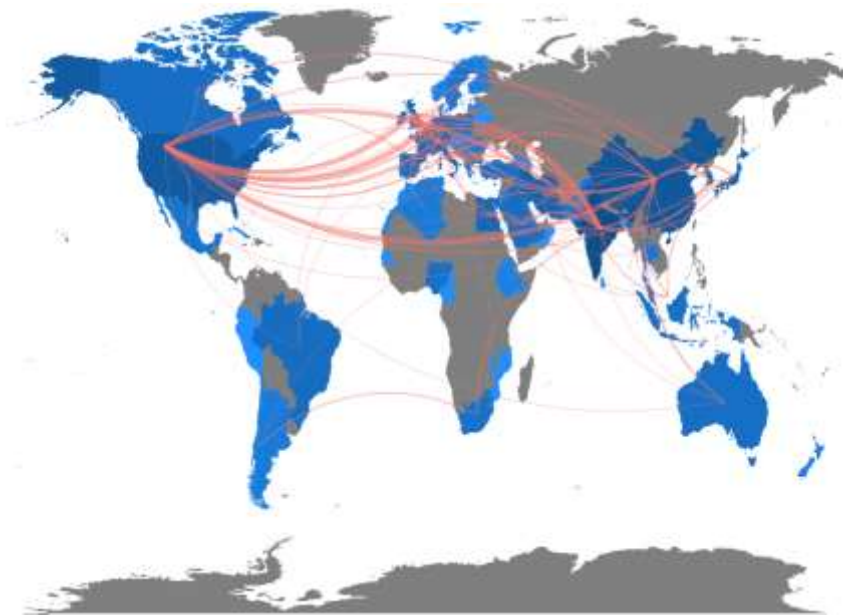


Figure-24. Geographical-wise distribution of contributions on the Earth map

Figure-25 depicts the name of the top 10 Institutions that published research and review papers related to green chemistry. Islamic Azad University researched 47 studies. Lovely Professional University, Anna University, and VIT University published 41, 33, and 31 papers. The top 10 institutions published 288 papers which is 11.2% of published papers.

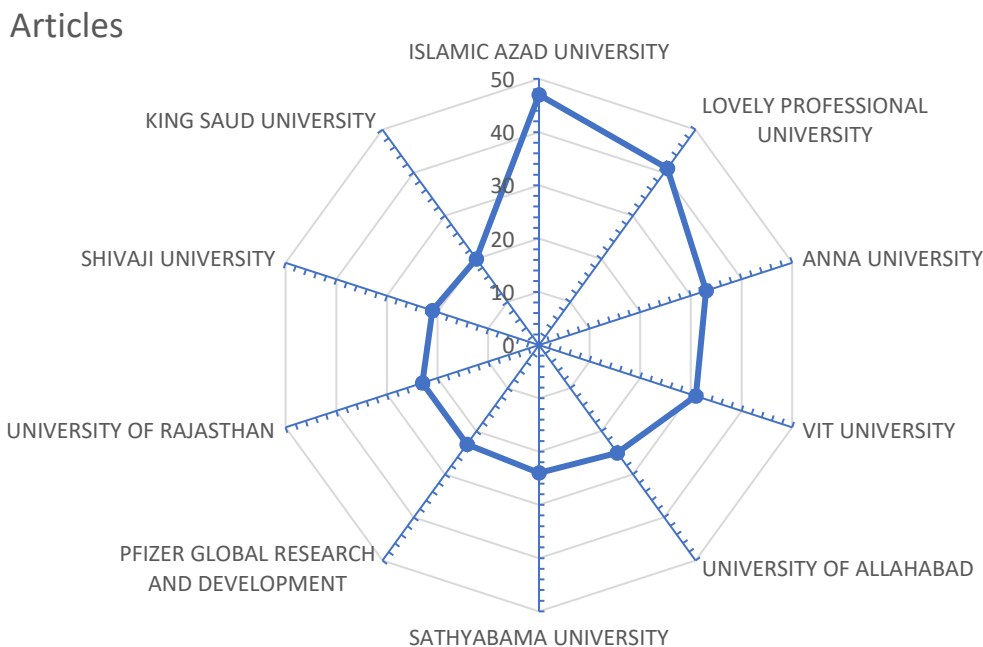


Figure-25. Top 10 affiliations that most published paper

Figure-26 depicts the relationship of three fields which are the name of corresponding Authors, affiliation, and countries. Figure-26 also indicates the collaboration of Authors/countries with each other. Broad lines between Authors and countries reveal the home countries of the Authors. The thin lines between Authors and countries expressed collaboration among corresponding Authors and colleagues' countries.

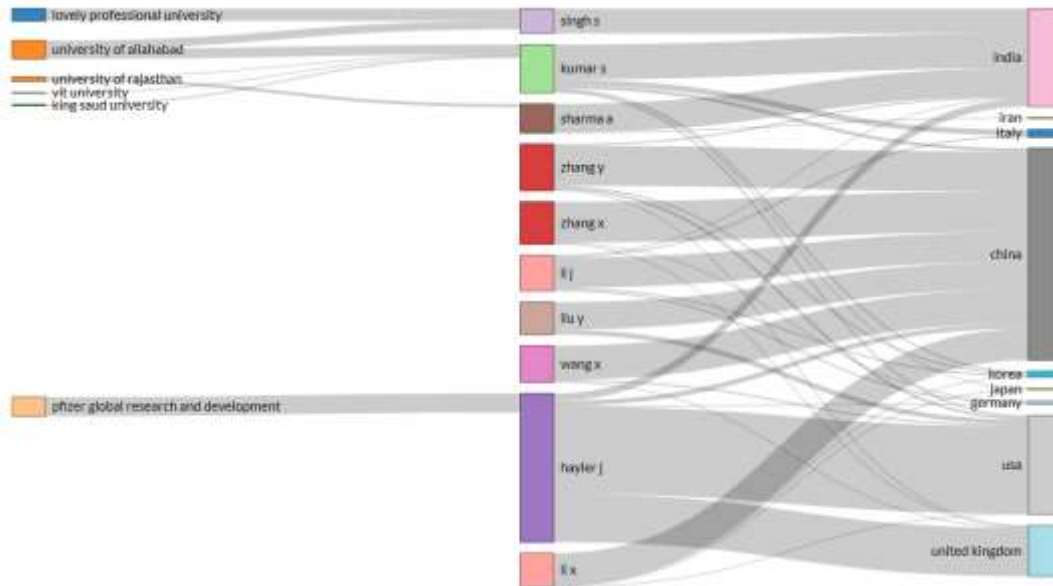


Figure-26. Three fields (corresponding Authors-Affiliations-Countries) relations plots.

4.17 Research Funding and Supporters

Figure-27 shows the year-wise funded and non-funded number of papers and the percentage of funding. However, there is no need to emphasize, financial supports for a project is very important for research activities. Especially, the cost of analytical equipment, consumable prices, and labor costs increase in these days. 709 research and review papers (27.5%) were financially supported and 1866 papers (72.5%) were not supported. As is seen in Fig. 15, the ratio between funded and not funded papers fluctuated over the years.

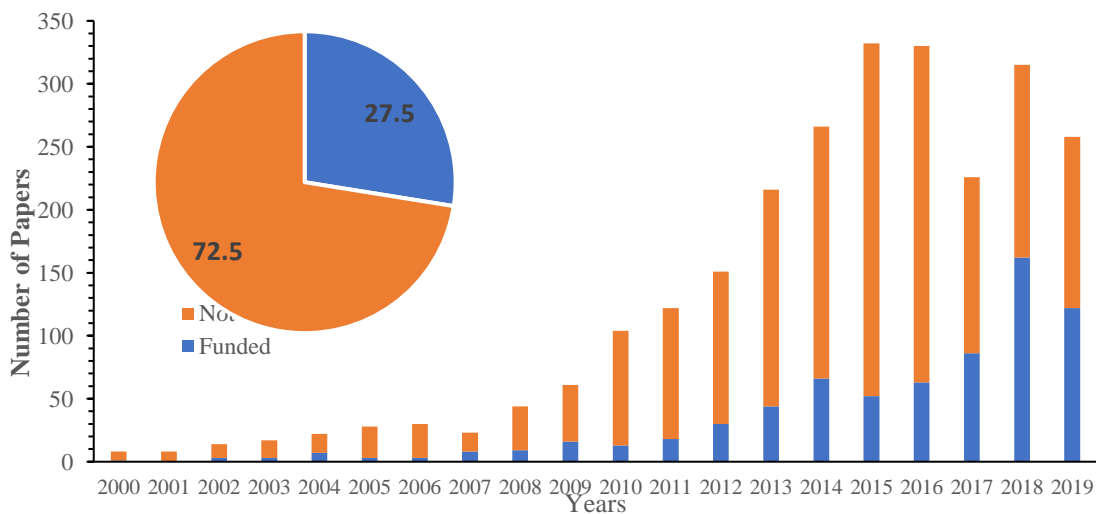


Figure-27. Year-wise funded and non-funded number of papers and percentage of funding

The project grants were supplied by national and international organizations which some of them were revealed in Fig.-28. 10.4% of papers were supported by listed funding organizations in Fig.-28. The National Natural Science Foundation of China has supported 105 papers. The National Institutes of Health of the USA and the University Grants Commission (*UGC*) of India was acknowledged 29 times in the research and review papers. The Japan Society for The Promotion of Science, National Science Foundation, USA, and European Commission were thanked for 13, 13, and 9 times, respectively.

