MAPPING OF CHEMICAL SCIENCE LITERATURE WITH REFERENCE TO WEB OF SCIENCE CITATION DATABASE: A SCIENTOMETRIC STUDY

A Thesis submitted to the Faculty of Science
and Technology, Kuvempu University
for the award of the degree to

Doctor of Philosophy
in
Library and Information Science

Submitted by

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(Registration No: LIS: 154)

Under the Guidance of

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DECLARATION

I hereby declare that this thesis entitled ***"MAPPING OF CHEMICAL SCIENCE LITERATURE WITH SPECIAL REFERENCE TO WEB OF SCIENCE CITATION DATABASE: A SCIENTOMETRIC STUDY"*** submitted to Faculty of Science and Technology, Kuvempu University, Shankaraghatta for the award of the degree of ***DOCTOR OF PHILOSOPHY IN LIBRARY AND INFORMATION SCIENCE,*** which is the result of the original work carried out by me in the Department of Library and Information Science, Under the guidance of **Dr. P. DHARANI KUMAR,** Assistant Professor, Department of P.G. Studies and Research in Library and Information Science, Kuvempu University Shankaraghatta.

I further declare that the results of this thesis have not been previously submitted for any other Universities in India or abroad.

Place: Shankaraghatta
Date: 21/6/18

Chaman Sab M
Research Scholar

CERTIFICATE

This is to certify that the thesis entitled ***"MAPPING OF CHEMICAL SCIENCE LITERATURE WITH SPECIAL REFERENCE TO WEB OF SCIENCE CITATION DATABASE: A SCIENTOMETRIC STUDY"*** submitted to the faculty of Science and Technology, Kuvempu University, Jnana Sahadri, Shankaraghatta for the award of the degree of ***DOCTOR OF PHILOSOPHY IN LIBRARY AND INFORMATION SCIENCE***, by Chaman Sab M, which is the original work carried out under my guidance. in the Department of P.G. Studies and Research in Library and Information Science, Kuvempu University, Jnana Sahadri, Shankaraghatta.

This thesis has not been provisionally formed the basis of the award of any degree, associateship etc., of any other University or Institution.

Place: Shankaraghatta
Date: 21|6|18

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Dedicated to my beloved guru

Prof. B. S. Biradar

for his Love, Support, Encouragement and

understanding throughout life

Chaman Sab

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CHAPTER - 1

INTRODUCTION

1.1. Introduction

Scientometrics is an application of quantitative methods in the history of science. It is also one of the techniques for documenting works of eminent scientists and researchers. Scientometrics is a discipline which analyses scientific publications to explore the structure and growth of science. The bibliometric / scientometric / informetric techniques used to analyze various quantitative or qualitative aspects of a publication. It is a scientific field that studies the evolution of science through some quantitative measures of scientific information, as the number of scientific articles published in a given period of time, their citation, impact, etc. The history of science and technology, philosophy of science and sociology of scientific knowledge are the related fields of scientometrics.

The term scientometrics is often used synonymously with bibliometrics that originated in Russia. It is the application of quantitative method to the history of science. Scientometrics is the science of measuring the science, which involves counting artifacts to the production & use of information and arriving at conclusions from the counts. Bibliometrics / Scientometrics research includes studies related to the scattering & growth of literature, author productivity, obsolescence of documents, distribution of scientific literature by country, by language, etc, which helps to monitor the growth pattern of research. India has a large cadre of chemical scientists and network of R & D institutions that would envy many. A large number of R & D institutions have been set up to take up the chemical science investigations. These institutions are created to provide government with basic quantitative and descriptive information in the field of chemical science as well as to investigate the problems in particular fields in order to solve the social problems. A part from the IITs and Universities, the council of Scientific & Industrial Research laboratories and specialized institutions in chemical science are being funded by the government in order to take up research in the field (Sangam, 2011).

At the time of independence, the S&T base of the country was very small. But, today it consists of a wide spectrum of infrastructure in terms of higher education institutions, research laboratories and institutions, in house R&D establishments of industry, etc. India being rich in natural resources and traditional medicinal chemistry has a long history of chemical investigation. The R & D activity in chemistry can be traced back to ancient period and the literature output covered in Chemical Abstract since its inception reveals that Indian scientists are engaged in chemical investigation for long. Since independence, research in this area has triggered due to establishment of a number of scientific institutions between 1940 and 1960 such as Council of Scientific & Industrial Research, National Physical Laboratory, and Indian Institute of Chemical Biology etc. More and more research is being done in this area due to industrial revolution and funding by government as well as industries (Gupta, 2012).

Science and technology (S&T) today has acquired an international character. It is not possible for many countries in the world, particularly the developing countries, to conduct scientific research at individual levels. They need the cooperation of other countries, which have the necessary knowledge-base and infrastructure along with the will to collaborate. In dealing with problems such as environment degradation, loss of biodiversity, pollution control, health and nutrition, developing countries face limitations like weak national S&T infrastructure, lack of trained S&T personnel, inadequate funding, weak and inadequate communication, internal upheavals (political, economic, and cultural), and linguistic problems. To cope with such problems research collaborations are, in fact, emerging as an important catalysis for accelerating research in these areas. In areas like traditional medicine, these collaborations are assuming greater significance because now even the developed countries want to have linkages with the developing countries for the flow of knowledge. Thus, science is being practiced today in a collaborative manner with participation of two or more countries. There are many factors which directly or indirectly affect the collaboration among nations – economic and educational exchanges with the political relationship being the most important (Gupta, Munshi, & Mishra, 2002).

Mapping

A map is a visual representation of an area- a symbolic depiction highlighting relationships between elements of that space such as objects, regions and themes. It is a graphical representation that helps to understand connections and corresponding relationships between things. In case of literature, it is a study of correlation of links between the past and present, research work using citation analysis. The information thus obtained is very vast in nature. Therefore, it requires a treatment through which it can be represented in a précised focused formatted condition. This requirement can be fulfilled by the technique called “mapping”.

Mapping helps us to create knowledge base of a specific area. It also provides an outline of the distribution of knowledge at different levels. The mapping is based on the subject that we select for e.g.: The papers published in the journals and the cross citations of every such paper. In such maps the main themes are placed in relation to each other. The more closely related are put together and less related are put apart. The different aspects of bibliographic may be used to create a map and each aspect shows a structure which is specific and also the relation with the structure of other aspects. Mapping is also described as graphic blueprint, a diagrammatic representation and a geographical metaphor of the research field (Sangam & Mogali, 2012).

Concept of Mapping

Mapping is a process of reorganizing and re-arranging most of the important ideas and information identified by reading the literature and converting it into a diagram with symbols which helps us to understand and remember easily. When we adopt it to research field, mapping is done in order to understand the patterns of research in a particular area, to locate the hidden areas of research, to identify the gaps in the research field and to know the boundaries of the topics under investigation. It also facilitates the researcher to identify the potential original areas of study and go through the paper and analyze it by using critical techniques. We have to identify the key concepts across the literature, which have got relevance to our piece of research. We have to note down the areas of consensus between different authors and also areas of disputes between particular authors and reasons for their difference of opinions. Further we have to note the implications of these aspects on our research. With help of above said parameters we have to draw a map. Every time whenever we read a new literature and identify the key concepts then we have make necessary changes in the map. If necessary we may have to add to the relevant area of map already drawn or can create a new conceptual area if necessary. The mapping is done as per the visualization of the person. Mapping is much simpler; it is done in two levels i.e. Macro level mapping and Micro-level mapping. Macro-level aims to capture the overall feature of the disciplines, and the Micro-level relates to analysis of individuals in the disciplines. The key elements of macro-level are Component, Distance, Cluster, Degree distribution and error. And the key elements of micro-levels are Degree distribution, Closeness centrality, and betweenness centrality (Sangam & Mogali, 2012).

Need for the Study

The assessment of research performance by using ***Scientometric*** technique is a valuable method for the identification of new scientific and technological knowledge. The growth of literature has become a major concern for the scientists, scholars and library professionals as they have to keep themselves abreast with the new advances in their subject. Publication profile is an indicator of the scientific activity of a country. It has seen from the available literature that a little study was done in this field. Many important observations can be derived by studying scientific publications through their bibliographic features such as the channels of communication, journal titles used for publication, the name and affiliation of author, authorship pattern and collaboration.

Thus the present study ***"Mapping of Chemical Science Literature with reference to Web of Science citation Database: A Scientometric Study (2002 – 2016)"*** is an attempt to examine the main features in the field of Chemical Science. The present study is to understand the information and communication channels, in one of the multidisciplinary subjects of Chemical Science literature published in the form of Journal articles, chapters in book, and conference proceedings in a span of 15 years that is from 2002 to 2016.

1.2. Statement of the Study

The Statement of the present study ***is "Mapping of Chemical Science Literature with reference to Web of Science Citation Database: A Scientometrics Study (2002 – 2016).***

1.3. Scope and Limitations of the Study

The study is to find out the publication trend of research articles in "Chemical Science Literature". The study is purely based on articles published in journals, books and papers published in conference proceedings and editorial books on Chemical Science from 2002 – 2016. The study is covered in web of science citation database. The study continuing to a limited period i.e. 2002 – 2016 for a studying 15 year.

1.4. Source of Data

Web of Science (WoS) is an online subscription-based scientific citation indexing service maintained by Clarivate Analytics that provides a comprehensive citation search. It gives access to multiple databases that refers cross-disciplinary research, which allows for in-depth exploration of specialized sub-fields within an academic or scientific discipline

A citation index is built on the fact that citations in science serve as linkages between similar research items, and lead to matching or related scientific literature, such as journal articles, conference proceedings, abstracts, etc. In addition, literature which shows the greatest impact in a particular field, or more than one discipline, can easily be located through a citation index. For example, a paper's influence can be determined by linking to all the papers that have cited it. In this way, current trends, patterns, and emerging fields of research can be assessed. Eugene Garfield, the "father of citation indexing of academic literature, who launched the Science Citation Index (SCI), which in turn led to the Web of Science.

Citations are the formal, explicit linkages between papers that have particular points in common. A citation index is built around these linkages. It lists publications that have been cited and identifies the sources of the citations.

Anyone conducting a literature search can find from one to dozens of additional papers on a subject just by knowing one that has been cited. And every paper that is found provides a list of new citations with which to continue the search. The simplicity of citation indexing is one of its main strengths.

1.6. Objectives of the Study

Following are the main objectives of the study

i. Examine the growth of Chemical Science literature covered in Web of Science Database for the period 2002 – 2016.

ii. To analyze the global share in Chemical Science literature.

iii. To find the international collaborative papers and identification of major collaborative partners.

iv. To identify the highly prolific authors in chemical science literature.

v. To understand the characteristics of highly productive institutions and highly cited papers.

vi. To identify the most, medium and low productive areas of research.

vii. To study the most preferred journals by the Chemical Science scientists/researchers.

viii. To determine the relationship existing between various Scienctometric indicates.

1.7. Hypotheses of the Study

The following hypotheses are formulated on the basis of the study of related literature and objectives framed above

i. There is an increasing trend (growth) in the Chemical Science publications;

ii. The share of international collaborative papers in the Chemical Science have increased over the years;

iii. Bradford's law of scattering positively fitted with Chemical Science Literature; and,

iv. Collaborative research plays a significant role in influencing the quantitative research output in the country.

1.8. Methodology

The study will analyze the research output of Chemical Science literature for the period 2002 – 2016 on several parameters including its growth and share in the world's research output, pattern of research communication in core domestic and international journals, geographical distribution of publications etc.

There are various sources contributing to the research output in the field of Chemical Science research by the scientists all over the world. In this study secondary sources are also taken for analysis. The Web of Science citation database has been used to retrieve the publications data for 15 years. The web of science is the search platform provided by Thomson Reuters. The study period 2002 – 2016 is selected as the database is available.

The present study is based on India’s Science & Technology research output indexed in Web of Science (WoS) which is an online subscription-based scientific citation indexing service maintained by Thomson Reuters that provides a comprehensive citation search. It gives access to multiple databases that refers cross-disciplinary research, which allows for in-depth exploration of specialized sub-fields within an academic or scientific discipline during 2002-2016. The cumulative publications, citations, subject areas, institutional collaborations, international collaboration and H-index for 15 years (2002 to 2016) have been taken. This study has identified the factors underlying its growth, stagnation and decline. It also examined. India’s position vis-à-vis selects developed and developing countries, in terms of its research output, citation visibility.

1.9. Organization of the Study

The present study has been organized into five chapters which are as follows:

Chapter 1 - Introduction: It deals with the introduction, need, Scope, objectives, hypotheses and methodology used for the present study.

Chapter 2 - Review of Literature: This chapter presents a comprehensive review of the related literature for the study in following subheadings; viz. Growth and development of research productivity, scientometric analysis of different subjects and sources, scientific productivity of institutional or organizations, author productivity and collaboration, ranking of journals and institutions, citation analysis of individual scientists. Collaboration works (Individual level, Institutional level & Country level), applications of bibliometric laws, obsolescence of literature and recent trends in scientometrics/bibliometrics.

Chapter 3 - Scientometrics: A Tool for Assessing and Evaluation Science Research: This chapter covers history, origin and different metrics used in Library and Information Science domain viz. Bibliometrics, Webometrics and Scientometrics etc.

Chapter 4 - Data Analysis and Interpretation: This chapter Provides analysis and interpretation of data under major heads: Growth and development, productivity and collaboration, productivity of Journals, productivity of scientific institutions of Chemical Science research.

Chapter 5 - Findings, Suggestions and Conclusion: It gives a brief summary of the findings, suggestions, conclusion and areas for further research,

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CHAPTER - 2

REVIEW OF THE RELATED LITERATURE

2.1 Introduction

The review of literature is an important element of any research study. It helps the researcher frame the research study on the chosen topic by providing new ideas, concepts, methods, techniques and approaches. The review of relevant literature covers the key sources, relevant to the present research topic. The review of literature is unique and it aims to provide an overview of the sources. The purpose of review is to identify relevant information and to outline the existing information, to identify the gaps in the current field of study and to position the present work, to evaluate and synthesize the information. That are obtained on par with the concepts that have been set in the present study and to provide justification for the study undertaken.

For this purpose literature search was carried out by using databases like, SCOPUS, Web of Science database (Science Citation Index), Social Science Citation Index, Emerald, Springer e-journals etc. Attempts were also made to trace and collect the relevant research papers and related documents such as journal articles, conference papers, books, etc.

The research publications gathered from various sources have been documented and the information so collected was used for evaluation. Finally the summary of the papers has been written. In this chapter, an attempt has been made to review the published literature under the following sub-headings:

- Growth and Development of research Productivity;
- Scientometric Analysis of different Subjects and Sources; Scientific Productivity of Institutions or Organizations;
- Author Productivity and Collaboration; Ranking of Journals and Institutions;
- Citation Analysis of Individual Scientists; Collaborative works (Individual level, Institutional level and Country level);
- Application of Bibliometric Laws;
- Obsolescence of Literature and
- Recent Trends in Scientometrics/Bibliometrics.

2.2 Growth and Development of research Productivity

Line & Stephen (1976) have conducted the study on the size, growth, and composition of social science. The study is based on the analysis of available statistics of serials and monograph publication in social science up to 1973. Authors have found that serial titles took exponential growth of 3.44% per annum between 1920 and 1970. The annual average mortality rate of current titles was 0.5%. It is seen that the growth was more rapid in case of secondary services than of primary serials. The monographs showed a high linear increase.

Boxenbaum (1982) has analyzed the growth in pharmacokinetics during 1964-1980. The literature doubled approximately every 1.6 years during most of this period. It is observed from the analysis that little or no growth during 1978-1980. Thus, the pharmacokinetic literature increased at a much more rapid pace than did the total chemical literature in general.

Schubert & Glanzel (1984) have applied a quantitative model for establishing a definite connection between literature growth and publication productivity distribution in prompt nuclear analysis. The model combines two simple and familiar postulates: that of self-reproduction asserting that newcomers in a field joining the population of authors at a rate proportional to the actual number of authors and cumulative advantage establishing a linear relation between the number of papers already published by a given author and his chances to produce a subsequent paper in the field.

Stephenson (1985) has investigated the growth of published literature in the field geochemistry and vertebrate paleontology by using a non-experimental design, an evaluative instrument is developed for assigning a quantitative score to publishe research based on the research method utilized. A Kendal tau c coefficient values were obtained and the hypothesis that a significant correlation exists between the presence of selected research method criteria in the published literature of a branch and the growth rate of the published literature of that branch is found to be supported.

Parvathamma & Gunjal (1993) have studied the growth and scientific productivity in the field of earth sciences. It indicates that the relative growth rate is declining from 0.35 to 0.11 and the growth pattern follows the logistic pattern. The productivity of authors is fairly close to Lotka’s Law as 63% of the authors contribute single paper and it follows the negative binomial distribution.

Glanzel (1996) has conducted the study on National Research Performance in the six selected fields of social science for the period of 1990-1992. He used bibliometric methods for the evaluation of National Research Performance of hard and Life Sciences were used. Found that SCI and SSCI appear to be identical or similar but there is a difference in coverage of bibliometric data. The SSCI covers fully and selectively journals while SCI covers the publication in any journal.

Braun, Schubert & Zsindely (1997) have calculated the growth rate of the nano-prefixed terms in the title of journal papers to examine the growth patterns of nanoscience and technology, the exciting new science. The study showed that the investigations dealing with graphite nanotubes represent kinetically the most active field of research in the Nano sciences.

Garg & Padhi (1998) have conducted a study on laser patent literature based on the papers published in the journal of Current Laser Abstract (JCLA) for the period 1967-1995. Paper indicates that innovative activity in laser science is at its peak in the early 1970s. A shift in emphasis from application of laser to experimental laser research and to theoretical laser research has been observed. The USA and the Japan are the leading countries in laser research with an emphasis on spectroscopy of laser out communication, application of laser research.

Braun (1998) studied the growth of social science literature during the period 1989-1995 by referring to SSCI, under the context of globalization. The study concludes that there is an exponential growth with doubling time of two years.

Khan et al (1998) observed LIS literature in Bangladesh for the period 1966-1997.The literature was retrieved from 37 periodicals originating from 14 countries containing 308 articles which were written by 116 librarians. The observation reveals that 256 articles (83%) were published from Bangladesh alone and 21 articles (6.82%) were from India. Out of the total articles published 92% were single author papers and only 25 articles were of multi-authorship.

Seetharam & Rao (1999) have conducted a study on Food Science and Technology (FST) based on the CFTRI publication output between 1950 and 1999. It traces and compares the trends in Food Science and Technology literature – books, reports, patents etc., produced by CFTRI and world output. The findings reveal that world's FST literature growth has increased by seven times since 1950 while Indian FST literature is 35 times. For this study Gompertz model followed by logistic are the best fitted models for both world as well as Indian FST literature.

Sharma & Garg (1999) have studied the structure and dynamics of mathematics discipline and found that out of 37 subfields of mathematics, 14 subfields output is more than 57% compared to others. The growth rate of mathematics as well as of its subfields follows the logistics growth pattern, and the growth rate is found to be declining in mathematics.

Jayashree & Arunachalam (2000) have made studies on mapping of fish research in India by referring to six databases, covering 460 papers roughly 5.5% of the world. Of them 82% are journal articles which have appeared in 113

Indian Journals. Less than 33% of articles have been published in journals indexed in SCI. Studies also include the contribution of papers from different Government laboratories and academic institutions. It is inferred that Kochi, Chennai, Mumbai and Mangalore are the cities and Tamil Nadu and Kerala are the states contributing large number of papers.

Karki (2000) has examined the activity and growth of organic chemistry research in India during the years of 1971 – 1989 by using Chemical Abstract as source database. The study reveals that the activity index of India is quite lower. However, the activity picked up speed and matched with world during the 1980s. The growth trend of world and India follow the same pattern which shows that the output in three subfields such as amino acids, alkaloids and general organic chemistry is not going to saturate in near future. For the data, exponential model has been found to be the best fitted.

Berthelemot & Russell (2001) have studied the distribution of world's social science journals, the analysis of 4,326 periodicals in the social science was done. These periodicals have been included in 1991 printed edition of the UNESCO, and DARE database. The quantitative studies in the field of social science is focused on the analysis of National Research Performance and Mapping of International Research. The multidisciplinary database SSCI was referred.

Gupta et al. (2002) found a suitable growth model for applicable to study the growth of publications in the six major sub disciplines of social science in the world. For the study Econolit, Sociofile, and Psychit databases were referred.

The results of the study reveal that the application of selected growth models to the cumulative growth of publication in anthropology (1963-1997), economics (1969-1997), history (1970-1997), political science (1970-1997), psychology (1974-1998) and sociology (1963-1998) indicate that growth models could explain their growth.

Sangam & Keshava (2003) have examined the growth pattern of literature in the field of social science. For this study data has been extracted from CD-ROM version of *Wilson Social Science Abstracts* for the period 1983-1998. Study has discussed among the following disciplines viz, Anthropology, Economics, History, Political Science, Psychology and Sociology. Calculation of relative growth rates and doubling time for publication has been done in order to determine the rate of growth of social science literature. Further, the study identifies the criteria on the growth models are to be selected for the appropriate application in the above said six disciplines.

Arunachalam & Rino (2003) have explored the growth and development of modern biology considering it in India and China. The study was based on the data retrieved from BBCI and BTCI. Journal country and impact factor, highly cited papers and internally co-authored papers have been identified. The result of the study shows that China's publication rate is much more than that of India in 1992-2000. There is a consistent growth during the period 1995-98.It is common in both the countries that highly cited papers were written in collaboration with foreign authors and institutions. In the year 1995, institutions contributed a more number of highly cited papers.

Sangam & Kadi (2003) have studied the growth pattern of research and priorities of demography research in different countries of the world, i.e., USA, UK, India and China for the period 1986 to 2000.For the study they have employed appropriate growth model to fit the time series data in order to study the trend of growth of subject for each country. The results show that over a period of time there is an increase in publication of literature.

Angadi et al. (2006) has conducted the scientometric study by analyzing 358 publications published by different social scientists working in Tata Institute of Social Science between 2001-2004.This was in order to study authorship pattern and collaboration trend. The result of study indicates that 90.22% of papers were by single author, 5.86% were by two authors, and 3.35% were by three authors.

Katy et al. (2006) has studied the publication data sets and analyzed to identify 500 most cited research institutions with spatio temporal changes in their inter-citation patterns. The approach is novel in analysis of the dual role of institutions as producers and consumers of scholarly knowledge and studying the diffusion of knowledge among them. A geographic visualization metaphor has been used to visually depict the production and consumption of knowledge. Finally the maps showing the highest producers and their consumers and highest consumers and their producers have been prepared.

Gunasekaran et al. (2006) has conducted study on chemical science research in India. Indian scientists have published 6186 papers in 569 journals. Of the papers in various journals, more than 45% have impact factor less than 1%. Nearly 2% of the papers published did not have any impact factor. The average impact factor for journal articles during 2002 was 1.359. Indians published nearly 26% of papers in the US journals. Of them Asian journal of Chemistry could publish 269 papers, Journal of Indian Chemical Society published 224 papers and Indian Journal of Chemistry could publish 209 papers.

Saxena et al. (2007) has written a paper with an aim to forecast a time series using a suitable model based on the analysis of historical data. A model is valued on the basis of its efficiency to perform the task for which it has been designed, and how best it fits the data. Various statistical models have been used to analyze the growth of literature; the one that suits the study is not yet finalized. In view of this, a study has been conducted to explore the models for growth of literature. One approach called multiplicative seasonal model approach and another is nonlinear model where the trend has exponential growth form. The result of the study reveals that adequate number of models came out with good fit parameters. This paper highlights the basic issues that are related to the forecasting growth of literature data.

Thompson & Williams (2007) havetracked the growth of drug therapy literature using the online provider PubMed MeSH. Publication numbers are compiled each year from 1966 to 2003. It was found that the drug therapy literature is growing at a faster rate than the disease literature on PubMed.

Davarpanah & Aslekia (2008) have conducted the quantitative study of productivity, characteristics and various aspects of global publication in the field of library and information science (LIS). A total of 894 contributions published in 56 LIS journals indexed in SSCI during the years of 2000 to 2004 were analyzed. A total of 1361 authors have contributed publications during the five years. Majority (89.93%) of the papers are single author. The average number of authors per paper is 1.52, all the papers are published in English and received few citations.

Wani & Gul (2008) have analyzed the growth and development of the scholarly literature in Scopus database from different points of view. The study found that Europe was in the lead in the scientific production, journals are the largest part of the published literature, and the physical sciences are the dominant disciplines. Also that, Asia produces a considerable proportion of worldwide research.

Sangam, Meera & Megeri (2008) have analyzed the growth pattern of chemical science literature in India in eight branches. And also measures the growth by calculating relative growth rate and doubling time for chemical literature. Further identify parameters and fit statistical branch for modeling the growth.

Bala & Gupta (2010) have analyzed the research output in India in neurosciences during the period 1999-2008 and the analyses includes research growth, rank, global publications share, citation impact, share of international collaborative papers and major collaborative partner countries and patterns of research communication in most productive journals. It also analyses the characteristics of most productive institutions, authors and high-cited papers. The paper compares the publication output and impact of India with China, Brazil and South Korea.

Sangam, Liming & Ganjihal (2010) have described the application of growth models to study the growth and dynamics of Indian and Chinese publications in the field of liquid crystals research during 1997-2006.

Glanzel (2010) has presented an overview over the opportunities of probabilistic models in scientometrics. Four examples from different topics are used to shed light on some important aspects of reliability and robustness of indicators based on stochastic models. Limitations and future tasks are also discussed.

Sangam (2010) has examined the growth models suggested by Egghe and Rao. The study reveals that during the period 1997-2006, India has contributed 1,567 papers whereas China has contributed 3,375 papers. India has contributed 193, the highest number of papers during the year 2004-2006 while China has the highest number of papers i.e., 535 during the year 2006. The rest of the countries have 45,217 publications and 4,929 is the highest during 2004.Further studies were conducted to identify appropriate growth models which fit into the Indian and Chinese cumulative growth of publications.

Sagar et al. (2010) has made an attempt to study the research publication on Tsunami during 1997-08 by referring Scopus database. 4,338 publications and 21,107 citations were examined and the growth of publications, country-wise distribution of publications, and activity index of countries most-frequently cited publications, authorship pattern, co-authorship index and distribution of keywords were traced. Out of the total publications of Tsunami 54.20% has been contributed by USA, Japan, UK, India and Australia. The incident of Indonesia’s tsunami on 26th December 2009 paved the way for more number of publications.

Gupta, Bala & Kaur (2011) have studied the research publication on AIDS/HIV during 1999-08. The data has been extracted from Scopus database. The data was analyzed on the aspects of growth, rank, global publication share, citation impact, share of international collaborative papers, contribution of major collaborative partner countries, contribution of various subject-fields and by type of tuberculosis and patterns of research communication in most productive journals. According to the study, India ranks the 12th position in the top 20 countries and its global publication share is higher than Brazil's. The inference of the study is that India needs to increase its output and bring about improvement in the quality of its research efforts.

Balasubramani & Murugan (2011) have taken up the study of research performance of India in tapioca during 1997 -2010. The main focus of the study in research of tapioca is its growth, share and impact in global publication, the patterns of international and major collaborative partners, the publication productivity and the impact of leading institutions of India, the characteristics of most prolific authors and high-cited papers and patterns of research communication in the productivity journals. For the study SCI through Web of Science provided by Thomson Reuters was used. Totally 447 records were used and analyzed by using histcite software application in order to fulfill the objective of the study.

Choudhury & Sarkhel (2011) have made an attempt to study the research publication on agriculture research in West Bengal for the period 1993-2007 by referring to CAB Abstracts. According to the study, 303 institutions have 10417 author papers in 1178 journals published from 53 countries. Only 8 foreign journals were from the top 50 journals with 30 papers. The institutions which produce high quality papers were noticed. The collaborative research trend was found among the authors.

Gupta & Bala (2011) have made an attempt to study the research publications on tuberculosis during 1998-09 by referring to Scopus database. The data was retrieved on the following aspects, the growth, rank and global publication share, citation impact, share of international collaborative papers, contribution of major collaborative partner countries, contribution of various subject fields and by type of tuberculosis and patterns of research communication in most productive journals According to the study, India ranks the 3rd position in the top 21 countries and the global publication share is higher in China. The inference of the study is that India needs to increase its output and bring about improvement in the quality of its research.

Rita et al. (2011) has conducted a study on publication productivity and career advancement by female and male psychology faculty. The study is concentrated on 511 university psychology professors in which 250 are women. The period of the study was from 1998 to 2004 and the database referred was PsycINFO. The result of the study reveals that overall women published less than men especially in international journals and as senior authors. Further studies also show that the scientific productivity of women is slower when compared to men's.

Sudhier & Abhila (2011) have done an analytical study on the research productivity of the social scientists at the Centre for Development Studies, Thiruvananthapur during 1998-2008. Total 599 research publications by CDS researchers have been considered. This includes 38.32% journal articles, 23.54% chapters in books and 15.03% working papers. The study reveals that the degree of authorship collaboration is found to be 0.043. More than 66% of articles were published in Indian Journals while 33.19% were published in foreign journals.

Liu et al. (2011) has analyzed the biodiversity research publications for the period of 1900–2009, based on the Science Citation Index (SCI) database. Analysis reveals the authorial, institutional, spatiotemporal, and categorical patterns in biodiversity research and provides an alternative demonstration of research advancements, which may serve as a potential guide for future research. The analysis shows Ecology, environmental sciences, biodiversity conservations, and plant science as most frequently used subject categories in biodiversity studies, and *Biological Conservation*, *Journal of Soil and Water Conservation, Conservation Biology and Biodiversity and Conservation* as most active journals in this field, and the United States as the largest contributor in global biodiversity research.

Gupta et al. (2011) has analyzed the Indian computer science research output for the period 1999-2008.The authors have used many collaborative parameters. A comparative study of publication output and the impact of India in comparison with China, Taiwan and Brazil was done.

Varaprasad & Ramesh (2011) have discussed the Indian chemical research activity during 1987-2007 using Scopus database. Tried to quantify the national contribution to world efforts, and identify areas of relative strengths and weaknesses. They explored the trend of growth in the output of Indian chemical research to the world as a whole and in sub-fields of chemical science. These details are discussed by using the activity index for the world and India.

Gupta & Bala (2011) have analyzed the research output of India in asthma during the period from 1999 till 2008. SCOPUS database has been used to retrieve the data on publication output in asthma research. India ranks 15^{th} position among the top 23 countries in asthma research, with its global publication share of 1.27% (862 papers), registering an average citation per paper of 3.43 and achieved an h-index of 33 during 1999-2008. Also, the impact and quality of Indian research is low compared to select developed and developing countries.

Gupta (2012) has analyzed the research output of Pakistan's science and technology for the period 2001-10 on several parameters including its growth and share in the world's research output, pattern of research communication in journals, geographical distribution of publications, high productive institutions, authors and cited papers. The paper suggests for Pakistan to increase its output and bring improvement in the quality of its research efforts.

Sangam & Meera (2012) have examined the chemical science research in India and prepared a map based on publication and citation data. In the study, the quantification of research and growth in the different subfields of chemical science literature has been done. The study was extended even to identify the research institutions which are leading in publishing large number of papers and journals. It was possible to mark the highly productive academic institutions, who contributed more number of Indian research papers in the field of Indian chemical sciences.

Saghafi, Asadi & Osareh (2013) have focused on visualizing the structure of the Iranian scientific publications in the field of engineering indexed in ISI accessible via web of science during 1939-2011. To draw the historiographical map of Iranian scientific outputs in the field of engineering, HistCiteTM software is used. Two indexes, Local Citation Score and Global Citation Score, were used for the purpose of ranking and visualizing data.

Zhang (2014) examines the China's performance on tissue engineering using scientometrics measure during 2008-2012, the publications data obtained from ISI Science citation index expanded the database. It determined Chinese share in international collaborative papers at the national level, along with h-core papers and high-cited papers, etc.

Xiang, Zhang & Zhu (2015) have studied the history and research status of earthworm research in developed and developing countries from 2000 to 2015, data was collected from the Science Citation Index Expanded. They found that the research of earthworm has increased during the studied 16-year period. USA has produced the highest research output among countries. The majority of articles and Total Location Citation Score (TLCS) values came from developed countries. Articles published with higher TLCS scores had a greater impact on the research and played an important role in research development. Developed countries have more research advantages in this field than that of developing countries.

Sangam, Madalli & Arali (2015) have studied the growth pattern, doubling time of world and Indian Genetics literature. There are several dimensions of national science indicators that can be used to study different aspects of the research output in the field of Genetics and its ten subfields. Study finally inferred that the Logarithmic and Linear growth models fit well for World's genetics literature whereas for India Exponential and Logistic models fit well.

Chaman, Dharani, & Biradar (2017) have analyzed the scientometric parameters for Indian Chemical Science literature; data for this study has been extracted from Web of Science (WOS) database for the period 2005 to 2014 for identifying the scientometric analysis of Indian chemical science literature. It also gives a comparative evaluation and performance of different types of scientometric indicators. Study analyzed that India has produced 86,914 papers, and received 7, 28,089 citations. India's publications are gradually increasing year by year. The global publications share of India during 2005-2014 was 5.44%, which has increased from 4.37 in 2005 to 6.47 in 2014.

2.3 Scientometric Analysis of Different Subjects and Sources

Ravichandra Rao & Suma (1999) have analyzed the Indian engineering literature for this the data has been extracted from COMPENDEX database. The authors found that the engineers in India publish their articles in journals and all papers published in English language. They publish in a selected few journals and only a few of the institutions have concentrated in engineering research. They observed that research output in applied physics, light & optics, bioengineering and information science are increasing both at the world and India level.

Sangam & Munavalli (2004) have focused on citing pattern of Information Professionals and that have changed with time. The paper concludes that Web based information resources have great role to play with information professionals and witnessed the impact of information technology.

Leydesdorff (2005) has studied the use of science indicators for evaluation of research and evolution of indicators. The paper focuses on the output indicators, methodological limitations, multivariate and dynamic analysis, cyber metrics and web metrics, reflexive scientometrics in detail.

McKiernan (2005) has described the bibliometrics to be traditionally associated with the quantitative measure of documentary materials and embraces all studies which seek to quantify the process of written communication. These include science studies, research evaluation, knowledge management, environmental scanning, trend analysis, and the optimization of library and information resources. Some significant Web resources relating to bibliometrics and related approaches are given.

Lima-Ribeir (2007) has carried out a scientometric analysis in population ecology to understand the importance and trends of the field throughout years, connecting them with the principal geopolitical regions around the world. The results contrast with the scientific stagnation widely criticized in ecology and indicate the progress of the population ecology as science, pursuing new horizons as well as new paradigms, laws, theories and principles that might be useful to the society.

Lalitha Kumari (2009) has analyzed the research output and impact in synthetic organic chemistry during 1998–2004,with standardized scientometric indicators. Based on the analysis, it is concluded that G7 nations, being leaders in respect of the volume of literature published, and citations attracted are showing a decreasing trend over the years probably due to shifting and diversification of their research efforts to other emerging research fronts.

Kaur & Gupta (2009) examined the India's performance based on its publication output in Immunology and Microbiology during 1999-2008, based on several parameters, including the country's annual average growth rate, global publications share and rank, institutional profile of top 15 institutions, international collaboration profile and major collaborative partners, patterns of communication in national and international journals, and characteristics of its top 15 most productive authors. The study uses 10 years publications data in Immunology and Microbiology from Scopus International Multidisciplinary Bibliographical Database.

Ping & Wolfgang (2009) have studied the Chinese regional contributions and international collaboration based the data extracted from the Science Citation Index Expanded (SCIE), and conducted a systematic analysis of in terms of scientific publications, publication activity, and citation impact by using scientometric methods. The authors found that regional contributions are highly skewed. The top positions measured by the number of publications or citations, share of publications or citations are taken by almost the same set of regions.