Chapter-5: Results and Discussion

5.1 A Bibliometric Study of Green Chemistry in Indian journals

In many of the areas mentioned in the introduction section, the researchers focused on converting traditional processes into greener ones. The green chemistry is reviewed, and its bibliometric features were given that reveals the characteristics of the research and review papers published in Indian journals. This study comprehends the research and review papers studied on twelve principles of green chemistry, bibliometric features, and characteristics of the research papers related. The bibliometric analysis will be performed on the literature cited in the SCOPUS from 1999 to 2020. The bibliometric analysis covers mainly year wise and geographical wise distribution, Authorship pattern and citation, etc. All these data were organized, analyzed, tabulated, and presented by using simple statistical methods.

In recent years, production, manufacturing industries, and other productive activities (mining, civil engineering, etc.) should concern and provide recycling and reduction of usage of chemicals and materials, waste minimization, and less energy consumption (Ghernaout, Ghernaout, and Naceur 2011). These attitudes correspond with the concept of green chemistry, which can be described by twelve principles; preventing waste generation, increasing conversion of reactions, designing more safe chemical syntheses, chemicals, and products, utilizing non-hazardous solvents and conditions of reaction, developing energy efficiency, utilizing renewable feedstocks, escape from chemical by-products, utilizing catalysts, designing products and chemicals to diminish after use, using real-time analysis to prevent pollution and to minimize the potential for accidents (Anastas and Eghbali 2010).

In history, some disasters such as chemical gas leakage (more than 40 tons of methyl isocyanate) accident in Bhopal, India in 1984 that resulted immediate killing of at least 3,800 people, cause to understand people the meaning of environmentally friendly technology (Broughton, 2006). This tragic disaster stimulated to produce environmentally benign synthesis, usage of non-hazardous materials, control and/or prevent the pollution, etc. (Bora et al., 2002). In Japan, TiO_2 is produced with the fixation of CO_2 and decomposition of chlorofluorocarbons. In Germany, molecular oxygen, H_2O_2 , and N_2O as known as environmentally benign oxidants are started to be utilized for the synthesis of chemicals. In the UK, the researchers invented new and efficient procedures for the production of hydroquinone, $\text{C}_6\text{H}_4\text{-1,4-(OH)}_2$ utilized in manufacturing polymeric materials.

In the USA, the adipic acid $(\text{CH}_2)_4(\text{COOH})_2$ is for the first time produced using enzyme catalysis (*Escherichia coli*) from glucose (Bora et al., 2002). The abovementioned examples are some of the examples in many cases.

The share of basic, specialty, and knowledge (pharmaceuticals, agrochemicals, and biotechnology, etc.) chemicals are about 57%, 25%, and 18%, respectively in India. (Web_page2). The pharmaceutical industry expands with an annual growth rate of around 12% and is estimated to reach \$100 billion by 2025 (Vesela et al., 2018). After the chemical disaster and rapid growth in the chemical industry, India made progress in green chemistry. The Indian University Grants Commission (UGC) established the Centre for Green Technology in 2005 (Yadav, 2006). The mission of the center can be summarized as follows:

- To increase outcomes of green products and processes
- To bring together the research outcome and industry for making environmentally friendly processes and products.
- To raise awareness in public, in scientific community and society, and industry for organizing national and international forums, publications and journals and supporting projects (Web_page1).

Vesela et al., (2018) exhibited scaling and reasons for green chemistry adoption and by the Indian pharmaceutical industry. The main motivations of green chemistry adoption in Indian pharmaceutical companies - 52 generic drug pharma and Active Pharmaceutical Ingredients (API) manufacturers - are found to be 85% due to cost-saving and 73% due to environmental regulations. The results of benchmarking studies are also showed that regulatory risk and delivery of drugs are the two most significant barriers for expanding the adoption of GC in India (Vesela et al., 2018). Bibliometrics was identified as 'the application of mathematical and statistical methods to books and other communication media' by Pritchard, A. (1969) (Velmurugan and Radhakrishnan 2016). The methods of bibliometric are used to analyze, authorship, citation and publication pattern, and the relationship within scientific domains and research communities and to structure of specific fields (Vijay and Raghavan 2007; Jermann et al. 2015; Verma, Sonkar and Gupta 2015; Demir and Sharma, 2019). The analysis of papers with various statistical methods can be directive for investigation studies, features and behavior of published pieces of knowledge for investigation of

the structures of research and scientific areas, and assessment of the administration of scientific information and research activity (Velmurugan and Radhakrishnan 2016).

This study comprehends bibliometric features and characteristics of the research papers related to green chemistry. The 570 Indian journals which are indexed by SCOPUS were surveyed for research and review articles about green chemistry topics between the years 1999 and 2019. The applied query was: (TS=green AND chemistry) AND DOCUMENT TYPES: (Article & Review papers) AND PUBYEAR > 1998 AND PUBYEAR < 2020). The search was made on the 5th of June 2020. 2575 research and review papers published in 125 Indian Journals (Table 1) were found from this search. These 2575 papers were extracted from 60000 research and review papers and were examined in Bibliometrix (Aria and Cuccurullo, 2017) and MS Excel program. The bibliometrics analysis of 2575 research and review papers was processed according to year wise and geographical wise distribution, Authorship pattern and citation, etc. All these data were organized, analyzed, tabulated, and presented by using simple statistical methods in Bibliometrix and MS excel.

Table 3. List of 125 Indian Journals published 2575 research and review papers about green chemistry indexed in Scopus Database (Alphabetically arranged by Title of the Journal)

| N | Title of the Journal | N | Title of the Journal |
|----------|--|----------|---|
| 1 | Advanced Materials Letters | 31 | Indian Journal of Agricultural Sciences |
| 2 | Annals of Arid Zone | 32 | Indian Journal of Agronomy |
| 3 | Annals of Biology | 33 | Indian Journal of Animal Research |
| | Annals of Tropical Medicine and Public | | |
| 4 | Health | 34 | Indian Journal of Animal Sciences |
| | Asian Biotechnology and Development | | |
| 5 | Review | 35 | Indian Journal of Biochemistry |
| | | | Indian Journal of Biochemistry and |
| 6 | Asian Journal of Chemistry | 36 | Biophysics |
| | Asian Journal of Microbiology, | | |
| | Biotechnology, and Environmental | | |
| 7 | Sciences | 37 | Indian Journal of Biotechnology |

| | | |
|----|---|---|
| | Asian Journal of Pharmaceutical and | |
| 8 | Clinical Research | 38 Indian Journal of Chemical Technology |
| 9 | Asian Journal of Pharmaceutics | 39 Indian Journal of Chemistry |
| | | Indian Journal of Chemistry - Section A |
| | | Inorganic, Physical, Theoretical and |
| 10 | Biochemical and Cellular Archives | 40 Analytical Chemistry |
| | | Indian Journal of Chemistry - Section B |
| 11 | Biology and Medicine | 41 Organic and Medicinal Chemistry |
| 12 | Biomedical and Pharmacology Journal | 42 Indian Journal of Environmental Health |
| | | Indian Journal of Environmental |
| 13 | Biomedical Journal | 43 Protection |
| 14 | Biomedical Research | 44 Indian Journal of Experimental Biology |
| | | Indian Journal of Heterocyclic |
| 15 | Biomedicine | 45 Chemistry |
| | Biosciences Biotechnology Research | |
| 16 | Asia | 46 Indian Journal of Microbiology |
| | | Indian Journal of Natural Products and |
| 17 | BioTechnology: An Indian Journal | 47 Resources |
| | | Indian Journal of Pharmaceutical |
| 18 | Bulletin of Materials Science | 48 Education and Research |
| | Bulletin of Pure and Applied Sciences - | Indian Journal of Pharmaceutical |
| 19 | Section F Geological Sciences | 49 Sciences |
| 20 | Carbon - Science and Technology | 50 Indian Journal of Pharmacology |
| 21 | Chemical Engineering World | 51 Indian Journal of Physics |
| 22 | Colourage | 52 Indian journal of public health |
| | | Indian Journal of Public Health |
| 23 | Current Science | 53 Research and Development |
| 24 | Defence Science Journal | 54 Indian Journal of Technology |
| 25 | Drug Invention Today | 55 Indian Veterinary Journal |
| | Ecology, Environment and | International Journal of Applied |
| 26 | Conservation | 56 Chemistry |

| | | | |
|----|--------------------------|----|---|
| 27 | E-Journal of Chemistry | 57 | International Journal of Applied Engineering Research |
| 28 | IETE Journal of Research | 58 | International Journal of Applied Pharmaceutics |
| 29 | IIOAB Journal | 59 | International Journal of Chemical Sciences |
| 30 | Indian Drugs | 60 | International Journal of ChemTech Research |

Table 3. Continued.