Haddow & Genoni (2010) have performed citation analyses for Australian social science journals to determine the differences between data drawn from Web of Science and Scopus. These data were compared with the tier rankings assigned by disciplinary groups to the journals for the purposes of a new research assessment model, Excellence in Research for Australia (ERA), due to be implemented in 2010. The findings suggest that the Scopus database provides higher number of citations for more of the journals. The implications for Australian social science researchers are discussed in relation to the use of citation analysis in the ERA.

Lopez et al. (2010) have explored general overview of academic production from the analysis of sample of articles published between 2005 and 2007 in the Psychology journals covered by Psicoredalyc. The results suggest that research networks should be strengthened and the publication in journals from other countries should be fostered.

Lu & Wolfram (2010) have investigated the growth and geographic distribution of metric research for the period 1987-2008. The United States continues to dominates as in other studies, but there has been a recent relative decline in North American contributions overall. European and Asian contributions have grown substantially. National and institutional collaborations that contribute to this growth do not necessarily follow close geographic proximity, although European nations have been more active with international collaborations overall, both within Europe and elsewhere.

Pouris (2010) has assessed the Southern Africa development community countries. The author has utilized National Science Indicators database of Thomson-Reuters and the online ISI Web of Knowledge in order to identify the number of publications of the 15 countries over a period of 15 years; the activity and relative impact indicators of 22 scientific disciplines for each country and their collaborative patterns.

Arencibia-Jorge & Moya-Anegon (2010) have studied the different metric approaches to the Cuban scientific activity by national and international authors. The article also develops a scientometric study of the Cuban Scientific production as included in Scopus during the period 1996-2007, using socio-economic indicators combined with bibliometric indicators supported by the SCImago Journal and Country Rank.

Satyanarayana (2010) has examined the evolution of measures and parameters for the evaluation of science and scientific journals from the first attempts during the early part of the last century to the development of the most popular, current and widely used metrics viz., citations, impact factor (IF) etc.

Rao (2010) has studied the two types of science indicators- quantitative and qualitative, and applied different growth models to growth of literature; indicators related to scientific productivity of scientists and issues in scientometrics are discussed.

Khan et al. (2011) has utilized scientometric approach to analyse and synthesize e-government literature that deals with the topics in developing countries from the lens of socio-technical theory. In the light of the findings, strengths, limitations, and future directions for e-government research in developing countries is discussed.

Yanning et al. (2011) has investigated that the highly-cited articles in physics (1979-2008), using citation data from the ISI Web of Science. In the study, 15, 44,205 articles were examined. Found that the USA is the world leading country in physics, and Japan has maintained the highest growth rate in the field of physics research since 1990.

Karpagam et al. (2011) has studied the growth pattern of Nano science and Nanotechnology literature in India during 1990–2009 (20 years), using Scopus Database. His study also identifies the Indian contributions in the field of Nano science and nanotechnology. Further, the authors measured in terms of country annual growth rate, authorship pattern, collaborative index, collaborative coefficient, modified collaborative coefficient, subject profile, etc. He has also examined the national publication output and impact in terms of average citations per paper, international collaboration output and share, contribution and impact of Indian Institutions and impact of Indian journals.

Andersen & Hammarfelt (2011) have studied the production of dissertations in eight research fields in natural sciences, social sciences and humanities with the help of ProQuest: Dissertations and Theses database covering years 1950-2007 is used to depict historical trends, and the Gompertz function is used for analyzing the data.

Jones et al. (2011) has described the methods of scientometric analysis to understand the nature of translational research and monitor policy interventions. The bibliographic and citation data has been downloaded from all articles published in 2009. 75 leading journals in cancer and in cardiovascular medicine have calculated citation relationship between his journals and articles.

Pouris & Pouris (2011) have studied the pandemic HIV/AIDS related research in South Africa and identified as producing an increasing number of HIV/AIDS related publications, making it one of the most prolific fields in the country. The rest of the world appears to have stabilized its research efforts after the development of highly active antiretroviral therapies. The USA is identified as the main producer of HIV/AIDS research while Europe appears to under-emphasize the issue.

Nikolic et al. (2011) has explored the trends and the evolution of publications covered on diadormouse fish from 1970s to 2010. Bibliometric techniques in the total number of research (articles, books, and conferences) in all country in function of main fields. The analysis comparisons shows the intensity of certain topics by species with the emergence of new ones, the economic impact on sciences and increased support of conservation plan management for certain species, such as salmon and lamprey in France.

Yoon & Lee (2012) have proposed a portfolio of scientometric methodologies to provide a framework in analyzing technological knowledge and enhance the utilization of scientometrics in conducting R&D activities by investigating practical cases. In addition, a scientometrics portfolio is developed by aggregating the matching tables of methodologies, technological knowledge and application objectives of the practical cases in which scientometrics is applied to examine R&D activities and implement S&T policies.

Vinluan (2012) has studied the research productivity in education and psychology in the Philippines against its Southeast Asian neighbors' research productivity in the same fields. Results show that the Philippines ranked low in research productivity compared to Singapore, Thailand, and Malaysia, particularly starting in the 1990s. This low research productivity is explained in terms of economic indicators, the local orientation of many social science research studies, funding, individual characteristics of researchers, and the epistemic culture of knowledge production in the country.

Hassan et al. (2012) has employed basic bibliometric methodology in order to draw a picture of Southeast Asian research strengths as well the amount and focus of S&T cooperation between the countries in Southeast Asia and the European Union. The results are found to be useful for interested public as well as scientific community and innovation policy-making.

Karamourzov (2012) has assessed the results of the independent development of the CIS countries in the field of science over the period 1990–2009. The analysis reveals that decrease of the number of expert researchers and the significant decrease in the scientific and technical output. Also provides the information about the dynamics of a set of indicators which allows drawing conclusions about the effectiveness of the research activity in the CIS countries.

Kakkar, Chauhan & Abbas (2012) have reviewed Indian rabies research, 93 articles published during 2001-2011. 61% of the total articles consisted of laboratory based studies on rabies virus and 8% studies on animals, the least studied group. One third of articles were published in three journals focusing on vaccines and infectious disease epidemiology. The top 4 institutions (2 each from the animal and human health sectors) collectively produced 49% of the national research output.

Heilig & Vob (2014) have opines that the popularity and rapid development of cloud computing in recent years has led to a huge amount of publications containing the achieved knowledge of this area of research. The interdisciplinary nature and high relevance of cloud computing research, it becomes increasingly difficult or even impossible to understand the overall structure and development of this field without analytical approaches. The results of the study provide a better understanding of patterns, trends and other important factors as a basis for directing research activities, sharing knowledge and collaborating in the area of cloud computing research.

Guo et al. (**2014)** has undertaken the bibliometric analysis of soil contamination research with articles published in journals in the SCI and SSCI databases from 1999 to 2012. The results showed environmental science, engineering environment, soil science and applied microbiology as the most frequently used subject categories, Chemosphere as the most active journal, USA exceeded all other countries with the most independent and collaborative papers and on heavy metal pollution as the hottest issue.

Rafols et al. (**2014)** has explored the pharmaceutical R & D dynamics by examining the publication activities of all R & D laboratories of the major European and US pharmaceutical firms (Big Pharma) during the period 1995-2009.

Wildgaard (**2015)** carried out the study on bibliometric indicators for researchers in Astronomy, Environmental Science, Philosophy and Public Health in Web of Science and Google Scholar. 17 author-level indicators were calculated for 512 researchers the indexing policies of WoS and GS were found to have a direct effect on the amount of available bibliometric data. Indicator rankings display the visibility of the scholar in the database not their impact in the academic community compared to their peers. Extreme caution is advised when choosing indicators and benchmarks in scholar rankings.

Kharabaf & Abdollahi (2015) have evaluated the activities in different branches of science in Iran and compared with other countries over the past 35 years. Essential Science Indicators, Web of Science and SCImago Journal & Country Rank (SJR) are searched for scientometrics data. The field of chemistry in Iran is found to be the most prolific in terms of the number of publications (16982) whereas economics and business is the least prolific (156). A growth in the quality of works of Iranian authors is evident by gaining higher H-index in the recent years.

Gupta, Sharma & Gupta (2015) have analyzed 510 India's publications on rabies research as indexed in Scopus International multidisciplinary database covering the period 1999-2014 - using scientometric indicators.

Jagannara (2015) analyzed the 11567 papers on global rabies research as indexed in CAB database covering the period 19642015 using indicators such as publication growth, language wise distribution, country-wise distribution, etc.

Gupta, Sharma & Gupta (2015) examines 6800 global publications on "Internet of Things" (IoT), as covered in Scopus database during 2005–2014, experiencing an annual average growth rate of 98.63% and citation impact of 1.97. 27.96% of the total global publications were cited one or more times during 2005–2014. Among subjects contributing to IoT, computer science contributed the highest publication share (64.93%), under broad subjects; the major priorities have been assigned to hardware (technology) with 43.87% share.

Sachithanantham & Raja (2015) analyzed 495 records of Indian research output in rabies as indexed Pub Med database covering the period 1950-2014 on indicators such as literature growth, world share, prolific authors profile, collaborative pattern, journal distribution, most productive institutions, and geographical distribution. The Bradford law of scattering did not apply to rabies research in India.

Thimmaiah (**2016**) analyzed the Polio literature during the period 1999 to 2014. He described in the article that, to assess the "growth of knowledge", time is an absolute yard stick. He reported that mean relative growth of polio literature during the period 1999 to 2014 has an increasing trend.

Gupta, Sharma & Gupta (2016) have examines 7818 world publications on global rabies research, as indexed in Scopus database covering the period 1999-2014. The global rabies research increased by 5.87% per annum and its citation impact averaged to 14.27 citations per paper. Top 15 most productive countries continued to dominate world rabies research through 1999-2014 both in terms of quality and quantity of research. Together they accounted for as much as 83.82% share of world total output during 1999-2014.

Govindharajan (2016) has investigated and analyzed the literature output on Polio during the period 2011-2015, identifies the literature growth over the period, literature distribution by language, journal, and publication type and authorship pattern. The data was obtained from PubMed using the keywords "Polio". The scientific literature published during the period 2011-2015 was considered for the study and found that a total of 2,118 literature is published during the period 2011-2015 in the field of Polio and 7,556 distinct authors contributed the literature in 18 languages in 688 journals in 13 publication types.

Dhawan, Gupta, & Gupta (2016) have analyzed the research output in e-publishing field on a series of scientometric indicators. Data were extracted from Scopus database the total world output was 7010 publications published in 10 years during 2005-2014. They found that e-publishing is still a young subject field growing at a slow pace, 3.41% CAGR growth and averaged 1.08 citations per paper. The body of research literature in this field is still in the early stage of its growth. Publication scatter in this field is still very high. To build top research centers in e-publishing field, it is important that funding agencies at national and international level should aggressively start providing planned funding support to research organizations.

2.4 Scientific Productivity of Institutions/Organizations

Bordons et al. (2003) have examined the productivity of the Spanish Council for Scientific Research scientists in Natural Resources and Chemistry during 1994-1999. A total of 260 Natural Resources scientists (24% of females) and 219 Chemistry scientists (38% of females) were studied. The results shows that the productivity tended to increase as professional category improved in two areas.

Gupta et al. (2003) have studied the performance of five state universities of Karnataka (India) in seven broad fields: physics, chemistry, engineering technology, clinical medicine, biomedical research, biology and earth and space science during the period 1996-2000. The study reveals that Mysore University, followed by Karnatak University, has reported maximum literature, and chemistry and physics are the areas where maximum research has been done. Karnatak and Mysore University have high activity index in chemistry.

Cheng & Liu (**2006)** have examined the classification of the top 500 world universities by their disciplinary characteristics using scientometrics. They classified the top 500 world universities and classified into 21 types according to their disciplinary characteristics using clustering method. The indicators used to represent the disciplinary characteristics of an institution are the proportion of publications in six broader disciplinary areas.

Gupta, Kaur & Bala (2011) have analyzed the research output in diabetes during 1999-2008 on several parameters, including its growth, rank and global publications share, citation impact, overall share of international collaborative papers, and share of major collaborative partners. They also analyzed the characteristics of most productive institutions, authors, and highly-cited papers.

Pradhan, Panda & Chandrakar (2011) have presented the trends in authorship pattern and author's collaborative research in Indian chemistry literature with a sample of 53,977 articles downloaded from SCI-Expanded database in Web of Science during the period 2000-2009. The average number of authors per article is 3.55 %. In the study, the degree of collaboration (C) during the overall 10 years (2000-2009) is 0.03.

Sangam & Bagalkoti (2012) have undertook a study of research output of top eight Asian countries under various indicators and data has been collected from the SCOPUS database. To determine the ranks, the total articles, citations, subject areas, authors, institutional collaborations, international collaboration and H-index were taken into account. In this article, all the indicators which measure quantifiable aspects of the application of science and technology are dealt in detail.

Gunasekaran & Balasubramani (2012) have analyzed the artificial intelligence research output during 1973 to 2011. The authors compared the profile of India's research output with other countries with help of scientometrics technique. The study shows that India ranks 1st among the top 17 countries with 219 (96.05%) papers.

Korzhavykh (2012) has discussed the importance and potential of scientometric assessment of the progress of innovative pharmacy. The author also described the Scientometric publications are analyzed and forecast new domestic drug R&D in historical perspective, the role of systemic informational analysis of science as a new methodological tool for research metrics is described.

Banateppanvar, Biradar, & Kannappanavar (2013) have described the citation study as an emergent field for university libraries. The study employed descriptive research design, data collected from 15 doctoral theses accepted by the Kuvempu University, Karnataka, India in the field of Biotechnology from

2003-2006. Total records 2906 and 2459 84.62% citations are observed. The degree of collaboration is found to be 0.85. The geographical distributions show that the USA literature is mostly used for the research by researchers i.e. 33.71%.

2.5 Author Productivity and Collaboration

Gordon (1980) has presented the data which shows a significant relationship exists between level of multiple authorship for papers submitted to a leading Astronomy journal and their frequency of acceptance for publication. Also argue that there is need for more extensive qualification while drawing inferences about actual social aspects of research activity, from trends in the multiple authorship of published papers.

Sangam (2000) has investigated the nature and type of collaborated research in India as reflected in Psyclit CD-ROM database 1974-98. The paper indicates the authorship pattern, explores the degree of collaboration in different sub-spectialities of psychology. Concludes that there is high degree of collaboration in the field of psychology research in India.

Beaver (2001) has studied the personal observations and reflections on scientific collaboration and its study, past and present, and future, containing new material on motives for collaboration, and on some of its salient features. Concludes with continuing methodological problems signed out, together with suggestions for future research to solve problems in collaboration.

Alfaraz & Calvino (2004) have analyzed the scientific production in food science and technology field for the period 1991-2000. Found that 8 selected Iberian-American (IA) countries contribute 97.6% of IA production and accounted for 6.6% of the world production. The journal articles are most frequent document type in English. Retrieved records display characteristically authorship patterns and preferred subject areas. Also 50 top ranked journals, 80% of which are indexed by the SCIE, encompass 2/3rd of the IA production.

Kademani et al. (2006) have studied the quantitative growth and development of world literature on thorium in terms of publications output as in SCI (1982-2004). USA is the top among 94 countries. Authorship and collaboration trend shows towards multi-authored papers. Bhabha Atomic Research Centre (India) topped the list followed by Los Alamos National Laboratory (USA). Most preferred journals are listed and English is the most predominant language used by the scientists for communication.

Keshava et al. (2010) have carried out study to know the characteristics of literature published in JCCC.UGC-INFONET e-journals consortia on a burning issue 'global warming'. The results show year wise distribution of articles, authorship pattern and degree of collaboration among authors in the field during 2005-2009.

Biradar & Rajashekhar (2010) have presented a study based on references appended to the articles published in open access e-journal AgBioForum for the year 1998-2009. The study highlights the authorship trend, average citations per article, collaborative research and use of web references. The study found that team research is preferred than solo research in the field of Biotechnology and maximum number of articles are contributed from USA.

Bartneck & Hu (2010) have performed bibliometric analysis of the CHI conference proceedings to determine if papers that have authors from different organization or countries receive more citations than papers that are authored by members of the same organization. The study showed no significant difference between these groups, indicating that there is no advantage for collaboration in terms of citation frequency. Furthermore, tested papers written by authors from different organizations or countries receive best paper awards or at least award nominations.

Jaric et al. (2012) have identified the recent patterns and trends in the methods, subjects, and authorships in the literature published in fisheries science (2000–2009). The results indicate that the most frequently studied group of species to be Salmonidae, although the interest for these species seems to be diminishing. They found a positive tendency in this direction. A growing rate of publications based on international collaboration is recorded, and such publications also demonstrate a higher number of citations than the single-country publications.

Manimekalai & Amsaveni (2012) have analyzed the growth of research publications and the authorship pattern on Genetics and other related subjects. The records considered for the study is 871 and the pattern of productivity of various author categories are identified. The total number of authors (4433) papers is divided into different categories, namely all authors, first authors, non-collaborative authors and co-authors.

Gupta (**2013)** analyses the research output of Bangladesh in S&T during 2001-10 on several parameters. The Scopus Citation database is used to retrieve the publication data for 10 years. Concluded that Bangladesh needs to increase its output and bring about improvement in the quality of its research efforts further.

Bajwa et al. (2013) has analyzed the research trends in Pakistan in the field of nanoscience and nanotechnology. Among the top 15 institutions with publications in nanotechnology, 13 are universities and only two are R & D organizations. Almost 35% of the research publications are in the field of material sciences followed by chemistry and physics in that order. The growth in the publications for period 2000-2011 is studied through relative growth rate and doubling time.

Rafols et al. (**2014**) has explored the pharmaceutical R & D dynamics by examining the publication activities of all R & D laboratories of the major European and US pharmaceutical firms (Big Pharma) during the period 1995-2009. They observed that there is a slow decline in their total number of publications particularly in Europe. There are more external collaboration and research in non-traditional disciplines.

Zyoud, Al-Jabi & Swelleh (2014) have analyzed the worldwide research output in the waterpipe tobacco smoking field to examine the authorship and collaboration pattern and the citations retrieved from the Scopus database for over a decade (2002-2012). The study revealed a promising rise and a good start for research activity in the field with USA producing largest number of publications.