| No. | Title of the Journal | No. | Title of the Journal |
|-----|--|-----|---|
| 61 | International Journal of Drug Development and Research | 94 | Journal of Scientific and Industrial Research |
| 62 | International Journal of Engineering and Technology | 95 | Journal of Surface Science and Technology |
| 63 | International Journal of Green Pharmacy | 96 | Journal of the Indian Chemical Society |
| 64 | International Journal of Integrative Biology | 97 | Journal of the Indian Institute of Science |
| 65 | International Journal of Pharma and BioSciences | 98 | Journal of the Institution of Engineers |
| 66 | International Journal of Pharmaceutical Quality Assurance | 99 | Journal of the Textile Association |
| 67 | International Journal of Pharmaceutical Sciences | 100 | Journal of Young Pharmacists |
| 68 | International Journal of Pharmaceutical Sciences Review and Research | 101 | Man-Made Textiles in India |
| 69 | International Journal of Pharmacognosy and Phytochemical Research | 102 | Nucleus (India) |
| 70 | International Journal of Pharmacy and Pharmaceutical Sciences | 103 | Pestology |

| | | | |
|----|---|-----|-------------------------------------|
| | International Journal of Pharmacy and | | |
| 71 | Technology | 104 | Pharma Times |
| | International Journal of PharmTech | | |
| 72 | Research | 105 | Pharmaceutical Reviews |
| | International Journal of Plastics | | |
| 73 | Technology | 106 | Pharmacognosy Journal |
| | International Journal of Research in | | |
| 74 | Ayurveda and Pharmacy | 107 | Pharmacognosy Magazine |
| | International Journal of Research in | | |
| 75 | Pharmaceutical Sciences | 108 | Pharmacognosy Research |
| | IPPTA: Quarterly Journal of Indian Pulp | | |
| 76 | and Paper Technical Association | 109 | Pharmacognosy Reviews |
| | Journal of Advanced Pharmaceutical | | Physiology and Molecular Biology |
| 77 | Technology and Research | 110 | of Plants |
| 78 | Journal of Applied Pharmaceutical Science | 111 | Plant Archives |
| | | | Plant Cell Biotechnology and |
| 79 | Journal of Biopesticides | 112 | Molecular Biology |
| 80 | Journal of Biosciences | 113 | Plant Physiology and Biochemistry |
| | Journal of Chemical and Pharmaceutical | | |
| 81 | Research | 114 | Pollution Research |
| | Journal of Chemical and Pharmaceutical | | Proceedings of the Indian Academy |
| 82 | Sciences | 115 | of Sciences |
| 83 | Journal of Chemical Sciences | 116 | Rasayan Journal of Chemistry |
| | | | Research and Development |
| 84 | Journal of Environmental Biology | 117 | (Barrington, Illinois) |
| | Journal of Environmental Science and | | |
| 85 | Engineering | 118 | Research Journal of Biotechnology |
| | | | Research Journal of Chemistry and |
| 86 | Journal of Food Science and Technology | 119 | Environment |
| | | | Research Journal of Pharmaceutical, |
| 87 | Journal of Global Pharma Technology | 120 | Biological and Chemical Sciences |

| | | | |
|----|---|-----|---|
| 88 | Journal of Nanomedicine and Nanotechnology | 121 | Research Journal of Pharmacy and Technology |
| 89 | Journal of Natural Remedies | 122 | Research on Crops |
| 90 | Journal of Pharmaceutical Sciences and Research | 123 | Science, Technology and Society |
| 91 | Journal of Pharmacy and Bioallied Sciences | 124 | Systematic Reviews in Pharmacy |
| 92 | Journal of Pharmacy Research | 125 | Trends in Carbohydrate Research |
| 93 | Journal of Polymer Materials | | |

5.2 General information and Year-wise distributions

Figure-28 presents the distribution of 2575 published research and review papers according to the years from 1999 to 2019. 2389 papers are research articles and 186 papers are review articles. 125 different Indian journals published 2575 papers and the average published papers per year is 128.75. In the last decade, the importance of green chemistry was understood by those concerned (researchers, scientists, and manufacturers, etc.). This phenomenon can be predicted by pie charts in Fig.28. 90% of published articles were published in the last decades. The number of papers increases with increasing years. The maximum number of papers (332) was published in 2015.

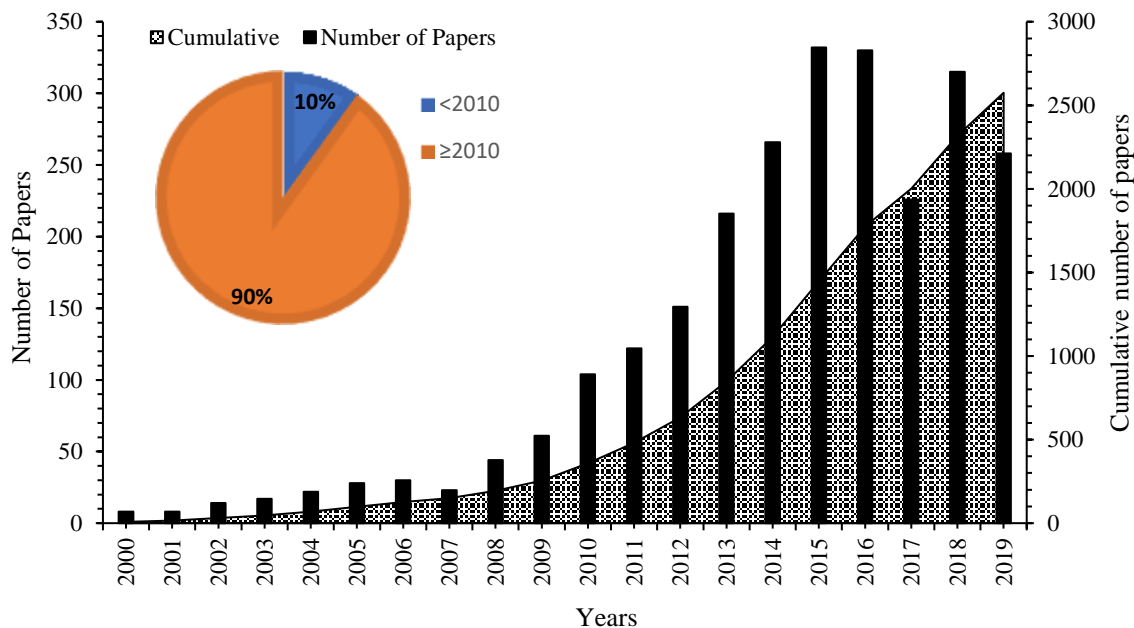


Figure-28. Year-wise distribution of the number of articles

5.3 The frequency of citations

The distribution of the year-wise citation score of research and review papers was shown in Fig. 29. The maximum citation scores were observed in 2015 and 2010 as 2953 and 2936 citations, respectively. The total number of citations during these years was 31381. The cumulative number of citations inherently increases with increment in years. The citation score is alive data and time needs for understanding papers' quality and published new research which cited old articles. The cumulative citation score increases with increasing years.

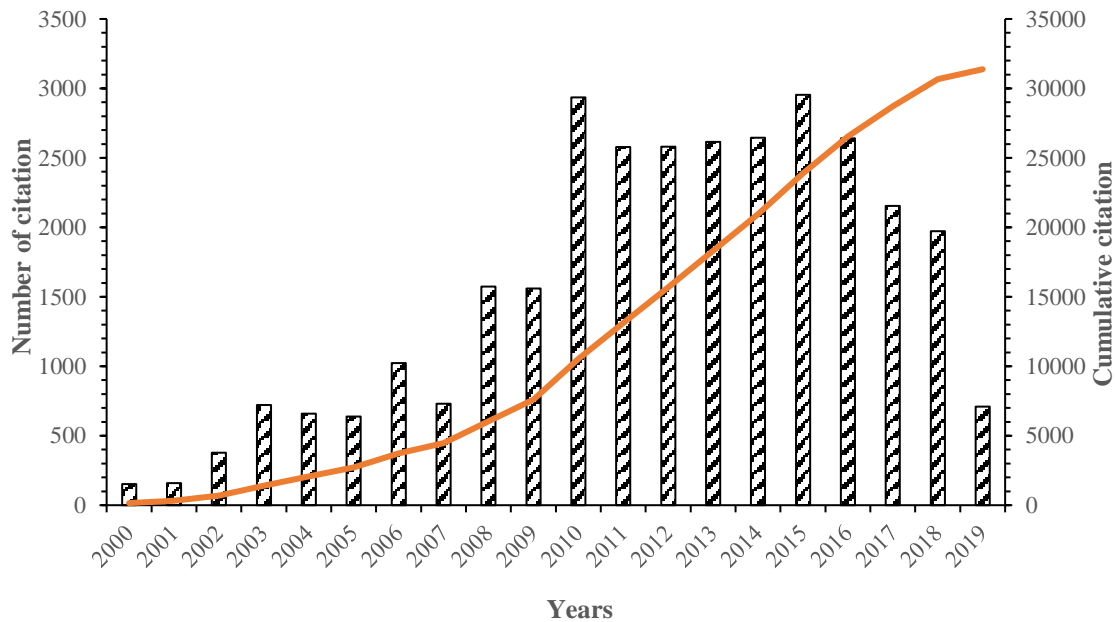


Figure-29. Year-wise citation score of papers

Figure-30 presents the distribution of the number of citations per paper (C/P) and the ratio of C/P per citable years. The citable years mean that the paper published in 2000 having 20 years till present chance for taking citation. An average citation per paper was 12.19 and the average citations per year were 1.8. The papers published in 2003 get highest the number of citations per paper with 42.5. The papers published in the last 6 years have lower the number of C/P than the average C/P. However, recently published papers have a high ratio of C/P per year which means that they obtained a high number of citations in a short time. Recent papers are promising that will obtain more and higher the number of citations than old papers.

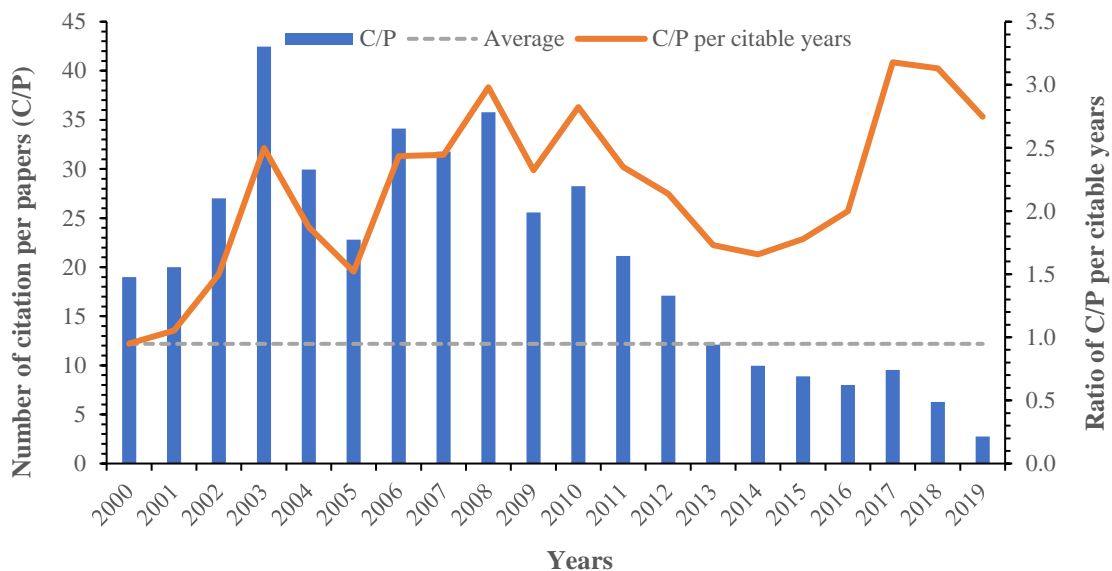


Figure-30. The number of citations per paper and ratio of C/P per citable years

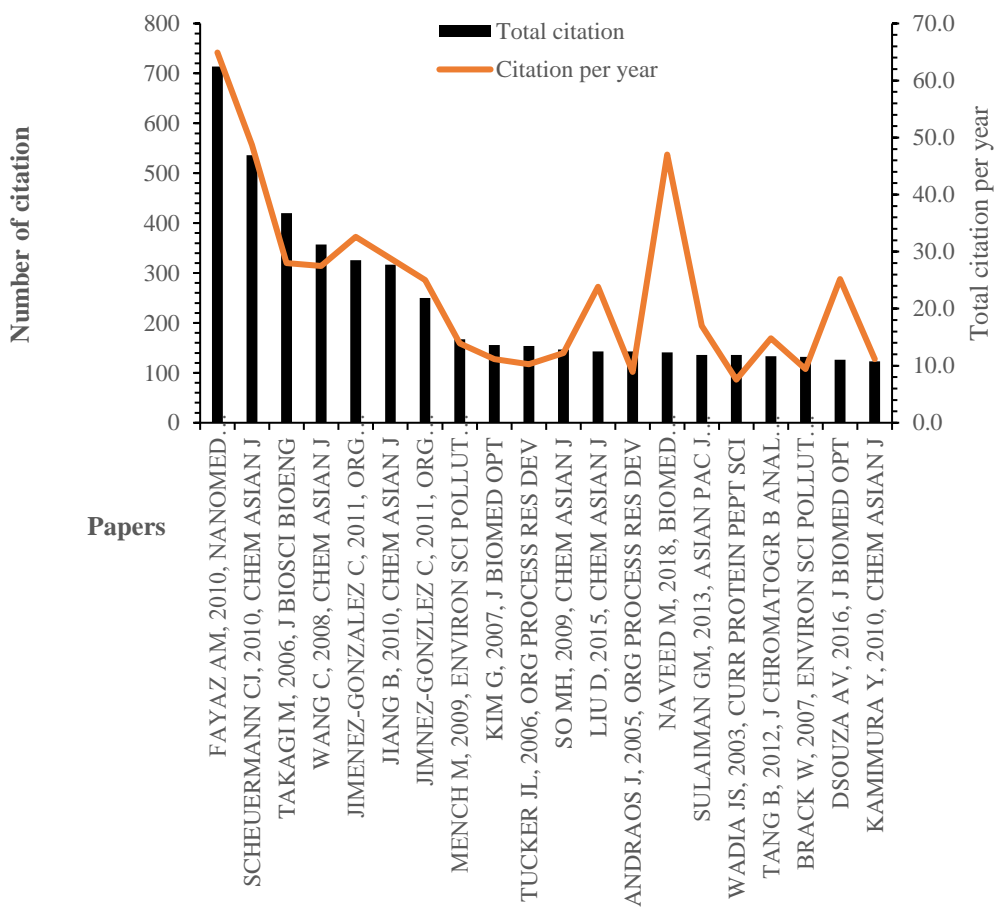


Figure-31. Top 20 most cited papers

Figure-31 reveals the most cited 20 papers and total citation per year value of these papers. The most cited article belongs to Fayaz A.M. with 714 citations published in 2010. Total citation per year values can be indicated the potential citation score of articles in the future. The total citation per year values of Fayaz (2010, research paper), Scheuermann (2010, review paper), and Naveed (2018, review paper) were observed as 64.9, 48.7, and 47.0, respectively. Article of Naveed M. published in 2018 and its total citation per year score is third-highest score among most cited 20 articles which indicates that would increase its number of citations in near future.

5.4 Authorship pattern

Figure-32 represents the Authorship pattern of research and review papers. The 11363 Authors including repeating of some Authors studied and published 2575 research and review papers. The exact number of Authors was 7722 without any repetition. The ratio of paper per Author was 0.33. 117 research and review papers were published by 81 single Authors. The percentages of papers authored by 2, 3, and 4 Authors were 18%, 21%, and 19%, respectively. 2458 papers were written by a collaboration of 7641 Authors. A ratio of Authors per paper can give a collaboration index which was 3.11 in this case. As is abovementioned, the green chemistry topic is interdisciplinary, for that reason, 96% of papers were studied by multiple Authors.

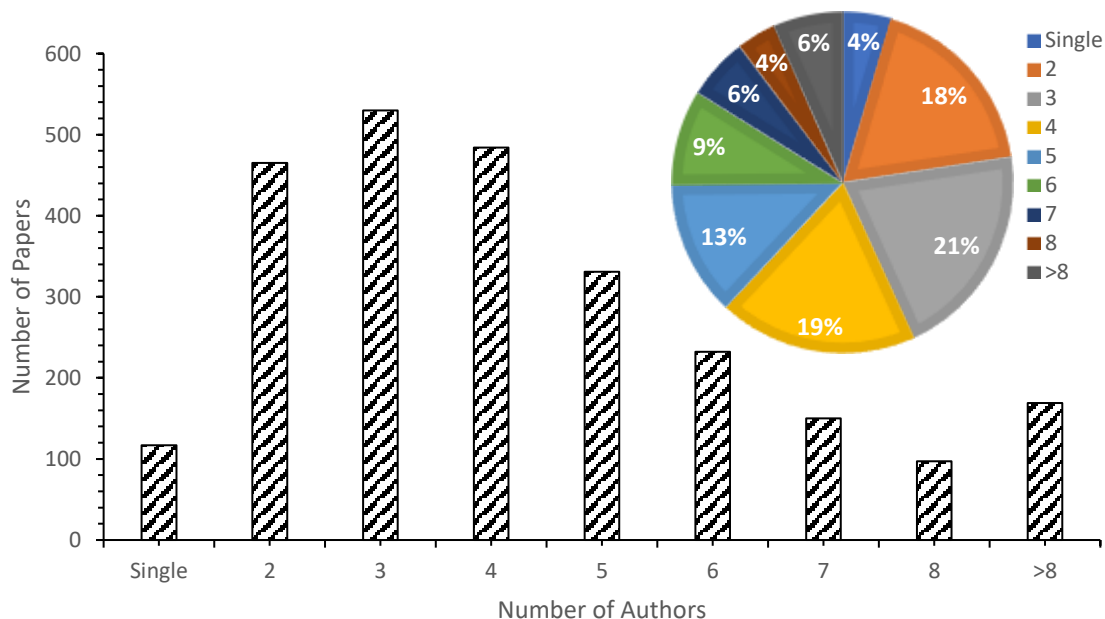


Figure-32. Authorship pattern of papers

Figure-33 illustrates the year wise collaboration index distribution and variation of authorship of papers against years. The collaboration index fluctuated before 2010 due to the low number of papers. After 2010, the collaboration index was almost steady and goes between 1.0 and 1.1.