Thanuskodi (2014) has analyzed the journal titled "D-Lib Magazine" for the period 2003 to 2012 to know the research output of Library and information science subjects. The results showed more number of joint authored articles, highest contribution from universities, and that majority of the contributors preferred journals as the source of information which occupied the top position with highest number of citations of the total citations.

2.6 Ranking of Journals and Institutions

Sengupta (1985) has applied the bibliometric technique to rank periodicals in the field of biophysical literature based on citation data collected from the bibliographic database published in the source journal namely Annual Review of Biophysics. Other findings are dominance of the USA journals and English language. The data is also analysed according to subject categorization of the ranked periodicals and has been discussed in relation to Bradford's law of scattering.

Sangam et al. (**2003)** have examined the performance of five state universities of Karnataka which have covered 7 subject fields from 1996-2004 and the study reveals that the Mysore University has the maximum output of publications.

Tsay (2004) has investigated the growth pattern, journal characteristics and author productivity of the subject indexing literature from 1977-2000 in LISA database. Logistic and Bradford-Zipf S-shaped curve are found to fit well for literature growth and journals respectively. Information organization, processing, storage and retrieval, and systems and services are the four major research topics in the area of subject indexing. The most productive 15 authors are identified with single authored articles in majority.

Sangam, Keshava & Agadi (2010) have pointed out that there is an increase in periodical literature by the significant increase in the quantum of research of national and international institutions. Also, the application of scientometrics to marine engineering and its characteristics is useful in understanding the communication and information use pattern in the field.

Singh (2010) has made attempts to provide a short historical background of the development of Nano science and Technology (NST) field in the world in general and India in particular over last 20 years (1988-2007). Also presents a brief literature survey of the scientific productivity along with the reason for why data has been taken from Web of Science.

Sangam & Meera (2011) have pointed out the periodicals as the best tool for scientific information communication. The study reveals five most productive journals. Out of 120 journals, 13 are basically from medical sciences, 17 physics and 8 belong to environmental sciences showing the interdisciplinary and multidisciplinary character of Chemical Science Literature. The distribution pattern of the articles in chemical science journals has followed the Bradford's distribution which shows that Bradford's law of scattering goes well with the Chemical Science literature.

Sangam & Bagalkoti (2012) have examines India's performance on the basis of its publication output in Science and Technology during 2001-2010. Also identifies the international collaboration, h-index and the National Assessment and Accreditation Council grade (NAAC) of top 50 productive universities. The study uses 10 years publications data from Scopus international multidisciplinary bibliographical database. 50 universities contributed 1, 08,666 papers and received 3, 36,027 citations during 2001-10, with the average citation per paper as 3.09. The study also indicates various criteria for ranking universities.

Asgary et al. (2013) has illustrated the statistical information about published articles in Pub Med-index journals vis-à-vis the various aspects of this biomaterial. Pub Med search is performed to retrieve the relative articles from 1993 to August 2012. Citation of each article till 2009 is obtained from Scopus and Google scholar databases. Data are analyzed to determine the related scientometric indicators. The majority of articles are four-authored (19.6%).

Maisonobe et al. (2013) has explained the current state of DNA Repair studies' global geography by focusing on the genesis of the community. Bibliometric data is used to localize scientific activities related to DNA Repair at the city level. Then, focus on the evolution of the research activity of "early entrants” in relation to the activity of “latecomers”. This article is an opportunity to share with DNA Repair scientists some research results of a dynamic field in Science studies: spatial scientometrics.

Mishra & Balhar (2013) have attempted to draw inferences on the trajectory of four broad domains of medical sciences in India over the span of 16 years, utilizing the available scientometrics information. The results are found to be indicative of differential growth trajectory in many sub-disciplines of medical sciences. Also the specialities such as epidemiology, obstetrics and gynecology, geriatrics and psychiatry and mental health, need to be pursued more seriously.

Pandita (2013) has examined the 310 articles published in Annals of Library and Information Studies (ALIS) journal during the period of 2002 to 2012 and identified that 65.81 % articles contributed to the journal during the period were co-authorship pattern. In all, authors from 16 different countries, Indian authors have contributed the majority of paper (87.61 %) to the journal.

Singh (2013) has made a study on citation analysis of Collection Building journal and observed that in all 2,388 citations from 179 articles, 85 citations were self-citation and journal article was the highest (42.71 %) cited source of materials. 65.92 % of articles were published by single author and majority of contributors 69.96 % were from US.

Bansal (2013) has evaluated the 391 papers were published in the DESIDOC Journal of Library & Information Technology. The maximum number of contribution (61.4%) was published by joint collaborations, and most of the contributions 88% were from India.

Wardikar & Gudadhe (2014) have explored the contribution in library and information science and theoretical aspects of the law. The applicability of Bradford's law of scattering is examined on periodicals in theses during 1982-2010. Rank list of journals is prepared and applicability of law in various methods is tested.

Pandita, Singh & Gaur (2014) have undertaken the bibliometric analysis of medical literature output in four most primer medical and research institutions of India. For the study, data has been collected from Web of Science with a view to assess the general publication trend of medical sciences in India by four medical institutes AIIMS, JIPMER, PGIMER and SGPGIMS. It is found that among four AIIMS, New Delhi has published and contributed maximum research results with steady increase in the research publications in medical sciences.

Magnone (2014) has analyzed systematically all chemistry- related scholarly communications collected from the Web of science in South Korea during 1993-2012. The study parameters included the growth in number of publications, language, document type, category, source, organization and collaboration-wise distribution of the South Korean communications. It was found the South Korean stood at 15th rank in the world in terms of informational communication activity in chemistry.

Sangam et al. (2014) have assessed the qualitative and quantitative research output of genetics research based on the distribution of publications in different branches of genetics. The study compares the research priorities of 16 branches of genetics in 10 Asian countries for two time-spans; 1992-2001 and 2002-2011. Since the raw publication counts are confounded by the size of the countries and the size of the subject specialties, cross-national comparison is made using a relative indicator-Research Priority Index.

Jeong & Huh (2014) have performed citation analysis of seven journals that have been indexed in PubMed/PMC since 2008. Trends for the impact factors of different years were analysed using BSTAT ver. 5. 0. It was found that there was an increasing rate of the impact factor for the seven non-Medline journals and five Medline journals concluding that it was an effect of the platform in which the journals are listed and not just an effect of free access.

Song et al. (**2014**) has conducted bibliometric analysis of the field of bioinformatics by extracting citation data from Pub Med for the period 2000 to 2011. Four measures used to identify productivity were most productive authors, countries, organizations and subject terms. Results showed that the overall trends from 2000 to 2003 and 2004 to 2007 were dissimilar, while trends between the periods 2004 to 2007 and 2008 to 2011 were similar. In addition, the field of bioinformatics has undergone a significant shift, co-evolving with other biomedical disciplines.

McCall (**2014)** has conducted bibliometric analysis to describe the annual trends in publication on PubMed during 1950 to 2012. The analysis shows that systematic reviews and yoga trials are increasing exponentially, indicating increasing prevalence of yoga research in western healthcare.

Baskarna & Sivakami (2014) have carried out quantitative analysis on Swine influenza disease research based on data obtained from PubMed database during 2006-2010. Analysis showed publication frequency, country, institution productivity, and collaboration, characteristics of most productive institutions, language and journals, also with majority scientists preferring to publish papers in multiple authorship.

Alvarez et al. (2014) have evaluated the impact of anatomy as multidisciplinary area and identified trends in research by anatomists during 1898 to 2012. Data has been collected from SJR, PubMed and JCR databases. Results show the percentage of publication in different databases and that the scientific production of anatomists has improved the quantity and quality of multi-disciplinary scientific activity in different knowledge areas.

Fatehi, Gray & Wootton (2014) have provided various capabilities that can enhance our search performance in PubMed database. So for more control over the search process one can use the Advanced Search Builder interface which provides a history of previous searches from which complex search query can be developed by using Boolean operators. Also suggest, identifying more appropriate MeSH vocabulary terms and using them in our searches.

Das (2014) analyzed the journal “Library Trends” with an aim to analyze the contributions of the author and the citations cited by various articles appeared in it. The study comprised of 206 articles published from 2007-2012. Highest number (51) of articles is published in 2007-08. Majority of authors preferred to publish their research results in individual authorship mode (122, 59.22%). The majority of articles 63 (30.58%) have the length of 16- 20 pages. The highest number of contributions have citations between 11to 20 is 48 (23.30%).

Vijayanathan & Kaliyamoorthi (2014) have examined the articles published in the open Software Engineering Journal from 2007-2012 to find out authorship pattern, degree of collaboration and geographical distribution of papers. The findings showed that: Majority of papers are multi authored. The degree of collaboration is found to be 0.75. The contribution by Finland and Canada is the highest in foreign. Maximum number of articles is 6 (37.50%) which have been contributed by Two authors.

Satpathy, Maharana, & Das (2014) have examined the top ten open access journals of Library & Information Science through bibliometric measures. The study indicates that a good number of papers have been published in these ten open access journals and these papers were mostly contributed by a single author. The degree of collaboration of authors also seems to be encouraging. Most of the contributors belong to the developed countries and the open access journals are yet to be popular in developing and under developed countries.

Dhanavandan (**2014**) is discussed about the published research articles and its citation from Universities in South Tamil Nadu. During period from 2009 to 2013, 377 articles were published which include, in the year 2009, 81

(21.49%) articles were published by three universities sand 45 citations were identified from Indian Citation Index.

Garg & Anjana (2014) have undertaken a bibliometric study on Journal of Intellectual Property Rights and analyzed the 605 papers published in the journals, about one fourth of the papers published in the journal were from abroad and the rest from India, among the performing sectors, academic institutions were the largest contributors to the journal followed by research institutions.

Padma & Ramasamy (2015) have undertaken a bibliometric study of contributions found in the 'Malaysian Journal of Library and information science' during the years 2007-2012. The analysis focused on the overall degree of collaboration for the period 2007-2012 is 0.725. 44 (36.67 %) articles were in the page range of 16-20 followed by 43 articles within the page range of 11-15. 45% (54) of the articles used 21-40 references and 37.5% of the articles used up to 20 references.

Verma, Sonkar & Gupta (2015) have studied the bibliometric study of the E-Journal, 'Library Philosophy and Practice' for the period 2005 to 2014. The study covers the growth of literature and authorship patterns of the journal, and various other bibliometrics aspects such as authors' degree of collaboration, geographical productivity in scholarly publications, subject wise distribution of articles and ranking pattern etc. 1177 number of articles was taken up for the evaluation. In all with an average 117 articles were published each year. Single authorship is leading authorship trend but also two authored articles have shown good number of contribution with the 0.51 rate of degree of collaboration.

Ghar & Urkudkar (**2016)** did a bibliometric study on "Journal of Biosciences" for the period 1979 to 2015. The data were downloaded from the journal's website. The analysis focused on: the research output performance of all areas of Biology; number of citations; authorship pattern of cited references; Age of citation references etc.

Gogoi & Barooah (**2016)** have conducted a bibliometric study on "Indian Journal of chemistry" to understand the usage pattern of information in the field of Material science and to ascertain the types of documents most frequently used in the research process. The year wise distribution of the cited documents reveals that publications of pre 1950s still continue to be cited in the source journal. The year-wise distribution of journals indicated that journals published from 2000 – 09 are highly preferred.

Manjunatha, Guruprasada & Varalakshmi (**2016)** have conducted a study to evaluate the pattern of growth of research output published in the 'Trends in Information Management' journal. The study focused on the analysis of authorship pattern, most prolific authors, most prolific institutions and geographical affiliation of contributors of the articles published in the journal during the period 2005 – 2013. There are 145 articles published in 'Trends in Information Management'. They found that the majority of articles 103(74.60

%) were research article and the highest numbers of articles 87(63.04%) were single authored publication.

2.7 Citation Analysis of Individual Scientists

Garfield (1984) conducted the Citation Analysis study on Lester R Aronson during the Anti-visection Controversy, in his series of two essays in Current Contents dedicated to Dr. S. R. Ranganathan, the Father of Indian Library Science highlighted in detail life and works in the first part and his contribution to Indian and International library science in the second part of the essay.

Mahapatra (1992) measured the degree of influence of Ranganathan's works on Indian Library and Information Science literature. She analyzed the references appended in journal articles and found that even after his death, Ranganathan continues to be cited frequently, especially for his works on classification and cataloguing.

Gupta (1993) analyzed the citations for all the publications of Xavier LePichon pertaining to sea floor spreading for the period 1965-1979. Out of the 127 cited publications, 13 papers were consistently cited. However, the most cited article is "Sea-floor spreading and continental drift" published in *Journal of Geophysical Research* (1968) which received 642 citations in all.

Furthermore, **Zipp (1996)** found that 'the most heavily cited journal titles in theses and dissertations can be used as a surrogate for the titles most heavily used by faculty in their publications'. This is because of the research interests of the faculty advisers.

Sangam et al. (2006) have analyzed 178 papers published by S. Ramaseshan during 1944–2000. The scientist S. Ramaseshan was a leading crystallographer from India. His publications were analyzed and classified into four domains. The work done by S. Ramaseshan has made a mark on the various areas he dealt with earnestly for the encouragement of science in India. No doubt, he helped science in the nascent years of the birth of modern physics in India.

Similarly, the biobibliometric study was conducted by **Parvathamma & Gabbur (2008)** on T. M. Aminabhavi. In his 36 years of teaching and 28 years of research experience in various fields of polymer science, he has published 521 research articles, 57 popular articles and 94 conference papers in eight domains of polymer science. He has three US patents to his credit. The authors expressed that the study of Prof. T. M. Aminabhavi's research output proves that long time commitment and sustaining efforts are necessary to achieve excellence in one's area of research.

The scientometric portrait study carried out by **Keshava et al. (2010)** to know the scientific work done by Prof. Kubakaddi and his role in the achievement of science in India especially in the field of physics. The results show that Kubakaddi had 85 papers to his credit during 1974-2008. Highest productivity was in 1987 with the output of nine publications (age 36) and the highest collaboration coefficient (0.71) of Prof. Kubakaddi is found at the age of 44-48 (1995-1999). Kubakaddi’s h–index was 7.

Radicchi & Castellano (2013) have analyzed the scientific profile of more than 30,000 researchers from a large bibliographic data set, namely Google Scholar Citations. They found that the relation between the h-index, the number of publications and the number of citations of individual scientists.

Gan, & Wang (2014) conducted a study on social media research in journals under the subject category “Information Science & Library Science” of the Social Science Citation Index. Results showed that, social media research steadily increased from the period of 2002 to 2013 and the annual publication output in 2012 and 2013 were almost half of the total. A total of 9,851 pages, 29,433 cited references, 1,540 authors and 3,740 citations were identified in all 646 articles, with the average per article of 15.25 pages, 45.46 cited references, 2.38 authors and 5.79 citations.

Hsu & Chiang (2014) have studied the research on SSME in information systems based on the science social citation index. A total of 4,513 entries in a span of 22 years from 1991 to 2012 were collected. This paper implemented and classified service science, service management, and SE articles. Also, the paper performs the K–S test to check whether the distribution of author article production follows Lotka’s law. The analysis indicated the most relevant disciplines for SSME subject category provided by business economics, information science and library science, and computer science.

Coursaris & Osch (2014) have conducted a research productivity analysis and citation analysis of individuals, institutions, and countries based on 610 peer-reviewed social media articles published in journals and conference proceedings between October 2004 and December 2011.

Havemann & Larsen (2015) have tested the 16 bibliometric indicators with respect to their validity at the level of the individual researcher by estimating their power to predict later successful researchers. They compared the indicators of a sample of astrophysics researchers who later co-authored highly cited papers before their first landmark paper with the distributions of these indicators over a random control group of young authors in astronomy and astrophysics.

Padma & Ramasamy (2016) have analyzed the content and reference metrics of e-library Science Research Journal covering 521 articles published from Jan. 2013 to Dec. 2015, the study reveals that most of the articles (280, 53.74%) have 6-10 pages followed by 151 articles (28.98 %). All 521 articles being analyzed have abstracts, 98.27 % (512) of the articles have Key words. A majority of 289 (56.45 %) articles have 1-10 references followed by 163 articles (31.84 %) with 11-20 references. The year 2014 had the maximum numbers of Print references i.e. 198 (40.75 %) followed by the year 2015 with 189 print references.

2.8 Collaborative Works (Individual level, Institutional level and Country level)

Gupta, Suresh Kumar & Karisiddappa (1997) examine collaborative pattern by using different collaborative measures. About 72% of authors have collaborated, and it is observed that the average author per paper is 1.86, and there is consistent increase in collaborative coefficient, and the productivity and collaboration count is found to be 2.34 and 2.08, using normal count and straight count method. Correlation between the number of publication/papers and average number of collaboration per author as 0.6944 (0=0.002) seems to be strong.

Mueen & Gupta (2013) examined the India's performance on antioxidants using several quantitative measures such as India's global publication share, rank, growth rate and citation quality, its publication share in various sub-fields in terms of national share utilizing last 10 year's (2001–10) publications data obtained from the Scopus database. They have also determined Indian share with international collaborative papers at the national level as well as is major international collaborative partners, besides analyzing the characteristics of its high productivity institutions, authors and high-cited papers, etc.

Tseng and et al. (2013) conducted the research performance of Education in Taiwan, more than 70,000 publication records over the years 1990 to 2011 from Web of Science were downloaded and analyzed. The overview analysis by data aggregation and country ranking shows that Taiwan has significantly improved its publication productivity and citation impact over the last decade. Based on journal bibliographic coupling, information visualization, and diversity and trend indexes, reveals that e-Learning and Science Education are two fast growing subfields that attract global interests and that Taiwan is among the top-ranked countries in these two fields in terms of research productivity.

Ji, Pang & Zhao (2014) have conducted the bibliometric analysis to evaluate Antarctic research from 1993 to 2012 based on the Science Citation Index database. According to samples of 30,024 articles related to Antarctica, the study reveals the evolution of the scientific outputs on Antarctic research from the aspects of subject categories, major journals, international collaboration, and temporal trends in keywords focus.

Mallik & Mandal (2014) have analyzed the global research output related to microRNA (miRNA), based on the fact that it has diverse expression patterns and might regulate various developmental and physiological processes. A sum of more than 14,000 documents found from Web of Science database, the study detected major productive countries, high productive-institutions, authors, research areas, journals and document types, along with their individual citation impacts. The authors observed that the number of publication increased from 8 in 2002 to 4,186 in 2012 with compound annual growth rate of 87 %. The compound annual growth rates of countries, institutions, number of journals, research areas, and authors are 36.60, 76.64, 64.80, 30.5, and 88.09 % respectively.

Morooka, Ramos, & Nathanie (2014) have focused the structure of interdisciplinary in Japanese rice research and technology development by analyzing the relationship among all relevant disciplines with the use of a compiled bibliography of Japanese rice research with 19,389 articles in 1,611 journals in the publishing years of 1990 to 2000. The 24 journal categories ranked in decreasing order of productivity of articles were divided into 3 zones; the first nuclear zone with a smaller number of highly productive journal disciplines; the second zone with a large number of less productive disciplines; and the last zone with a larger number of the least productive disciplines, which characterized the structure of interdisciplinary in Japanese rice research and technology development.

Moed & Halevi (2014) have explored that bibliometric approach to tracking international scientific migration, they introduced a model that relates base concepts in the study of migration to bibliometric constructs, and discusses the potentialities and limitations of a bibliometric approach both with respect to data accuracy and interpretation. It is concluded that the bibliometric approach is promising provided that its outcomes are interpreted with care, based on insight into the limits and potentialities of the approach, and combined with complementary data.

Zyoud & Swelleh (2014) have analyzed the worldwide research output in the water pipe tobacco smoking field to examine the authorship and collaboration pattern.

Yua et al. (2016) opines that the research performance becomes increasingly important for academic institutions in competition for rankings, student recruitment, and funding, many performance indicators have been developed to measure various aspects of research performance. Research Gate combines bibliometrics and altmetrics to create a more comprehensive performance measure for researchers and institutions.

Maharana (2014) has conducted study on research growth and development at Sambalpur University during 2008 – 2012. The researcher identified that The University's publication ranges from 38 to 83 papers with an annual average growth rate percent of 11.29 papers and the maximum number of papers were three authored publications.

Uma & Dhanavandan (2015) have explored that the research articles and their citations available in the Indian Citation Index by the authors from University of Madras during the period of their study 538 articles were published which includes 480 (89.22%) Research Articles type, 19(3.53%) short communication type and 10 (1.86%) articles each from Review articles and Case Studies type.

Dhanavandan (2015) has discussed about the published research articles and its citation available in the Indian Citation Index by the authors from Annamalai University. The relevant are data collected from Indian Citation Index and it was were analyzed. During the period (2005-2014) 3233 articles were published which are indexed in Indian Citation Index. The growth rate of article productivity increased from 2005 onwards up to 2010 in Indian journals but after 2010 it was in the decreasing order

2.9 Application of Bibliometric Laws

Narendra Kumar (2010) has examined the applicability of Lotka's law as a general inverse power (alpha = 2) and as an inverse square power relationship (alpha = 2) to the distribution of the research productivity in Council of Scientific and Industrial Research (CSIR), India. The two data sets of the research papers (6076 and 17681) contributed by CSIR's scientists during the period of 1988-1992 and 2004-2008 were collected from SCI-CD-ROM and web of science for analysis. A K-S test was applied to measure the degree of agreement between the distribution of the observed set of data against the inverse general power relationship and the theoretical value of (alpha= 2.) It was found that the inverse square law of Lotka did not conform as such.

Ahmad et al. (2012) have discussed the theoretical and practical aspects of an important bibliometric law known as Lotka's law of Author Productivity. First the theoretical and mathematical explanation of the law is presented based on various disciplines. In addition, it presents the practical application of the law in the literature of two important disciplines, i.e. Agricultural Sciences and Economics. In practical use the Lotka exponent is applied with different values to check its application in two selected fields of studies.

Zafrunnisha (2012) has studied one hundred and forty one Ph.D. theses accepted in the field of psychology for the award of doctoral degrees and analyzed to identify the Bradford's zones and productivity of journals cited in the theses. The productivity of cited journals was measured after dividing the journals into four equal groups. The average rate of productivity of journals in the first group is 254 articles, whereas it has considerably gone down to 10.73 articles in the fourth group. The journal distribution as per the Bradford's law reveals the ratio as 17:46:358 in psychology, dispersion of journal titles in psychology does not satisfy the Bradford's Law of Scattering.

Tamilselvan et al. (2013) has applied the Lotka's law pertaining to author productivity which is considered as one of the important classical laws of bibliometrics. According to them, the study clearly indicates that Lotka's generalized inverse square law holds good to Engineering and Technology literature published by the faculty of NIT's in India during the study period 2001 – 2010. In the study it has been found n=1.89 and c.v. = 0.24 and c=0.59 for overall data using least square method, and hence they are of the opinion that Lotka's law can be satisfactory applied to the literature brought out by the faculties of NITs.

Neelamma & Anandhalli (2016) have studied the research output performance of Crystallography literature; the data were extracted from Web of Science database for the period of 1989-2013. The study elaborates on various bibliometric components such as distribution of citations by documents type, Country wise publication of citations, further the study also list out the most productivity journals in the field of crystallography.

Budd (2016) has conducted bibliometric analysis of higher education literature by applying Bradford's and Lotka law. The laws were applied to citations to journals in 569 articles on higher education. With regard to higher education literature both the laws do not fit perfectly but the results do suggest that the underling concepts of the laws may well have applicability of two examination of discipline.

2.10 Obsolescence of Literature

Biradar & Vijayalakshmi (1997) havestudied the obsolescence literature, Annual Aging factor (AAF), Mean Life (ML) and Utility Facotr (UF) of periodicles in the field of chemistry. The study is based on references appended to the articles published in IndianJournal of Chemical Technology during the year 1994, 1997 & 1999. Obsolescence of literature was studied and half life of literature found to be 11.8 years. Study also applied Brooker's formula for identifying Annual Aging Factor and average value of a was found to be 0.9754 and Mean Life (ML) and utility factor (UF) were cluclated found to be 16.1958 and 40.65 rpresentively as a source of decreases with age.

Sangam (1989) conducted a study on the obsolescence in psychology field. For the study the doctoral theses of the period 1982-84 have been considered. The result of the study shows that half-life of the cited journals is 10 and books is 13 years. It follows the Bradford's law of scattering.

Sangam & Biradar (1990) discussed the pattern of information use by researchers in the field of surgery as indicated by citations in the M. S. Dissertations submitted to the Gulbarga University, Kalburgi during 1982-1989. They identified the use of different sources of information, their languages, countries of origin and subjects, and also state the obsolescence of literature and lastly apply Bradford’s Law of Scattering. Finally they found that, implications for the development of need based collection in library and information centers in the field of surgery.

Sangam (1999) studied an obsolescence of literature in the field of psychology. For the study the data from five psychological periodicals were used. Further the bibliometric techniques of citation analysis were applied. The study with regard to the relation between growth and obsolescence reveals that higher the growth of literature more will be obsolescence and higher the half-life.

Sangam & Meera (2012) have conducted a study on obsolescence factors and pattern of citation distribution in the field of chemical science. The study is based on citation received by two journals viz. *Indian Journal of Experimental Biology* and *Asian Journal of Chemistry*. These two journals have received 30,142 references for 3,027 articles at the rate of 9.95 references per article for 5 year data.

Egghe & Rousseau (2013) have studied the notions, aging, obsolescence, impact, growth, utilization and their relations. It is shown how to correct an observed citation distribution for growth, once the growth distribution is known. The relation of this correction procedure with the calculating of impact measures is explained. They have also shown how the influence of growth on aging can be studied over a complete period as a whole. It is found that the growth can influence aging but that does not cause aging.

2.11 Recent Trends in Scientometrics/Bibliometrics

Franceschet (2010) studies the current availability of different bibliometric indicators and of production and citation data sources, the following two questions immediately arise: do the indicators' scores differ when computed on different data sources? More importantly, do the indicator-based rankings significantly change when computed on different data sources? We provide a case study for computer science scholars and journals evaluated on Web of Science and Google Scholar databases. The study concludes that Google scholar computes significantly higher indicators' scores than Web of Science. Nevertheless, citation-based rankings of both scholars and journals do not significantly change when compiled on the two data sources, while rankings based on the h index show a moderate degree of variation.

Wildgaard, Schneider & Larsen (2014) have opines that an increasing demand for bibliometric assessment of individuals has led to a growth of new bibliometric indicators as well as new variants or combinations of established ones. The authors reviewed the 108 indicators that can potentially be used to measure performance on individual author-level and examines the complexity of their calculations in relation to what they are supposed to reflect and ease of end-user application.

Mingersa & Leydesdorff (2015) in their article 'a review of theory and practice in scientometrics' opines that scientometrics is the study of the quantitative aspects of the process of science as a communication system. It is concerned with the analysis of citations in the academic literature and plays a major role in the measurement and evaluation of research performance. In this review they consider: the historical development of scientometrics, sources of citation data, citation metrics and the "laws" of scientometrics, normalisation, journal impact factors and other journal metrics, visualising and mapping science, evaluation and policy, and future developments.

Inferences drawn from the Review of Literature

1. The research publications gathered from various sources have been documented and the information so collected was used for evaluation. Finally the summary of the papers has been written. Further the papers have been categorized based on chronological and subject field such as Growth and Development of research Productivity; Scientometric Analysis of different Subjects and Sources; Scientific Productivity of Institutions or Organisations; Author Productivity and Collaboration; Ranking of Journals and Institutions; Citation Analysis of Individual Scientists; Collaborative works (Individual level, Institutional level and Country level); Application of Bibliometric Laws; Obsolescence of Literature and Recent Trends in Scientometrics/Bibliometrics.

2. For this purpose, literature survey was carried out by using SCOPUS Database, Web of Science database (Science Citation Index), Social Science Citation Index, Emerald, Springer e-journals full-text database. Attempts were also made to trace and collect the relevant research papers and related

documents such as journal articles, conference papers, books, etc. Attempts were also made to trace and collect the original articles and the same have been used for review and works of Eugene Garfield, Braun, T, Glanzel, W., Moed, H. F., S. L. Sangam, B. M. Gupta, and K. C. Garg and others.

3. A few studies on scientometric analysis of different subjects and sources are noticed in the literature.

4. In the review of literature the origin of the concepts were highlighted which are published in journal articles and recent studies are also covered.

5. Most of the studies are based on Indian authors and foreign studies are to some extent minimum with a ratio of 55:45.

6. There are more number of studies on scientific productivity and citation analysis of individual scientists as compared to other subheadings in the literature.

7. Though there are few studies were carried out on science output of different states within India and different countries and with different study period and databases. The present study deals with mapping of chemical science literature with reference to web of science citation database: a scientometric study covering a total of 15 years from 2002 to 2016.

8. It is evident from the study that few scientists/authors such as Eugene Garfield, Braun, T, Glanzel, W., Moed, H. F., S. L. Sangam, B. M. Gupta, and K. C. Gargcontribute more than 50% of the articles covered under review of literature.

9. It is observed from the review of literature that Collaborative works (Individual level, Institutional level and Country level) is more as compared with other indicators.

10. The sources, *‘Scientometrics’*and *‘Collenet Journal of Scientometrics and Information Management’*is the highest referred journals by the authors which are appeared in the references list.

Conclusion

With the help of the reviewed articlesit is reveals that,many studies are done about scientometric measures. The application of scientometric techniques on scientific literature shows that the bibliometric models are better fitted to the scientific literature. It has been observed that the collaboration is gradually increasing in the scientific publications. Considerable number of the article has been reported on subject and journal productivity. It has been found that a number of scientometric studies have been done in science at the micro level. Indian Chemistry literature has been found to be more investigated research in the area ofworld science and technology.

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CHAPTER 3

SCIENTOMETRICS: A TOOL FOR ASSESSING AND EVALUATING SCIENTIFIC RESEARCH

3.1 Introduction

Scientometrics research should be regarded as a means of understanding the process of the evolution of science, its health, structure and dynamics, rather than merely as an 'evaluative tool'. The available expertise can be pooled together and reoriented towards use of mathematical and statistical models for preparing national reports of the type prepared by Royal Society under the concept of health of science. National mapping of science to produce an atlas showing the direction of change and the structure of research in various disciplines, along with international comparison, is recommended.

For the last few years, a Scientometrics has been increasingly used to evaluate the research performance of the productive researchers and the growth of various discipline of science. Hence it implies and induces to examine the nature extent of contributions made by the scientists of a particular discipline of a institute, country or a few major countries or for a particular period of times by using primary or secondary source, that facilities the proper and effective analysis.

Training programmes in modeling and statistical methods are recommended to reorient the existing capabilities in scientometrics and to generate new capabilities in the use of modern statistical and mathematical modeling techniques. Research programme on models of growth of knowledge is recommended, to elucidate the various stages of development in a field and the structures of scientific communities about its validation and closure of scientific problems.

The field of Bibliometrics or Scientometrics has become an important tool to study the patterns of communication among the scholars in various fields. It has two major dimensions namely enumerative and evaluative. Enumerative dimension, studies the publication count, authorship pattern, collaboration pattern, publishing pattern, core journals etc. The evaluative dimension, studies the usage of documented information like citation analysis, referencing pattern, obsolescence of subjects, transience and continuance of authors in a field etc. The most important databases used for bibliometric or scientometric studies are Web of Science and Scopus.

3.2 Scientometrics: As a tool for Scientific Research

The term "Scientometrics", often used synonymously as 'Bibliometrics', which originated in Russia, is quantitative methods of applications in measuring science. The measurements involve counting artifacts to the production and use of information, and arriving conclusion from the counts. The term like 'Librametrics' 'Bibliometrics' 'Informetrics' and 'Scientometrics' have been used synonymously in order to study the growth of literature in a discipline and other aspects of literature quantitatively.

The term Scientometrics was introduced and came into prominence with the founding of journal named *Scientometrics* by T. Braun originally published in Hungary and now in Amsterdam. According to Nalimov and Mulchenko Scientometrics is the application of those quantitative methods, which are dealing with the analysis of science, viewed as an information process in 1969.

Evaluative scientometrics is a special field of scientometrics which deals with the study of scientometric aspects of scientometric organizations in order to draw quantitative conclusions concerning the relative performance of the organizations assessed. Preferable topics of this activity are the comparative studies of the information production and the information impact of the organizations evaluated.

Scientometric analysis is being used very frequently for evaluating R&D Activity and its impact of regions, countries, institutions up to the level of individual scientists as well as mapping of growth of scientific disciplines. These studies initially provide linear ranking lists and they have now evolved into multidimensional indicators with development of powerful data processing tools (UNESCO, 2001). Simple counting of absolute number of publications and peer review are not adequate tools to analyze the complex process of research.

3.3 History and Development of Scientometrics Indicators and Statistical Techniques

Scientometric indicators are developed to assess, categorize and measure specific characteristics of science, such as the effectiveness of scientific work and research performance. Results arrived from quantitative studies (often branded as bibliometrics, informetrics or scientometrics) to study and understand the phenomena of science, i.e., growth, impact, education etc., are generally known as science indicators. They are concerned with the systematic collection and interpretation of information about science and technology and its social impact for the purpose of assisting in policy formulation management and organization (Anon, 1992).

Scientometric indicators are standard tools for evaluation and analysis in research management and science policy. They are a system of indicators for describing the state of the entire scientific endeavor and to identify strengths and weaknesses of the enterprise and to chart its changing state. They are a set of rules describing the operation to be carried out to make measurements. These are statistical techniques designed to display a broad base of quantitative information about science, engineering and technology or the use of public and private policy makers.

The Advisory and Planning Committee on social indicators which is a part of the Social Science Research Council (SSRC) and the Centre for Co-ordination of Research on Social indicators (CCRS) of U.S.A are vital organizations set up for the purpose of identifying rated indicators of science and technology. The UN conference on Science and Technology for Development held in Vienna in 1979 has devoted considerable efforts in developing appropriate science indicators.

Since 1980, a good deal of experience in building and analyzing scientometric indicators of national research performance has been cumulated at the Information Science and Scientometric Research Unit (ISSRU) of the library of the Hungarian Academy of Science Budapest, Hungary. In one of the projects, Schubert and Braun, based on a sample comprising the three years publication output (1976 - 1978) of 85 Hungarian Research Institutes, studied values of correlations between some measures of publishing performance, scientific manpower and citation impact; further they are compared across the research fields such as mathematical and physical sciences, chemical sciences, biological and medical sciences, agricultural sciences and engineering. They also suggested a new quality measure of publishing performance 'the total impact' of the journal papers of individual institutions (Sen, et al., 1965).

The basic methodology of using scientometric indicators are reported in the monograph by Braun and others in 1985, where a 32country comparative evaluation of publishing performance and citation impact is reported. The first six developed countries (US, USSR, UK, West Germany, France and Japan) are not included. Indicators such as number of first authors, number of publications, the distribution of publications by subject matter, the number and fractions of uncited and highly cited publications, the observed, expected, relative and mean citation rates and the mean impact factor are enumerated (Cole & Eales, 1917).

In India, an attempt was made to survey scientific research in various departments of 25 Indian Universities as early as 1965, in the report given by the Survey and Planning of Scientific Research Unit of the Council of Scientific and Industrial Research (CSIR), New Delhi (Arunachalam & Manorama, 1989). The data was collected from the annual reports of these universities based on the numbers of papers published by the university departments since 1952; the distribution of research papers according to important fields in a subject and the distribution of papers by the category of journals in which they are published, are analyzed.

The National Institute of Science and Technology and Development Studies (NISTADS), New Delhi is working on the concept of S & T indicators. In February 1985it organized a workshop in collaboration with the Common Wealth Science Council (CSC), London (Pruthi & Nagpaul, 1987). The main objectives of the workshop were to stimulate research cooperation among the commonwealth countries; to undertake a comparative analysis of socio-economic and cultural factors influencing the productivity and climate of research; and facilitate national policy making process in extensive analysis of data regarding the study of R & D systems in the fields of their interests. In its symposium proceedings in 1985, NISTADS distinguished two types of science and technology indicators namely intrinsic and extrinsic indicators.