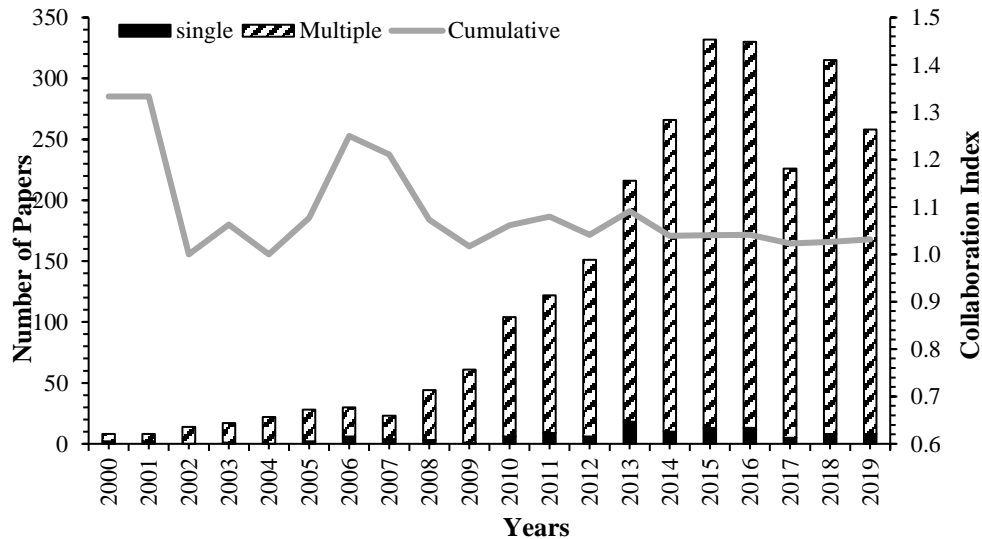


Figure-33. Year wise collaboration index and authorship of papers

Figure-34 illustrates the top 10 Authors' published research and review papers over time. Kumar S. published 46 research and review papers between 2006 and 2019 years and his papers got 452 citations during these years. Following Author is Zhang Y. published 24 papers and got 270 citations. Li J. got 202 citations with 32 published research and review papers.

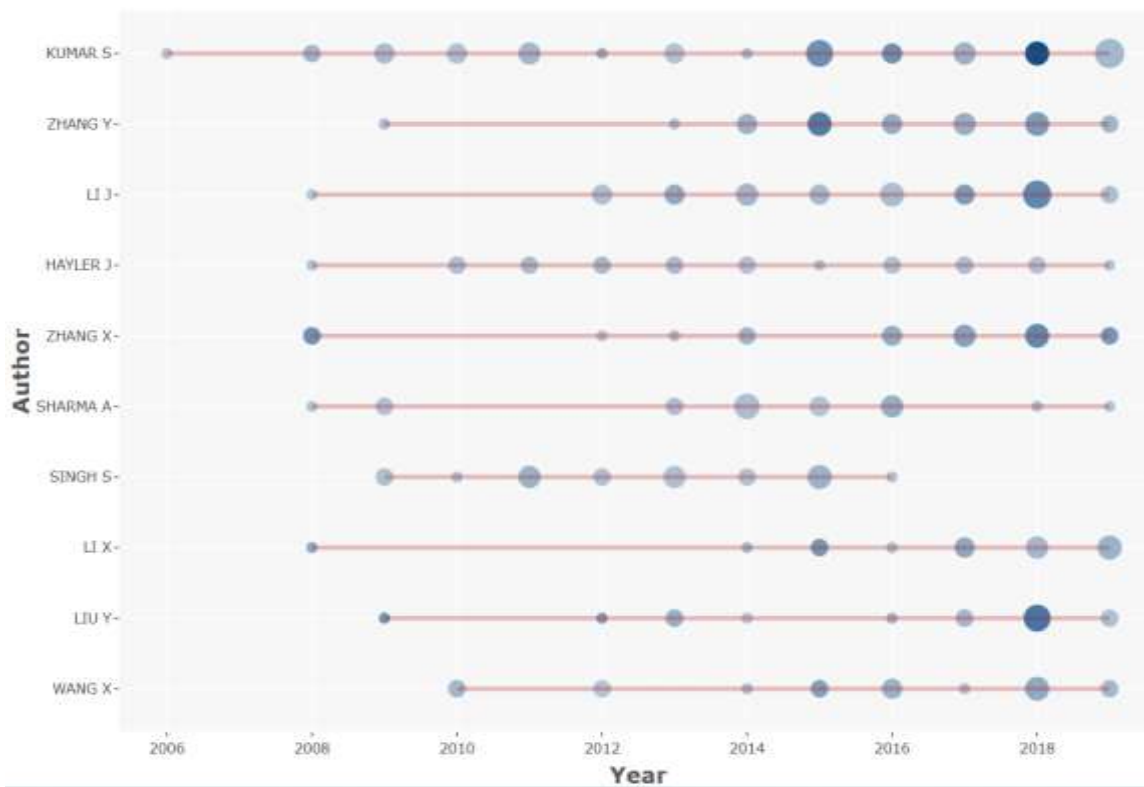


Figure-34. Top 10 Authors' production against years

5.5 Scientific categories and trend topics

Figure-35 indicates trend topics as well as scientific categories of published papers. The titles of 2575 published papers were analyzed and at least 20 times repeated words were plotted against years. This analysis can give information about research trends of green chemistry. The concept of green chemistry, as well as most of its twelve principles, directly related to “chemistry”. In the year between 2011 and 2013, researchers focused on utilizing microwave and irradiation techniques, solvent-free and oxidation reactions. In recent years, the extraction method becomes prominent. Nanoparticles, oxides, and algae were trend materials that researchers mostly studied.

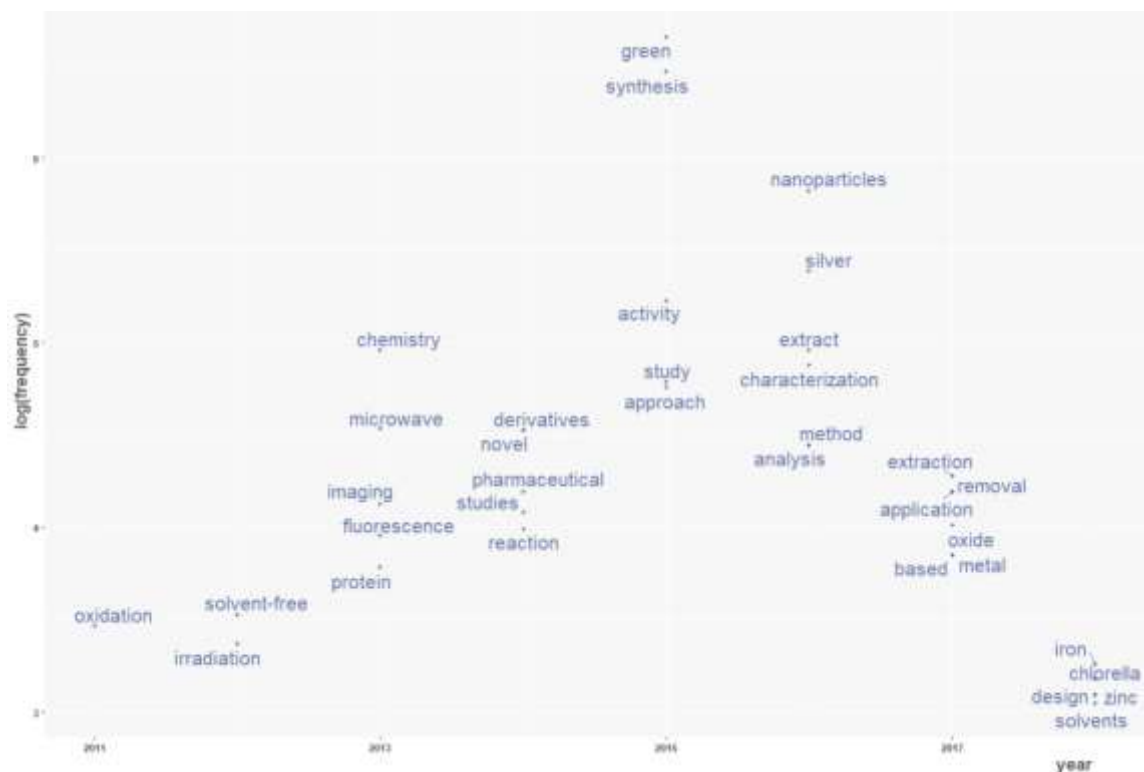


Figure-35. Trends of science categories of published papers

5.6 Top journals and h index

Figure-36 depicts the name of the top 10 journals that published research and review papers related to the green chemistry topic. 388 research papers were published in Environmental Science and Pollution Research journal. The top 10 journals as shown in Fig. 36 published 43.0% of all research and review papers. The research journal of pharmaceutical biological and chemical sciences journals published 220 research and review papers with 8.5% of all papers. The Journal of biomedical optics published 4.3% of 2575 that is equal to 111 papers.

Figure-37 illustrates the H index of journals publishing most articles. The *h-index* indicates that the published *h* papers have been cited at least *h* times (Hirsch, 2005). Environmental Science and Pollution Research journal have 33 *h-index*. The *h-index* of the journal of biomedical optics, chemistry and Asian journal, and organic process research and development were 31, 27, and 26, respectively.