In November 1993, a brain storming session on 'Bibliometrics, Informetrics and Scientometrics' was held at NISTADS, New Delhi with the intent of evolving a national programme of action. The recommendation of the session has boosted research on science indicators at the national level. This session has given many essential recommendations.

International conferences on science and technology indicators were held in 1988and 1991, in Leiden and in Biefield in 1990. The fourth international conference on science and technology indicators was held during 5-7th October 1995 at Antwerp, Belgium. Papers on science indicators derived from databases; reassessment of co-citation methods for science indicators etc. were presented in this conference. In 1996, NISSAT has launched several projects for national mapping of science using CDROM databases, under its scientometrics /informetrics programme.

A national seminar was held at Annamalai University during February 28-29, 1996on the progress in bibliometric indicators to discuss the significance of literature-based science indicators. Many papers were presented. For instance:

a. Citations as bibliometric indicators of cognitive styles and communication behavior of scientists;
b. bibliometrics in India during the last 25 years;
c. a review of scientometric measures and methods;
d. the purpose of bibliometric indicators;
e. bibliometric indicators for publication productivity analysis of an individual scientist;
f. author productivity in Indian physics;
g. mapping oncological research by co-author analysis;
h. circulation data analysis; ix) analysis of institutions and countries;
i. indicators for measuring information retrieval and use; and
j. bibliometric study of gender differences in psychological research etc. were presented at the conference.

The following Scientometrics indicators and statistical techniques are employed while analyzing the any data on research output collected.

i. Relative Growth Rate (RGR)
ii. Collaborative Coefficient (CC)
iii. Activity index (AI)
iv. Co-Authorship Index (CAI)
v. Doubling Time (Dt)
vi. Author Productivity
vii. Degree of collaboration (DC)
viii. Bradford's Law of scattering and lotka's Law
ix. Research Priority Index (PRI)
x. Cluster Analysis
xi. Multidimensional Scaling (MDS)

3.4 Science/Scientometric Indicators

Some indicators are therefore essential to control, organize, select and disseminate this over exploding scientific information. The rapidly increasing accumulation of scientific knowledge and proliferation of publications have been important bases for the development and application of scientometric indicators.

The purpose and function of scientometric indicators are to study and understand changes in scientific enterprises and their components, over time and thereby to reveal strength and weakness, as they begin to develop. Such indicators if updated regularly can provide early warnings of trends that might improve the ability of science of nation. They reflect the neglected areas in scientific researches; indicate signals of pathology in science and locate technological gaps.

Scientometric indicators can make decision makers more aware of the inter-relatedness of the many variables which describe the nation's scientific effort. Science indicators can assist those who set priorities for the enterprise and allocate resources to it. Inter-institutional and cross-national comparisons are possible with the help of science and technology indicators. National and international collaboration among authors, aging of literature, and quality of researches can be brought in light through a study of scientometric indicators. Their impact on the economic growth of a nation and the world economy are equally important.

Indicators relating in age, quality and mobilizing of scientific personnel would be helpful for policy purposes. Relation between age and scientific creativity helps in determining the utilization of scientific manpower. Science indicators help in termination of products not meriting support, in reduction of wasteful expenditure in projects, in reorientation of research activities into areas having higher national priority and in shifting of the focus of research into industrial organizations where opportunities for practical exploitation may be superior.

The participation of different countries in the international scientific enterprise can be estimated with international indicators. Identification of core journals, popular scientists, leading institutions and high impact papers in a specific field can be done with the help of scientometric indicators.

Scientometric indicators can also explain publishing patterns of scientific co-authorship. Correlation between input (manpower and budget) and output (papers published, processes developed, patents accepted) variables in an institution or country can be measured by scientometric indicators.

3.5 Scientometric Indicators

Scientometric indicators are developed to assess, categorize and measure specific characteristics of science, such as the effectiveness of scientific work and research performance. Results arrived from quantitative studies (often branded as bibliometrics, informetrics or scientometrics) to study and understand the phenomena of science, i.e., growth, impact, education etc., are generally known as science indicators. They are concerned with the systematic collection and interpretation of information about science and technology and its social impact for the purpose of assisting in policy formulation management and organization.

Scientometric indicators are standard tools for evaluation and analysis in research management and science policy. They are a system of indicators for describing the state of the entire scientific endeavor and to identify strengths and weaknesses of the enterprise and to chart its changing state. They are a set of rules describing the operation to be carried out to make measurements. These are statistical techniques designed to display a broad base of quantitative information about science, engineering and technology for the use of public and private policy makers.

3.6 Indicators Related to Publications

The indicators related to publications, who used it, when, where and what for. Simple counting of publications is probably the crudest and most straight forward among science indicators. It is the simple counting of the publications for measuring scientific growth. Growth of different types of documents like journals, monographs, books, patents, thesis and standards in a specific subject, are measured through publication counts.

Cole and Eales (1917) used this technique to study the growth of comparative anatomy; Fletcher (1972) to study the growth of economic literature; and Gilbert (1978) also used counting as the simplest indicator of growth.

3.7 Measures of Collaboration

3.7.1 Collaborative Index (CI)

Collaborative Index: It is defined as the number of authors per paper (Lawani, 1986).

CI=Total number of Authors/ Total number of Papers

CI= 1044/600=1.74

3.7.2 Degree of Collaboration (DC)

Degree of Collaboration in respect of a discipline or an organization is the ratio of multi-authored papers published during a year and total number of papers published during that year.

Formula by the K. Subramanyam (1993).

$$\boldsymbol{DC} = \frac{Nm}{Nm + Ns}$$

Where,

DC = Degree of Collaboration in a discipline

Nm = Number of multi authored papers in a discipline

Ns = Number of single authored papers

Multi Authored Papers $\frac{4377}{4377+3374} = 0.56$

Single Authored Papers

3.7.3 Collaborative Coefficient (CC)

Collaborative coefficient (CC) is a measure of collaboration in research that reflects both the mean number of authors per paper as well as the proportion of multi-authored papers. Although it lies between the values 0 and 1, and is 0 for a collection of purely single-authored papers, it is not 1 for the case where all papers are maximally authored, i.e., every publication in the collection has all authors in the collection as co-authors.

If the number of 'j' authored papers is given by n (j) in the sample population of articles or publications of number N then collaboration coefficient.

$$CC = 1 - \frac{F1\ \left(\frac{1}{2}\right)\ F2 + \left(\frac{1}{3}\right) + \left(\frac{1}{4}\right)\ F4 + \cdots \ldots \ldots .. \left(\frac{1}{k}\right) Fk}{N}$$

Where, F1 indicates single authored papers

F2 indicates double authored papers

F3 indicates three authored papers

F4 indicates four authored papers, likewise

N is total number of papers in the discipline

Where

$$f1=327, f2=152, f3=65, f4=54$$

$$= 1-[327 + (1/2)\ 155+ (1/3)\ 65 + (1/4)\ 53]/600$$

$$= 1- [327 + 77.5 + 21.66 + 13.25] = 439.41/600$$

$$= 1 – 0.73235$$

CC = 0.26765

3.7.4 Relative Growth Rate (RGR)

The Relative Growth Rate (RGR) is the increase in number of articles per unit of time. This definition is derived from the definition of relative growth rates in the study of growth analysis of individual plants and effectively applied in the field of Botany. There exists a direct equivalence between Relative Growth Rate and Doubling Time. If the number of articles in a subject gets doubled during a given period then the difference between the logarithms of numbers at the beginning and end of the period must be logarithms of number 2. If natural logarithm is used this difference has a value of 0.693. The mean RGR of articles over the specific period of interval is represented as

$$R = W_2- W_1/T_2 – T_1$$

Where

R = mean relative growth rate over the specific period of intervals;

W_1 = Log W_1 (natural log of initial number of publication);

W_2 = Log W_2 (natural log of final number of publication);

$T_2 – T_1$ = the unit difference between the initial and final time

This formula even holds good for the calculation of RGR Subject wise

3.7.5 Doubling Time (D_t) Doubling Time (Dt)

The doubling time is the given period required for quantity to double in size or value. This can be calculated by using the formula.

Doubling time D_t = 0.693/R

Here, Dt (P) = average doubling time of publications

3.7.6 Activity Index

The Activity Index (AI) characterizes the relative research effort of a country for a given subjects. It is defined as;

$$AI = \frac{\text{given field's share in the country' s publication output}}{\text{given field's share in the world's s publication output}}$$

Mathematically

$$AI = \frac{nij/nio}{noj/noo} \times 100$$

Where:

nij	-	Indian output of papers in particular field
nio	-	Total Indian output on all subjects
noj	-	World output of papers in particular field
noo	-	Total World output on all subjects

3.7.7 Participative Index (PaI)

Garcia et al. (2005) proposed Participative Index to evaluate the performance level of research of an institution; an index called 'Participative Index' (PaI) has been calculated. PaI is the ratio of the number of papers generated in a country or institution and the total number of documents collected in this repertoire. This can be expressed as:

$$PaI = \frac{No. of\ Papers\ Generated\ in\ an\ Institution}{Total\ No. of\ Documents\ Collected\ in\ this\ repertoire}\ X\ 100$$

3.7.8 Indicators related to citations

The following indicators are related to citations, who used them, when, where and what for. Studies on indicators based on citations (references) at the end of a journal article, book, thesis, conference paper or secondary periodical dates back to 1920 when Cole and Cole did their study on. Citation based indicators have been successfully used by Eugene Garfield, Peterson, Fletcher, Narin, Rytrinskii, Brown, Gardner, Pasquariella to evaluate research trendsineconomics,biomedical,literature,populationstudies,astrophysics and accountancy.

3.7.9 Impact Factor

Impact Factor (IF) is one such indicator devised by Eugene Garfield (1975) to estimate the perceived quality of the sources in which the researchers publish, based on their citations. Impact factor of a journal relates the number of citations received to the number of articles it publishes.

$$IF = \frac{No. of\ Citations\ received\ in\ year\ 3\ by\ articles\ published\ in\ years\ 1\ \&\ 2}{Number\ of\ Articles\ published\ in\ year\ 1\ and\ 2}.$$

For Ex:

$$\frac{No. of\ citations\ received\ by\ a\ journal\ in\ 1990\ for\ articles\ published\ in\ 1988\ and\ 1989 = 81}{No. of\ Articles\ published\ in\ 1988\ and\ 1989\ = 115}$$

Then IF = $\frac{81}{115} = 0.7$

$$NIF = \frac{IF\ of\ the\ journal\ of\ sub\ discipline\ NIF}{Highest\ IF\ of\ that\ sub\ discipline}\ X\ 10$$

Here 10 is an arbitrary constant. To quote an example NIF of the journal Food

Review International is$\frac{0.417}{1.699}\ X\ 10\ \ = 2.454$

The Journal Citation Report (JCR) usually uses a two years' impact factor. Two year journal impact factor is now called Conventional impact factor.

IF (2) = (C(1) + C(2))/(P(1) + P (2))

3.7.10 Immediacy Index (II) is another citation based indicator to measure how quickly the papers in a journal are cited (Bujdoso and Braun, 1983).

$$II = \frac{No.of\ Articles\ which\ received\ at\ least\ one\ citation\ in\ year\ X}{No.of\ \ articles\ published\ in\ a\ journal\ in\ year\ X}$$

To give an example 120 articles are published in a journal in 1990 out of which 40are cited at least once. Then the II = 40/120 = 0.33.

Influence Measure is another citation-based indicator to measure the prestige of the citing journal. Narin and Carpenter used this to rank academic departments in UK, in 1975(Narin & Carpenter, 1975).

Total influence = Influence per publication x Total number of papers
Influence per publication = Influence weight x average number of references per paper.

Obsolescence rate, literature aging and half-life of literature are other important citation-based indicators.

Schubert and Braun (1986) introduced a citation equivalent of the activity index called the Attractivity index (AAI).

$$AAI = \frac{\%\ of\ citations\ earned\ by\ Institution\ or\ University\ A\ in\ a\ field}{\%\ of\ citations\ earned\ by\ all\ Universities\ or\ Instituions\ in\ a\ field}$$

To represent the relative impact of a country's publications in a given subject field AAI can be defined as

$$AAI = \frac{The\ Country's\ share\ in\ citations\ attacted\ by\ publications\ in\ the\ given\ field}{The\ country's\ share\ in\ citations\ attracted\ by\ publications\ in\ all\ science\ fields}$$

AAI = I indicate that the country's citation impact in the given field corresponds precisely to the world average: AAI > 1 reflects higher-than-average, AAI < 1 lower-than-average impact.

Schubert et. al. in 1989 used AI and AAI to measure the output of various countries[27].In a country, some topics may be low in activity but high in attractivity and vice-versa.

Bujdoso and Braun (1983) used AAI to study the relative research efforts in physics subfields. Schubert and Braun (1986) and Vinkler (1988) introduced the relative citation rate (RCR) as an indicator of individual and institutional productivity. RCR can be defined as

$$RCR = \frac{\sum observed\ citation\ rate}{\sum expected\ citation\ rate}$$

Where $\sum$ denotes summation over all papers published by the given country in the given field.

RCR = 1 indicates that the set of papers under study are cited exactly at an average rate. RCR > 1 suggests that the citation rate of the RCR can be used to compare individuals and institutions in different subject fields. Glanzel and Schubert (1992) found with AAI that higher the level of aggregation the greater the heterogeneity of the population.

Bibliographic coupling is another citation-based clustering technique. This refers to a pair of documents having a common reference or a number of common references. Kessler (1965) applied this indicator to study relationship between scientific papers. Here clusters are formed by the citing documents.

Fractional Citation Counting another citation-based indicator is used for mapping of scientific subjects. The citing paper will have a total citing strength of 1 which is divided equally between all its references. The fractional contributions from all citing papers give the fractional citation count for a particular cited item. This gives a much more balanced and representative cross section of the literature from various disciplines than the usual integer counting. Variable level clustering is another citation-based technique where the citation clusters of various sizes are mapped to depict a subject. Here inputs are cited documents and outputs are clusters of cited documents.

Correspondence Analysis (CA) also known as dual scaling technique is an effective multivariate data analysis technique, based on citations. Highly related points will be located in each other’s' vicinity while those which are apart are relatively unrelated.

Vander Heijdern, and DeLeeuw (1983) used CA complementary to log linear analysis, according to them CA results can be displayed in a simultaneous and partial representation of scores assigned to the rows and columns of a matrix Quasi Correspondence Analysis (QCA) is a modification of CA. This is suitable for the analysis of citation-based transaction matrices which are incomplete or in which the incorporation of certain transactions may seem inappropriate. A transaction matrix has been modeled by assuming that the number of transactions is the result of independent row and column contributions.

3.7.11 Indicators to measure nation's science output

The list of indicators to measure nation's science output, who used them, when, where and what for. Indicators which reveal the structure of a country's science and technology and its position in world scenario can be termed as ‘indicators to measure nation's science output’. Indicators of basic research in science and technology of a nation at a given time, or over a period of time, help the nation to frame its science policy.

These indicators help in determining the relationship between input and output allocation of government resources for the support of science; in evaluating the economic value of research; in detecting the technology gap, neglects in research and national pathology in scientific progress; in reduction of wasteful expenditure in not worthwhile projects; and in reorientation of research activities into areas having higher national priority.

Nation's scientific manpower, quality of scientific personnel, employment statistics, Nobel prizes received, number of doctorate holders, percentage of scientists and engineers in a country's population; government support for scientific research; scientific productivity of individual laboratories in a country; total publications of the country in science and technology; citation counts of scientific papers; number of conferences held in a country and impact factor of journals of a nation are some of the science indicators which measure the nation's science output.

3.8 Conclusion

Scientometric indicators are thus quantitative measures to analyze the growth, impact, obsolescence, collaboration, productivity, utility, half-life etc. They are imperative for national and international progress, research management and science policy. Broadly, Scientometric indicators have been classified as those based on publications; those based on citations; those explaining productivity and collaboration; those measuring nation's scientific output and those meant for international comparisons.

Indicators based on citations help in determining core journals in a subject and ranking them for weeding purposes; mapping the subject, in the compilation of bibliographies; to identify important contributors in the subject; to determine the aging of literature, obsolescence rate and half-life; to measure scientific quality; and help in national and international comparisons. Productivity and collaboration indicators are simple and accurate, but extremely laborious and time consuming. National and international indicators tend to have the flaw of diversity in parameters which make comparisons defective.

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CHAPTER 4

DATA ANALYSIS AND INTERPRETATION

4.1 Introduction

This chapter reports the data analysis of chemical science research in the World, and India. Different data sets have been used for application of different indicators. The analysis of chemical science, presented under different heads, chemical science research; growth and development; productivity of various branches; activity index, priority index, authorship and collaboration; productivity of journals; and productivity of scientific institutions have been studied. The data has been collected from Web of Science database.

The assessment of research performance of countries, region, institution and individuals based on counting of publications and citations are prominent in studies of science and in research policy for identification and evaluation of the strength and weakness in scientific achievements. As growth in Scientometric Indicators (SI) like publication profile of individuals, institutions, countries etc. are closely related to overall R & D of a country, they are primarily intended to identify, compare and evaluate relevant aspects of input and output of scientific productivity and research with more objectives in quantitative and qualitative fashion. Thus, the assessment of research performance using scientometric technique is a valuable method for the identification and evaluation of the strength and weakness in scientific achievements. The generation of new scientific and technical knowledge/information has been accelerating over the past several years. In recent years an increasing attention has been paid to the social dimensions of scientific community that produces sciences. But this unprecedented growth in literature has become a major concern for the scientists, scholars, and library professional as they try to keep themselves abreast with new advances in their subject, and information professionals try to organize this knowledge. How the growth, origin and language of literature reflect in various national level activities in R&D is a matter of great concern to the managers of the scientific activities in government sector and in academic community.