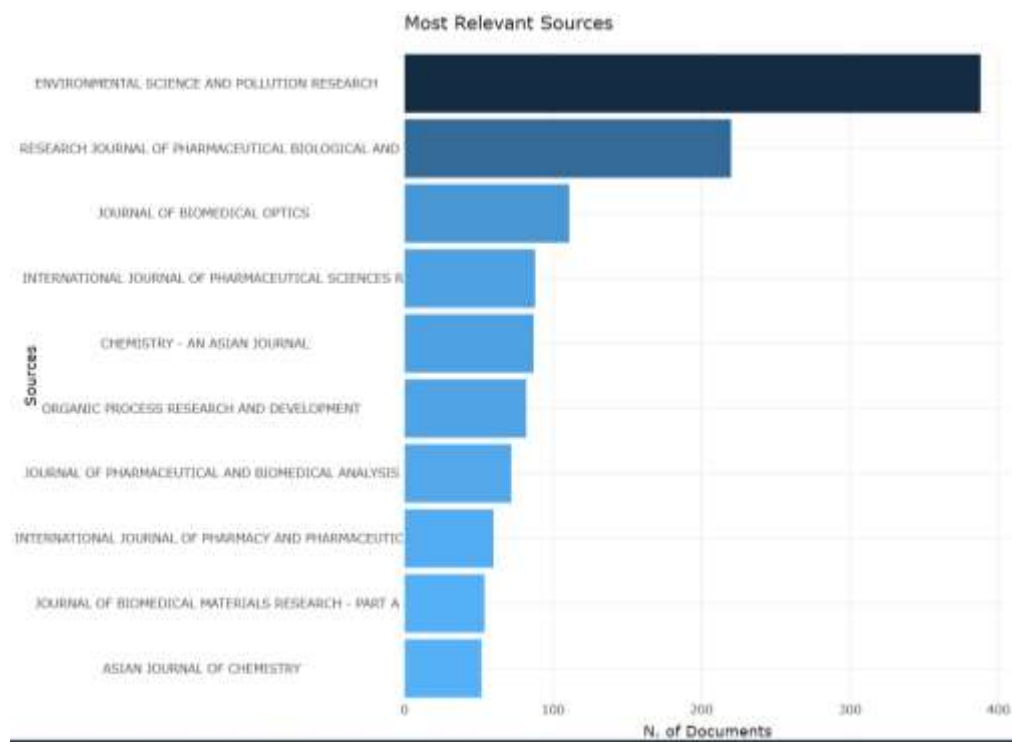


Figure-36. Top 10 journals and number of published papers

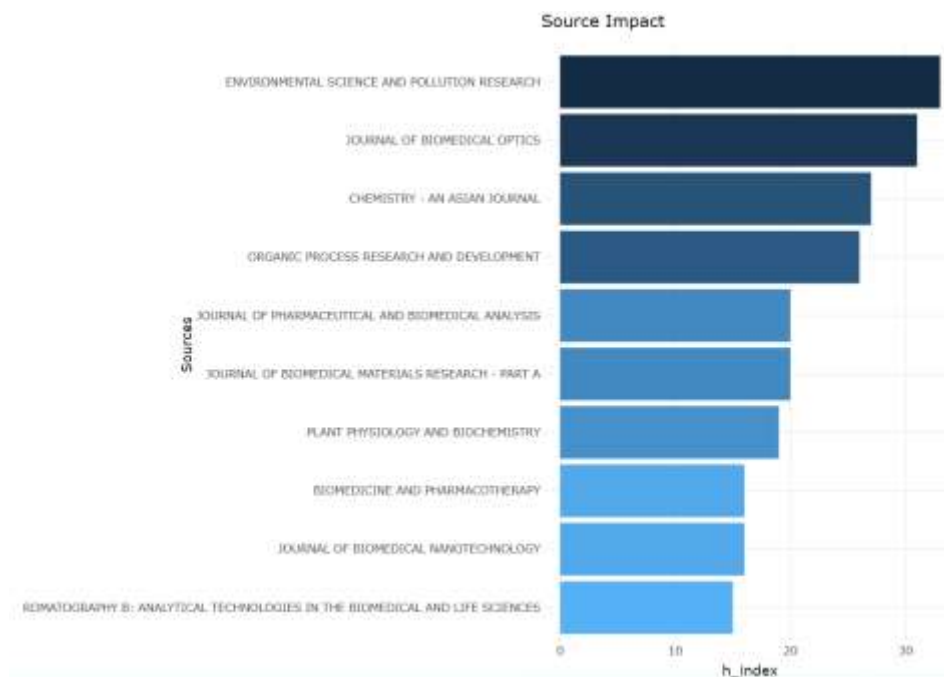


Figure-37. The H index of journals publishing most articles

5.7 Country-wise distribution of contributions and affiliations

Figure-38 illustrates the distribution of contributions made by countries. The maximum contributions were made by India (1825). Following India, the contributions of Iran, the USA, and China were 246, 555, and 763, respectively. The 76 countries in the world contributed these 2575 research and review papers in Indian journals.

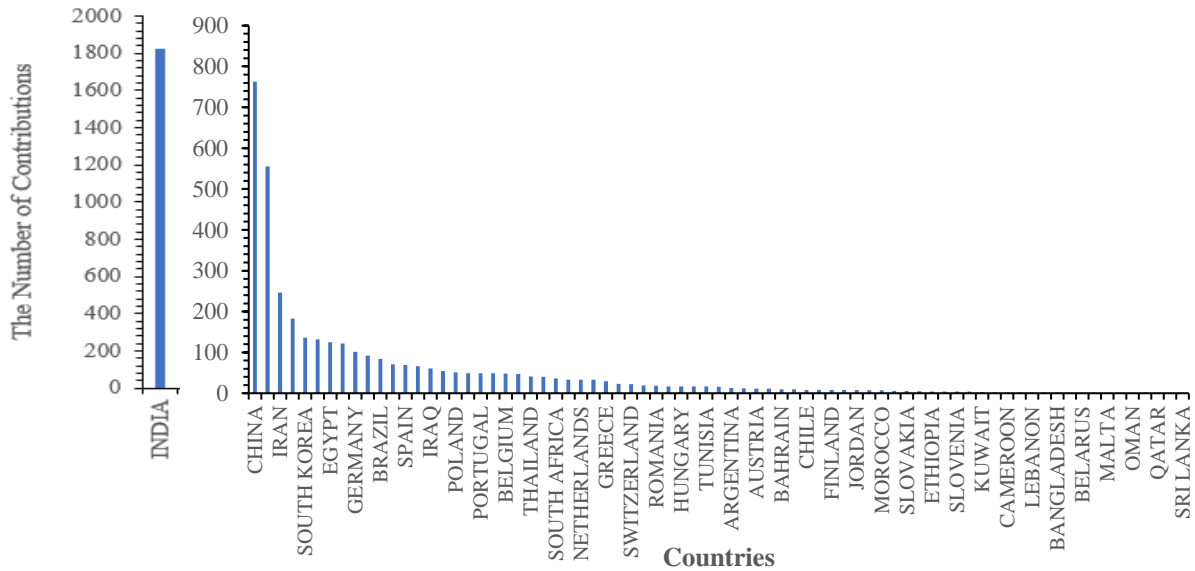


Figure-38. Country-wise distribution of contributions

The geographical-wise distribution of contributions was represented on the Earth map as shown in Figure-39. The intensity of published research and review papers was shown from dark to light color. 76 countries were spread around the seven countries. The red lines indicate the international collaborations.

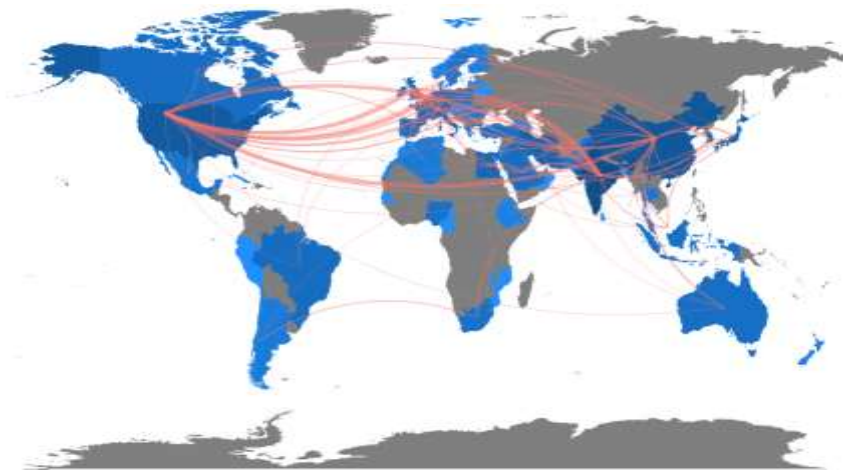


Figure-39. Geographical-wise distribution of contributions on the Earth map

Figure-40 depicts the name of the top 10 Institutions that published research and review papers related to green chemistry. Islamic Azad University researched 47 studies. Lovely Professional University, Anna University, and VIT University published 41, 33, and 31 papers. The top 10 institutions published 288 papers which is 11.2% of published papers.

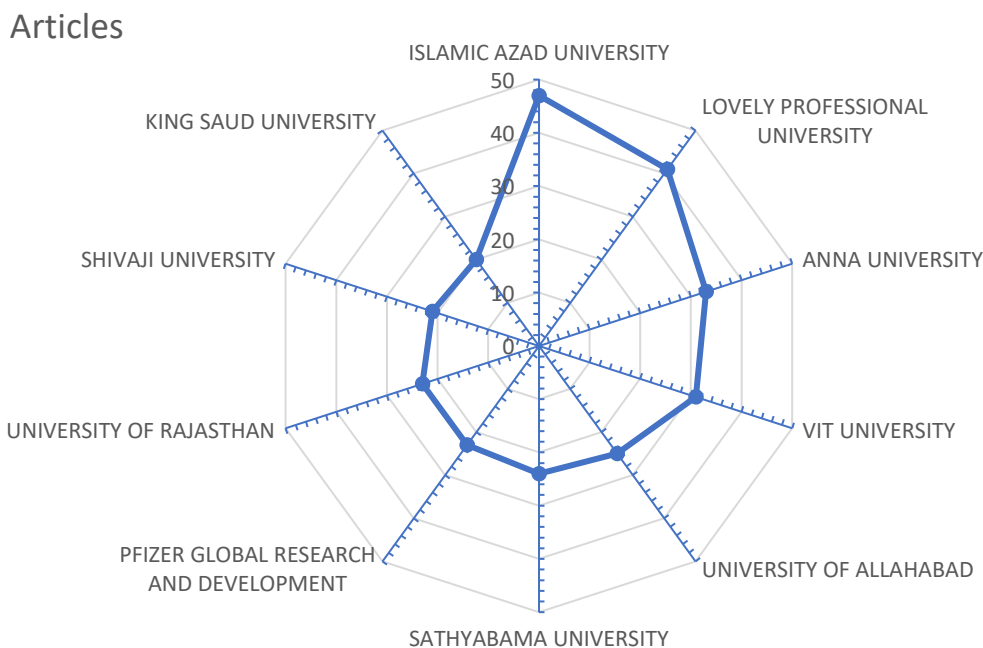


Figure-40. Top 10 affiliations that most published paper

Figure-41 depicts the relationship of three fields which are the name of corresponding Authors, affiliation, and countries. Figure-41 also indicates the collaboration of Authors/countries with each other. Broad lines between Authors and countries reveal the home countries of the Authors. The thin lines between Authors and countries expressed collaboration among corresponding Authors and colleagues' countries.

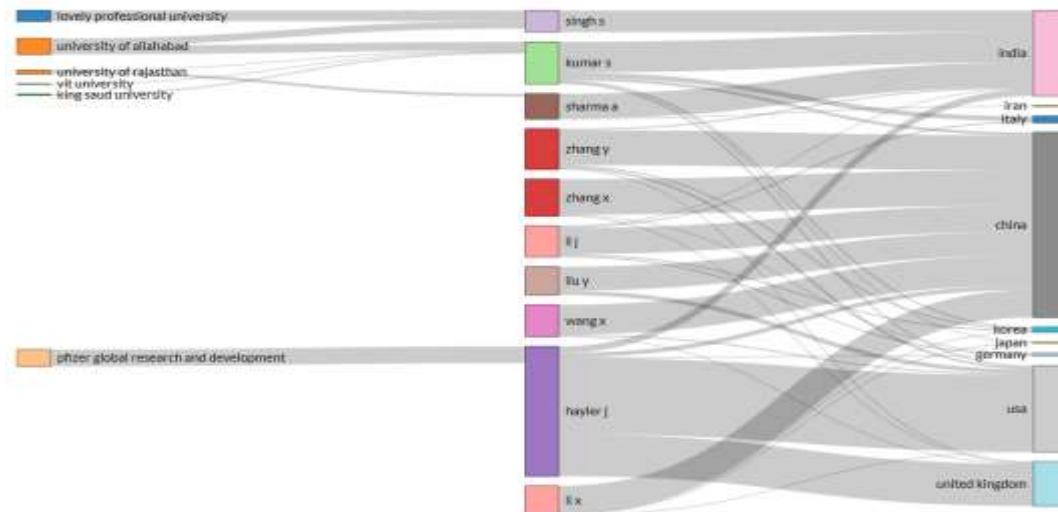


Figure-41. Three fields (corresponding Authors-Affiliations-Countries) relations plots.

5.8 Research funding and supporters

Figure-42 shows the year-wise funded and non-funded number of papers and the percentage of funding. However, there is no need to emphasize, financial supports for a project is very important for research activities. Especially, the cost of analytical equipment, consumable prices, and labor costs increase in these days. 709 research and review papers (27.5%) were financially supported and 1866 papers (72.5%) were not supported. As is seen in Fig. 42, the ratio between funded and not funded papers fluctuated over the years.

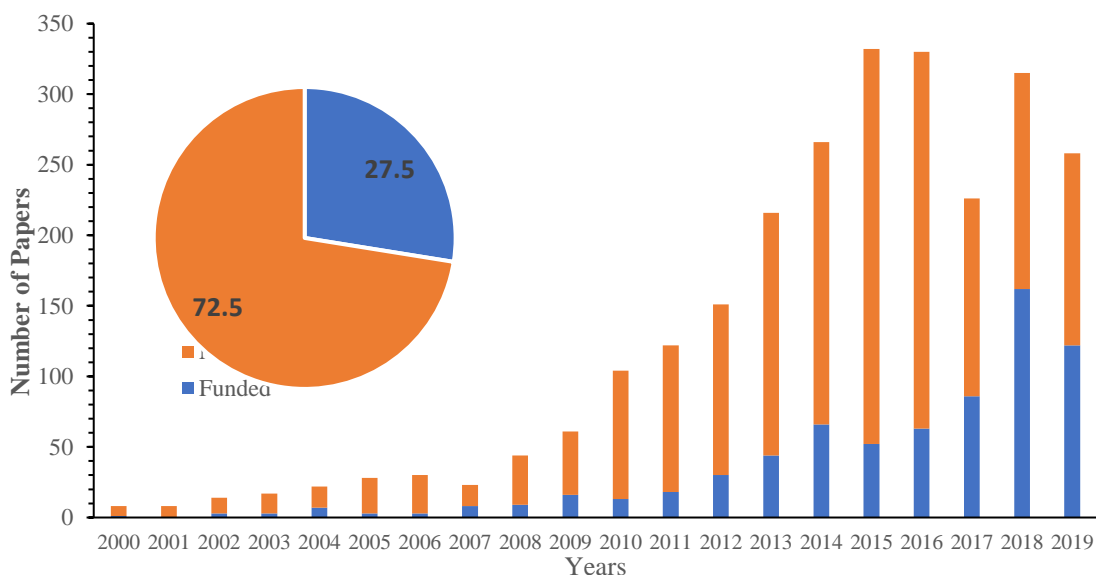


Figure-42. Year-wise funded and non-funded number of papers and percentage of funding

The project grants were supplied by national and international organizations which some of them were revealed in Fig. 43. 10.4% of papers were supported by listed funding organizations in Fig. 16. The National Natural Science Foundation of China has supported 105 papers. The National Institutes of Health of the USA and the University Grants Commission (UGC) of India was acknowledged 29 times in the research and review papers. The Japan Society for The Promotion of Science, National Science Foundation, USA, and European Commission were thanked for 13, 13, and 9 times, respectively.

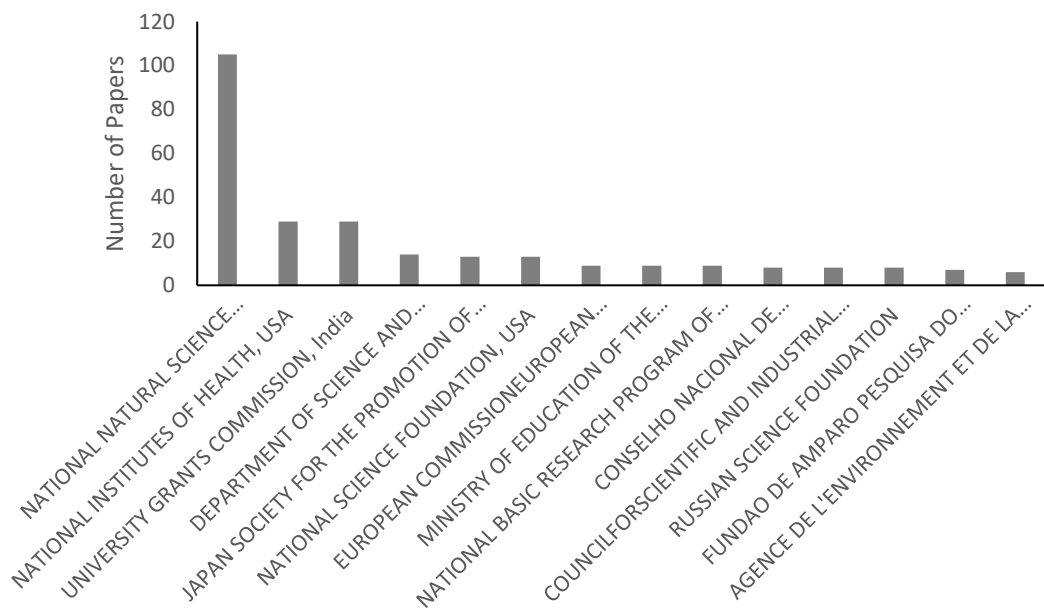


Figure-43. Top 15 of foundation organizations

Chapter-6: Findings/ Summary and Recommendations

The 2575 papers published in Indian journals were extracted from approximately 60000 research and review papers and were examined in Bibliometric and MS Excel program. The studies were surveyed successfully on the list of SCOPUS. The bibliometric analysis was found out for investigating Authorship pattern, international collaboration, and funded/not-funded researches. The following remarks were summarized:

- 7722 Authors from 76 countries contributed concerning the green chemistry concept.
- 125 different Indian journals published 2575 papers and the average published papers per year is 128.75.
- 90% of published articles were published in the last decades.
- The ratio of paper per Author was 0.33. 117 research and review papers were published by 81 single Authors.
- 2458 papers were written by a collaboration of 7641 Authors. A ratio of Authors per paper can give a collaboration index which was 3.11.