4.2 Growth Pattern of Chemical Science Literature

The word ‘growth’ refers to an increase, expansion in actual size, implying a ‘change of state’. Change in size of literature over a specific period of time is termed as ‘growth of literature’. A systematic study of the increase in scientific literature, scientific community and institutions etc. facilitates quantitative and qualitative understanding of science and various scientific phenomena. In the recent past, studies dealing with the assessment of scientific research in chemical science by different countries have been reported in this study. The present study seeks to assess the contribution of major countries as reflected by the coverage of publications in web of science database during 2002 to 2016.

The past decade has witnessed the modern advances of high-throughput technology and rapid growth of research capacity in producing large-scale biological data, both of which were concomitant with an exponential growth of chemical science literature. This wealth of scholarly knowledge is of significant importance for researchers in making scientific discoveries and healthcare professionals in managing health-related matters. However, the acquisition of such information is becoming increasingly difficult due to its large volume and rapid growth. In response, the web of science and other citation databases are continuously making changes to their web service for improvement to help users in quick and efficient search and retrieval of relevant publications.

4.3 Methodology

The data for the present study were retrieved from ISI Web of Science database (including Science Citation Index (SCI), Social Science Citation Index (SSCI) and Arts & Humanities Citation Index (AHCI)). The data were extracted from Web of Science before 22nd April, 2017. By using suitable search syntax, the data have been downloaded for the period 2002-2016. The collected data were analysed using MS-Excel Spreadsheet and MS-Word.

Garcia – Garcia et al. (2005) proposed Participative Index (PaI) to evaluate the performance level of research of a country or an institution. PaI is the ratio of the number of papers generated in a country or an institution and the total number of documents collected in this repertoire. This can be expressed as:

$$\mathrm{PaI} = \frac{No. of\ Papers\ generated\ in\ an\ institution}{Total\ number\ of\ document\ collected\ in\ this\ repertoire} \times 100$$

Chen and Guan (2011) proposed a new index called Publication Efficiency Index (PEI) to determine if the impact of publications produced by a given country is significantly related to the research effort. Mathematically, the

Publication Efficiency Index (PEI^t_i) for the *i* th country in the *t* th year during the given period can be defined as follows:

$$PEI = \frac{(C^{t+2}i/\sum C)}{(P^t i/\sum P)}$$

- C^{t+2}_i is the citations by the *i* th country.
- $\sum C$ is the citations by the *i* th country during the given citation period.
- P^t_i is the publications by the *i* th country in the *t* th year.
- $\sum P$ is the publications by the *i* th country during the given publication period.

4.3.1 Relative Growth Rate (RGR) and Doubling Time (Dt.)

The Relative Growth Rate (RGR) is the increase in number of articles per unit of time. This definition is derived from the definition of relative growth rates in the study of growth analysis of individual plants and effectively applied in the field of Botany (Hunt {1978 and 1982}; Poorter and Garnier, 1996; Hoffmann and Poorter, 2002). There exists a direct equivalence between the relative growth rate and the doubling time (Bradford, 1934). If the number of articles of a subject get doubled during a given period then the difference between the logarithms of numbers at the beginning and end of this period must be logarithms of number 2. If natural logarithm is used this difference has a value of 0.693.

The mean Relative Growth Rate (R) over the specific period of interval can be calculated from the following equation as given by Krishnamurthy et al. (2009).

$$\overline{R}_{1\text{-}2} = \frac{\log_e {}_2W - \log_e {}_1W}{{}_2T - {}_1T}$$

Whereas

$\overline{R}_{1\text{-}2}$ - Mean Relative Growth Rate over the specific period of interval

$\log_{e1}W$ - log of initial number of articles

$\log_e {}_2W$ - log of final number of articles after a specific period of interval

${}_2T - {}_1T$ - the unit difference between the initial time and the final time

The year can be taken here as the unit of time. The RGR for articles is hereby calculated.

The Doubling Time for each specific period of interval and for both articles and pages can be calculated by the formula:

Doubling Time (Dt.) = 0.693 / $\overline{R}$

4.3.2 Activity Index (AI)

Activity index characterizes the relative research efforts of a country in a given subject field. It is defined as:

AI = (given fields' share in the country's output) / (given fields' share in the world's publication output)

AI = 100 indicates that the country's research efforts in the given field corresponds precisely to the worlds' average.

AI > 100 reflects higher activity than the world's average and

AI < 100 indicates lower than average efforts dedicated to the fields under study.

Activity Index has been calculated by using the formula:

$$AI = \{(Ii/Io) / (Wi /Wo)\} \times 100$$

Where Ii = Indian output in the year i

I_0 = Total Indian output

Wi = world output in the year i

W_o = Total world output

4.4 Status of World Chemical Science Literature

It could be clearly observed from the table 1 the research output of India and average citations per papers of India. India has produced 1,31,212 papers, and received 12,70,317 citations during the period 2002-2016, average citations per Paper is 9.68. As per the Web of Science data, the cumulative publications growth of chemical science research output of India had increased from 27,613 publications during 2002-2006 to 41,693 publications during 2007-2011, and 61,915 publications during 2012-2016.

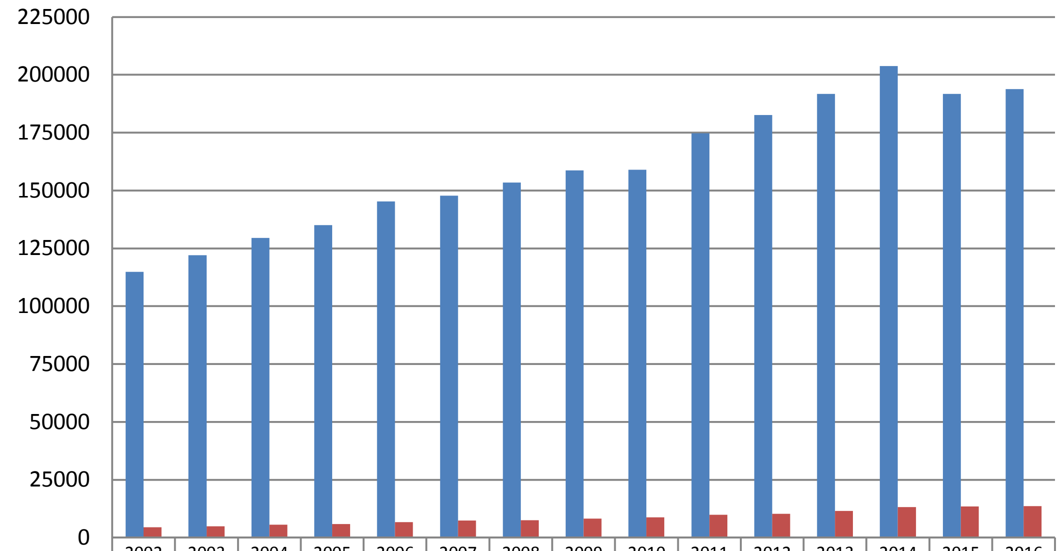
India has produced the highest publication i.e.13,544 papers in 2016. The lowest publication is 4,522 in 2002. Chemical science publications are gradually increased year by year, the publications share of chemical science which has increased from 3.94% in 2002 to 6.99% in 2016. According to the research the trend line shows that there is a steady and significant increase in the publications in chemical science Graph - 1. India's publications are gradually increased year by year. The global publications share of India during 2002-2016 was 5.46%, which has increased from 3.94 in 2002 to 6.99 in 2016. This analysis proves the **hypothesis one "There is an increasing trend in the Indian Chemical Science research".**

Table - 1: Status of World and Indian Chemical Science Literature

WORLD			INDIA				
Year	**TP**	**%**	**TP**	**TC**	**ACPP**	**H-index**	**TP Share**
2002	114912	4.78	4522	94726	20.95	105	3.94
2003	122020	5.08	4930	102072	20.7	113	4.04
2004	129479	5.39	5539	120603	21.77	114	4.28
2005	135085	5.62	5859	126800	21.64	122	4.34
2006	145318	6.04	6763	138815	20.53	127	4.65
2007	147836	6.15	7348	142009	19.33	119	4.97
2008	153488	6.38	7503	131716	17.56	112	4.89
2009	158723	6.60	8238	138103	16.76	110	5.19
2010	158913	6.61	8760	135258	15.44	109	5.51
2011	174805	7.27	9844	140215	14.24	100	5.63
2012	182690	7.60	10277	NA	NA	NA	5.63
2013	191773	7.98	11476	NA	NA	NA	5.98
2014	203848	8.48	13127	NA	NA	NA	6.44
2015	191732	7.97	13491	NA	NA	NA	7.04
2016	193822	8.06	13544	NA	NA	NA	6.99
2002-2006	**646814**	**26.90**	**27613**	**583016**	**21.11**	**NA**	**4.27**
2007-2011	**793765**	**33.01**	**41693**	**687301**	**16.48**	**NA**	**5.25**
2012-2016	**963865**	**40.09**	**61915**	**NA**	**NA**	**NA**	**6.42**
2002-2016	**2404444**		**131221**	**1270317**	**9.68**	**NA**	**5.46**

TP= Total Papers; TC= Total Citations; ACPP=Average Citations per Paper

Graph - 1: Status of World's Chemical Science Literature



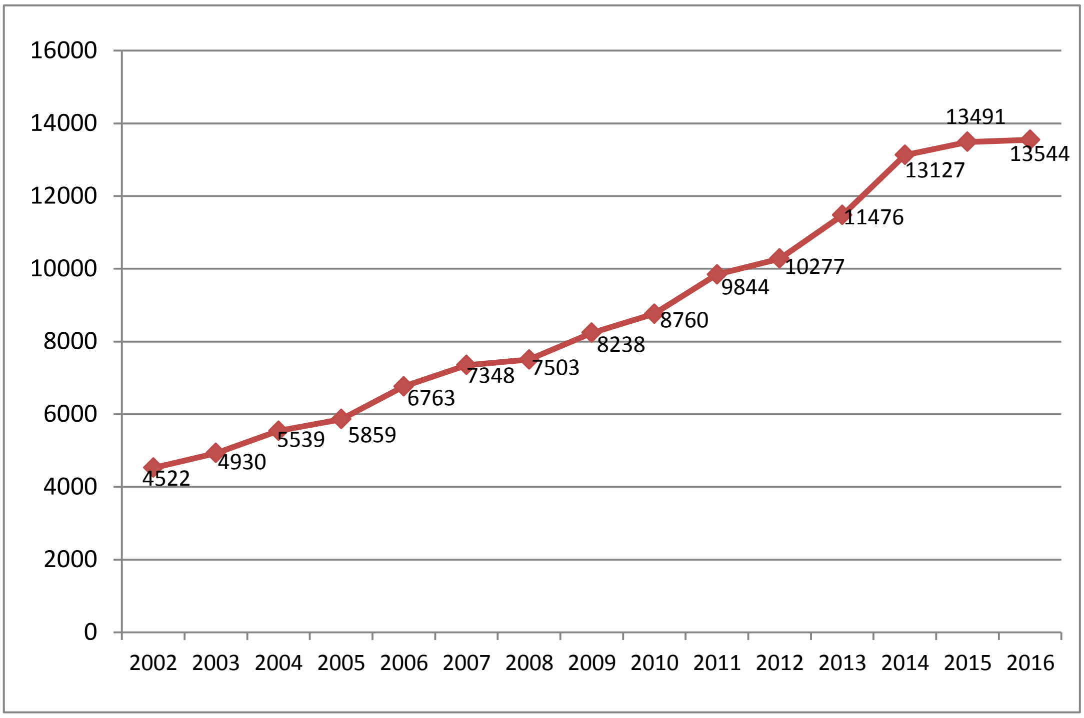
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
WORLD TP	114912	122020	129479	135085	145318	147836	153488	158723	158913	174805	182690	191773	203848	191732	193822
INDIA TP	4522	4930	5539	5859	6763	7348	7503	8238	8760	9844	10277	11476	13127	13491	13544

The global research output in chemical science has increased from 1,14,912 in 2002 to 1,93,822 in 2016. World's publications had increased from 6,46,814 publications during **2002-2006** to 7,93,765 publications during **2007-2011**, and 9,63,865 publications during **2012-2016**. In the same manner, the Indian research output in chemical science too has increased from 4,522 in 2002 to 13,544 by 2016 (Table - 2).

Table - 2: Indian Research output in Chemical Science

Year	TP	% of TP Share
2002	4522	3.94
2003	4930	4.04
2004	5539	4.28
2005	5859	4.34
2006	6763	4.65
2007	7348	4.97
2008	7503	4.89
2009	8238	5.19
2010	8760	5.51
2011	9844	5.63
2012	10277	5.63
2013	11476	5.98
2014	13127	6.44
2015	13491	7.04
2016	13544	6.99
2002-2006	27613	4.27
2007-2011	41693	5.25
2012-2016	61915	6.42
2002-2016	131221	5.46

Graph - 2: Indian Research Output in Chemical Science



It is observed from the study that the above point gets clarified when we analyse the percentage of India's papers compared to that of the world's papers. India's share of science and technology research output increased from 3.94% in 2002 to 6.99% in 2016. The plot graph - 2 shows a significant increase and the trend suggests a 5.46% average growth in the share per annum in the study period.

4.5 Relative Growth Rate and Doubling Time

The table also represents the chronological distribution, Relative Growth Rate (RGR is the growth rate relative to the size of population or continuous growth rate with reference to scientific literature publication time, Relative Growth Rate (GR) is the increase in the number of publications per unit time) and Doubling Time (The doubling time (Dt) is the given period required for quantity to double in size or value) of world publications in the field of chemical science during the period 2002-2016.

One of the obvious features of scientific literature in recent years has been its rate of growth. A number of growth models have been proposed regarding the rate of growth. Price (1963) proposed an exponential rate of growth of scientific literature. He predicted a regular exponential growth with doubling period of ten to fifteen years.

a) World and India

The total output of world and India has been shown in Table - 3 and graph - 3 (fifteen year) along with the growth rate and doubling time. The table shows that the relative growth rate of world output decreasing gradually from 0.72 to 0.02 in fifteen year's periods (2002-2016). The reason for this growth is due to the information communication technology and World Wide Web. The doubling time ($D_{t)}$ correspondingly increases from 0.96 to 8.25 in this period. The mean growth rate and doubling time for the world is **1.13** and **1.17**respectively.

Indian output, as shown in Table - 3, the growth rate decreases gradually from 0.74 to 0.11 during fifteen years period (2002-2016). This growth may be due to the establishment of major scientific institutions like DST, CSIR, NPL, NCL, etc., which resulted into more scientific research in chemical science. Correspondingly, the doubling time increases from 0.94 to 6.36 in the same period. The mean growth rate and doubling time for Indian output is **0.12** and **0.93**.

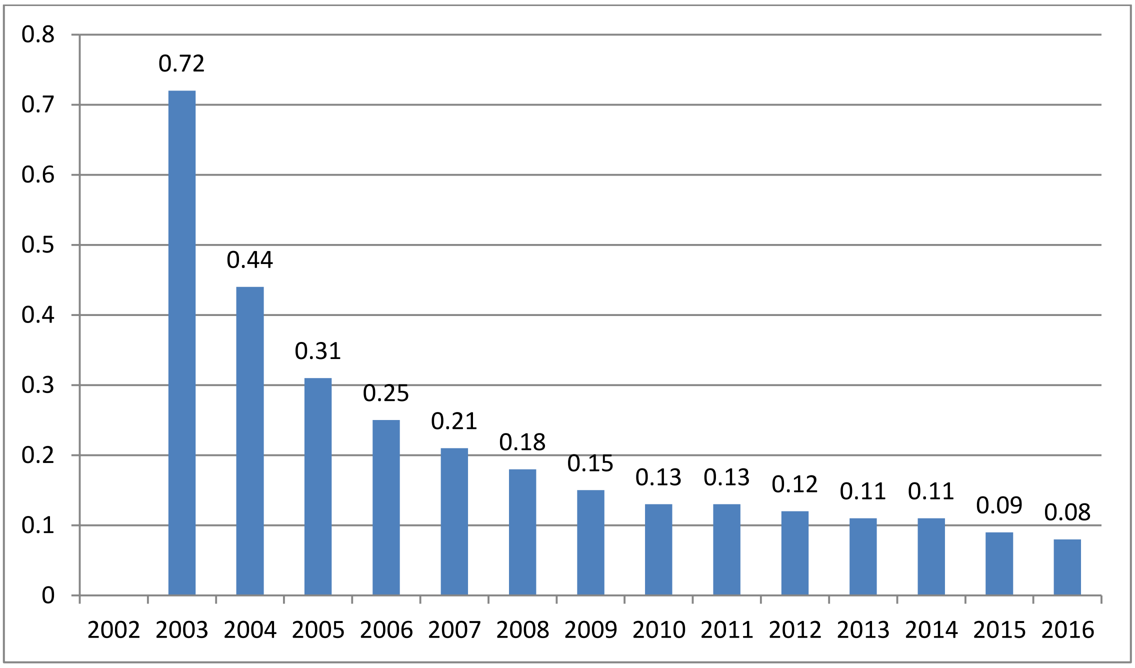
But the year-wise analysis of growth rate and doubling time for world and India indicates a different finding. The growth rate of World is comparatively more than that of India. The average growth rate of world and India is 0.22 and 0.20 respectively. Correspondingly, the doubling time of world is 4.58 and India is 3.83 respectively.