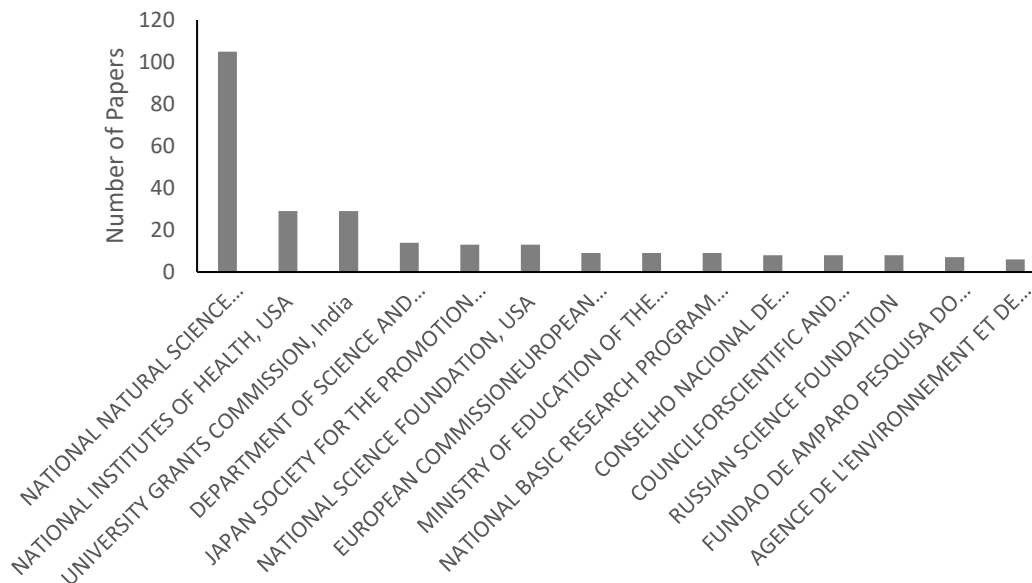


Figure-44. Top 15 of foundation organizations

- The total number of citations from 1999 to 2019 was 31381. The average ratio of C/P per citable years was found as 2.2.

- 388 research papers were published in Environmental Science and Pollution Research journal. The top 10 journals published 43.0% of all research and review papers.
- Islamic Azad University published 47 research and review papers.
- 709 research and review papers (27.5%) were financially supported and 1866 papers (72.5%) were not supported.

Recommendations

1. Green Chemistry is a very new area of chemistry and relatively not much popular in higher educational institutions, therefore its required to first make people aware about this subject and its importance. Because this subject is directly related to our environment and its sustainability, which is a topic of the global concern.
2. Secondly, from this research it has been revealed that very less number of research papers have been published in Indian journals based on green chemistry. Reason is quite obvious and mentioned in point no. 1. To overcome this situation, we should motivate people to pursue research in the area of green chemistry and encourage them to publish their work in good Indian journals. And, if they publish, it should be rightly appraised.
3. The beauty of such studies is , that it theoretical research based on your analytical skill and approach. Therefore, such bibliometric studies open a door of interdisciplinary research as well. Such type of work should be encouraged at institution level.
4. Library science may be a great helping department in such studies. We can encourage qualified librarians available in HEIs to be associated in such studies, so that they could also improve their profile and grow in their career.
5. HEIs can take help from NGOs working in the area of Environmental sustainability for better execution.
6. Such studies may be carried out on Institutional collaborative mode. So that resources could be optimizing utilized and all the stakeholders get benefited from the outcome of the study.
7. Last but not least, outcome of such studies must be published either in form of journal's articles or in form of brief book, as we published the present study from CRC Press Taylor & Francis, UK.

Research Summary/ Annotation of Project

Title: “Share of ‘*Green Chemistry*’ in Indian Chemistry Journals: A Comprehensive Bibliometric Study”

Author: Prof. Sanjay K. Sharma, FRSC, Professor, Department of Chemistry, JECRC University, Jaipur

Institution: JECRC University, Jaipur, Rajasthan

Year: 2021

Brief Description of the project, describing the purpose and outcome of the study

In Science and particularly in Chemistry there is no such comprehensive bibliometric study available **SO FAR**, which can give any idea about the share of ‘Green Chemistry’ in Indian Chemistry journals. That’s why I found this topic of proposal quite apt and important. I am sure, it will be a unique type of research and very interesting results are anticipated from it.

Based on the topics mentioned by NSTMIS, DST in the invitation for proposals, we found a strong need of this study. The need of Green Chemistry and its systematic implementation and study is very important for the students, research scholars and faculty actively involved in research.

Increasing industrialization is a big threat to the sustainability of the environment. In such circumstances, such studies will motivate researchers and scientists to carry out their research as per the ‘12 principals of the Green Chemistry’ and also motivate them to publish their finding in good research journals.

Ultimately, its all related with the Sustainability of environment, the growth and well-being of the mankind.

Objectives of the Study

The following objectives will be addressed in the present study:

3. To determine the geographical distributions of contributions in the journal
4. To find out Authorship Pattern
5. To find out the degree of Collaboration
6. To find out volume wise contributions
7. To find out the statistics of distributions in various fields of ‘Green Chemistry’

8. To find out the statistics of distributions of 12 Principles of 'Green Chemistry'
9. To find out the author self-citation ratio
10. To display volume wise dispersion of references

Outcome of the Project

The 2575 papers published in Indian journals were extracted from approximately 60000 research and review papers and were examined in Bibliometrix and MS Excel program. The studies were surveyed successfully on the list of SCOPUS. The bibliometric analysis was found out for investigating Authorship pattern, international collaboration, and funded/not-funded researches. The following remarks were summarized:


- 7722 Authors from 76 countries contributed concerning the green chemistry concept.
- 125 different Indian journals published 2575 papers and the average published papers per year is 128.75.
- 90% of published articles were published in the last decades.
- The ratio of paper per Author was 0.33. 117 research and review papers were published by 81 single Authors.
- 2458 papers were written by a collaboration of 7641 Authors. A ratio of Authors per paper can give a collaboration index which was 3.11.
- The total number of citations from 1999 to 2019 was 31381. The average ratio of C/P per citable years was found as 2.2.
- 388 research papers were published in Environmental Science and Pollution Research journal. The top 10 journals published 43.0% of all research and review papers.
- Islamic Azad University published 47 research and review papers.
- 709 research and review papers (27.5%) were financially supported and 1866 papers (72.5%) were not supported.

Important: This Bibliometric Study, has been published as a Focus Book by CRC Press Taylor & Francis, USA, entitled- "Green Chemistry in Scientific Literature: A Bibliometric Study and Research Trends". In the book, we have rightly acknowledged the grant of the project. We are submitting One copy of this book along with this Project report for the record.

End Project Deliverables

This Bibliometric Study, has been published as a Focus Book by CRC Press Taylor & Francis, USA, entitled- “Green Chemistry in Scientific Literature: A Bibliometric Study and Research Trends”. In the book, we have rightly acknowledged the grant of the project. We are submitting One copy of this book along with this Project report for the record.

This book will be a nice reference for the people willing to pursue research in this field. It’s a very interesting type of research, which is keep changing on regular basis, therefore this book will be a guideline in the true sense.



1st Edition
Green Chemistry in Scientific Literature
A Bibliometric Study and Research Trends
By *Sanjay Sharma, Hasan Demir*
Copyright Year 2020

ISBN 9780367430863
Published December 3, 2019 by CRC Press
100 Pages 10 B/W Illustrations

Fig.-29

How the outcome of this project will be beneficial to various stakeholders

1. **For Green Chemistry community:** Because this study is first of its type so far in the area of Green Chemistry, it is the first and foremost benefit to the scientific community at large. Academicians, Research Institutions, Publication Houses, Research Journals , Policy makers may use it as a reference and do the needful as per their requirements.
2. **For students/researchers:** The outcome of this project will be a nice reference for the students/researchers willing to pursue research in this field Bibliometric studies. It's a very interesting type of research, which is keep changing on regular basis, therefore this book will be a guideline in the true sense.
Such studies enhances the analytical skills and understanding of the students , which will be quite helpful for them in their career and growth.
3. **For Research Institution/ Higher Education Institutions:** The bibliometric study may be carried out in any subject or any domain area of the research. For HEIs , it's a big opportunity to motivate their faculty and students to take up this type of research in different areas/ subjects. Such studies overall improve the analytical ability and the intellect of a HEI.
4. **For Libraries:** The outcome of such studies is very good addition in various libraries of national and international importance, where people can explore it.
5. **For Principal Investigator:** It's a wonderful experience of exploring a new dimension of scientific publications. I am thankful to the DST for providing me this valuable opportunity. Being an author, editor and professor, it was a very fulfilling experience for me. Thanks a lot DST.
6. **For DST:** Such successful studies will be referred as case studies and motivate others to propose new projects in this area of research with more dynamic way of working and execution. I am sure DST will be happy to grant funds to such meaningful studies, which will be a great addition in the scientific literature and intellect of Indian scientists.

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