Table - 3: Relative Growth Rate and doubling time of World and India

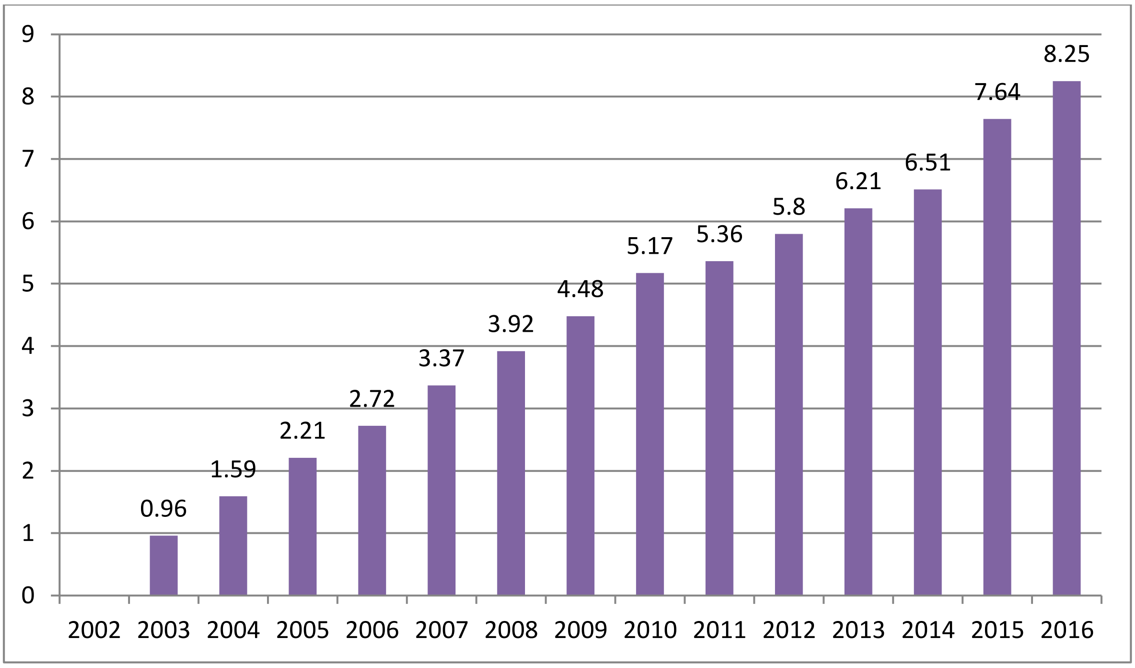
Year	World Output	RGR	Dt	India Output	RGR	Dt
2002	114912			4522		
2003	122020	0.72	0.96	4930	0.74	0.94
2004	129479	0.44	1.59	5539	0.46	1.50
2005	135085	0.31	2.21	5859	0.33	2.10
2006	145318	0.25	2.72	6763	0.28	2.47
2007	147836	0.21	3.37	7348	0.24	2.94
2008	153488	0.18	3.92	7503	0.19	3.56
2009	158723	0.15	4.48	8238	0.18	3.91
2010	158913	0.13	5.17	8760	0.16	4.35
2011	174805	0.13	5.36	9844	0.15	4.52
2012	182690	0.12	5.80	10277	0.14	5.01
2013	191773	0.11	6.21	11476	0.13	5.14
2014	203848	0.11	6.51	13127	0.13	5.15
2015	191732	0.09	7.64	13491	0.12	5.69
2016	193822	0.08	8.25	13544	0.11	6.36
		Mean RGR 1.13	**Mean Dt 1.17**		**Mean RGR 0.12**	**Mean Dt 0.93**

RGR = Relative Growth Rate; Dt = Doubling Time

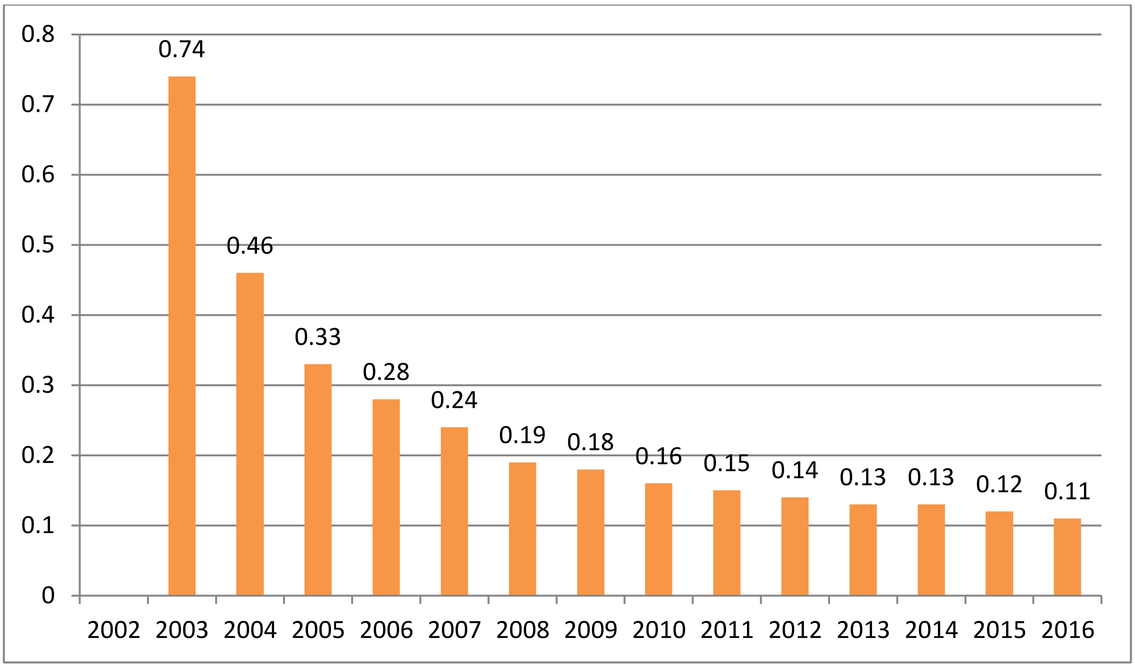
Graph - 3: Relative Growth Rate of World



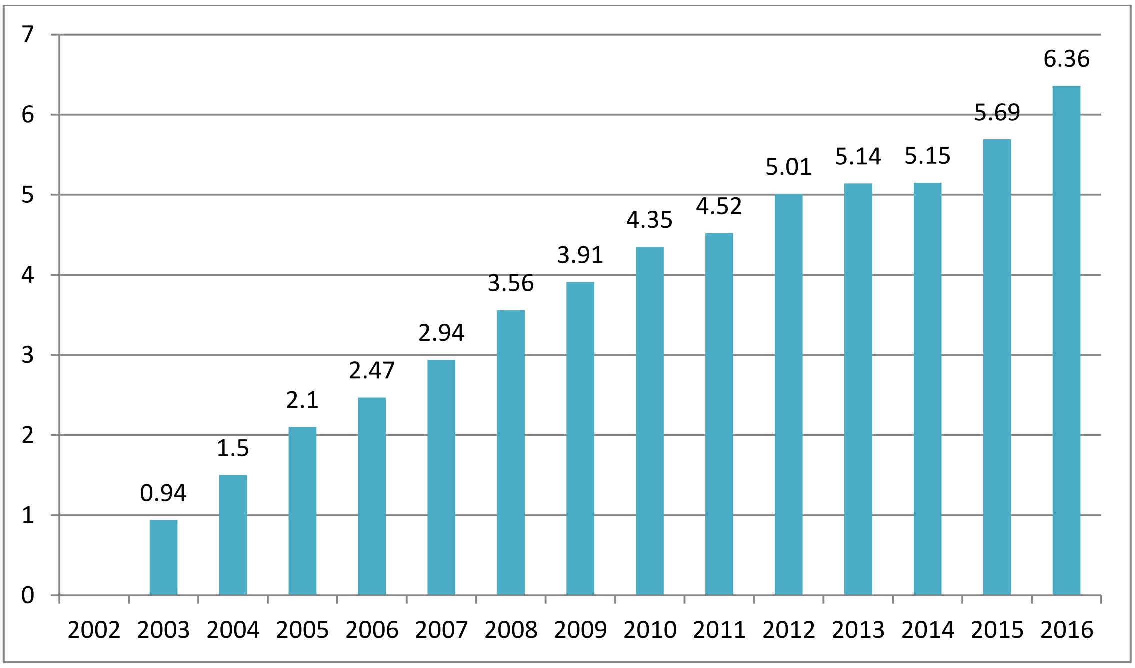
Graph - 4: Doubling Time of World



Graph - 5: Relative Growth Rate of India



Graph - 6: Doubling Time of India



4.6 Most Productive Authors in Indian Chemical Science Research

The table - 4 shows the highly productive authors from Indian chemical science research output during the study period. The top 25 authors having been identified as most productive authors in Indian chemical science research, the publications profile of these 25 authors along with their research output, citations received and h-index values are presented in Table - 4. These 25 authors together contributed 21,257 papers with an average of 817.58 papers per author and account for 16.20% share in the cumulative Indian publications output during 2002-2016.

Table - 4: Most productive authors in Indian Chemical Science Research

Sl. No.	Authors	Affiliation	TP	131221	TC	ACP	H-index
1	Kumar, A.	National University of Singapore, Department of Chemical & Bio molecular Engineering	2227	1.70	29647	13.31	65
2	Kumar, S.	Indian of Technology, Chemical Engineering, Gandhinagar	1674	1.28	19748	11.8	52
3	Ghosh, S.	Indian Institute Science, Bengaluru	1253	0.96	16984	13.55	51
4	Singh, S.	National Institute of Pharmaceutical Education and Research, Mohali	1121	0.85	12222	10.9	45
5	Kumar, R.	Guru Jambheshwar University, Haryana	1101	0.84	15068	13.69	51
6	Yadav, J. S.	Indian Institute of Chemical Technology, Hyderabad	914	0.70	17521	19.17	54
7	Das, S.	Indian Institute of Technology, Uttar Pradesh	897	0.68	11881	13.25	45
8	Singh, A. K.	Indian Institute of Technology, Uttar Pradesh	845	0.64	11457	13.56	46
9	Kumar, P.	Centre for Development of Advanced Computing, Pune	804	0.61	9524	11.85	41
10	Kumar, V.	Polymer Research Laboratory, Govt. Autonomous Science College, Jabalpur	760	0.58	9642	12.69	41
11	Sharma, S.	Indian Institute Science, Bengaluru	719	0.55	6784	9.44	33
12	Roy, S.	Indian Institute of Petroleum, Dehra Dun	698	0.53	8908	12.76	43
13	Kumar, M.	Gauhati University, Assam	677	0.52	9944	14.69	46
14	Sharma, A.	National Chemical Laboratory, Pune	663	0.51	8730	13.17	42
15	Singh, A.	Guru Nanak Dev University, Punjab	625	0.48	6058	9.69	28
16	Singh, P.	Indian Institute Technology, Kanpur	615	0.47	6995	11.37	35
17	Das, D.		594	0.45	8671	14.6	44
18	Ghosh, A.	Indian Institute Science, Bengaluru	585	0.45	9290	15.88	46
19	Reddy, B. V. S.		578	0.44	11101	19.21	49
20	Pal, S.	Indian Institute of Chemical Technology, Hyderabad	574	0.44	7444	12.97	36
21	Kumar, D.	Birla Institute Technology & Science, Pilani	573	0.44	6764	11.8	36
22	Singh, N.	Guru Nanak Dev University, Punjab	569	0.43	8975	15.77	45
22	Banerjee, S.	National Chemical Laboratory, Pune	569	0.43	8036	14.12	38
23	Singh, B.	Indian Institute of Technology, Kanpur	551	0.42	6146	11.15	38
24	Sarkar, S.	Centre for DNA Fingerprinting and Diagnostics, Hyderabad	537	0.41	6960	12.96	37
25	Bhattacharya, S.	Jadavpur University, Kolkata	534	0.41	8881	16.63	42

According to study highest publications are by Kumar, A, occupies first rank with 2,227 articles (29,647 citations) with 13.31 of average citations per paper and his h-index is 65, followed by Kumar, S. published 1,674 papers and received 19,748 citations with an average of 11.8 and his h-index is 52, Ghosh, S. published 1,253 papers (16,984 citations), Singh, S. produced 1,121 papers and received 12,222 citations (h-index 45), Kumar, R. published 1,101 articles and received 15,068 citations. Yadav, J. S. has published 914 articles and received 17,521 citations with an average of 19.17 and his h-index is 54 and Das, S. published 897 articles and recieved 11881 citations with 13.25 average citations per paper and his h-index is 45.

4.7 Channels Used for Communicating Chemical Science Research

The table - 5 reveals channels used for communicating of Chemical science research include articles published in the journals, reviews, conference and seminars proceedings, editorial materials, corrections and book chapters. This study has observed a total of 1,31,221 publications in chemical science from India It has been observed from the table there are many communicating channels are used by scientists to publish their research articles in Indian chemical science literature. The majority of publications are published in Journals i.e. 1,22,712 (95.62), followed by Reviews 3,150 (2.40%) publications, 2,692 (2.05%) papers published are from conference Proceedings, 1,317 are as published as meeting abstracts and less than 1% of articles are published in other communication channels.

Table - 5: Channels Used for Communicating Chemical Science Research

Sl. No.	Document Types	TP	131221
1	Articles	122712	95.62
2	Reviews	3150	2.40
3	Proceedings Papers	2692	2.05
4	Meeting Abstracts	1317	1.00
5	Editorial Materials	525	0.40
6	Corrections	506	0.39
7	Letters	185	0.14
8	Book Chapters	47	0.04
9	Biographical Items	36	0.03
10	Retracted Publications	27	0.02
11	Software Reviews	11	0.01
12	News Items	7	0.01
13	Retractions	3	0.00
14	Reprints	2	0.00
15	Book Reviews	1	0.00
	Total	**131221**	**100%**

4.8 Language-wise Distribution of Publications of IndianChemical Science Research

The table - 6 reveals the language-wise distribution of publications, the scientists researchers from Indian chemical science are published in different languages; English, Chinese, Japanese, German, Welsh, French, Estonian and Danish. It is observed that 99.98% of articles published in english language, 0.008 % articles published in chinese language and very small number of articles are published in remaining languages.

Table - 6: Language-wise Distribution of Publications of Indian Chemical ScienceResearch

Sl. No.	Languages	Records	131221
1	English	131202	99.987
2	Chinese	10	0.008
3	Japanese	3	0.002
4	German	2	0.002
5	Welsh	1	0.001
6	French	1	0.001
7	Estonian	1	0.001
8	Danish	1	0.001
	Total	**131221**	**100%**

4.9 Organizational / Institution productivity in the field of chemical science literature

Table - 7 reveals the ranking list of top 25 highly productive Research Institutions in India based on their highest publications, citations, average citations per publication and h-index. According to the web of science database Indian Institute of Technology (IIT), Delhi contributed the highest publications to the field of chemical science, i.e. 13,297 publications, followed by Bhabha Atomic Research Centre published 4.02 % i.e. 5,273 articles and received 1,00,899 citations with an average (average citations per paper) 19.14 and h-index is 102, Indian Institute of Chemical Technology produced 5,078 papers and received 61,095 citations next to this Indian Institute of Science published 3.73% of papers (4,888 papers and received 1,04,872 citations), National Chemical Laboratory published 3,992 papers, University of Delhi produced

3,373 articles and received 63,109 citations and average citations per paper is 18.71, Banaras Hindu University produced 3,306 articles and received 61,905 citations and University of Hyderabad published 3,008 papers with 16.08 average citations per paper.The study has identified most active institutions engaged in chemical research and proves the hypothesis, **Collaborative research plays a significant role in influencing the quality and quantity of research output in the country.**

Table - 7: Organizational / Institution productivity in the field of chemical science literature

Sl. No.	Organizations	TP	TC	ACP	H-index	%
1	Indian Institute of Technology	13297	NA	NA	NA	10.13
2	Bhabha Atomic Research Centre	5273	100899	19.14	102	4.02
3	Indian Institute of Chemical Technology	5078	61095	12.03	79	3.87
4	Indian Institute of Science	4888	104872	21.45	113	3.73
5	National Chemical Laboratory	3992	85250	21.36	103	3.04
6	University of Delhi	3373	63109	18.71	88	2.57
7	Banaras Hindu University	3306	61905	18.73	88	2.52
8	University of Hyderabad	3008	48361	16.08	72	2.29
9	University of Calcutta	2845	50596	17.78	84	2.17
10	National Institute of Technology	2806	40332	14.37	71	2.14
11	Aligarh Muslim University	2697	48244	17.89	81	2.06
12	Anna University	2480	35230	14.21	70	1.89
13	Jawaharlal Nehru Centre for Advance Science Research	2423	38147	15.74	74	1.85
14	Guru Nanak Dev University	2132	26736	12.54	55	1.62

15	Panjab University	2127	44319	20.84	82	1.62
16	University of Rajasthan	1844	21229	11.51	55	1.41
17	University of Madras	1836	27524	14.99	64	1.40
18	Annamalai University	1603	50581	31.55	96	1.22
19	Shivaji University	1577	37419	23.73	90	1.20
20	University of Allahabad	1556	21176	13.61	59	1.19
21	Central Drug Research Institute	1461	15184	10.39	44	1.11
22	Institute of Chemical Technology	1440	19515	13.55	58	1.10
22	Indian Institute of Technology Guwahati	1342	23742	17.69	60	1.02
23	Osmania University	1280	18435	14.4	58	0.98
24	Sri Venkateswara University	1265	12981	10.26	39	0.96
25	University of Kalyani	1247	19268	15.45	58	0.95
	Total	**76176**	**1076149**	**418**	**1843**	**58.06**

TP = Total Publications; TC = Total Citations; ACP = Average citatipns per paper.

4.10 Top Productive Indian Universities in the Field of Chemical Science Literature

Good number of works are carried out on the academic rankings of universities and have appeared in the literature to focus on the performance of individual institutions or universities. Some of the International studies (Johnes and Johnes, 1995) on Research funding and performance in U.K. University, Departments of Economics: A frontier analysis: Berghe, et al., 1998 on Bibliometric indicators of university research performance in Flanders; Zhu, et al., 2004 are Highly Cited Research Papers and the Evaluation of a Research University: A case study: Peking University 1974-2003; Van Raan, 2007 on Bibliometric statistical properties of the 100 largest European Research Universities: Prevalent scaling rules in the science system.

Table - 8: Top Productive Indian Universities in the field of Chemical Science Literature

Sl. No.	University	Records
1	Jadavpur University	2764
2	University of Delhi	2444
3	Banaras Hindu University	2121
4	University Hyderabad	1972
5	University Calcutta	1808
6	Aligarh Muslim University	1444
7	Anna University	1373
8	Guru Nanak Dev University	1330
9	Panjab University	1255
10	University of Rajasthan	1189
11	University of Madras	1177
12	Annamalai University	1148
13	Shivaji University	1063
14	University of Allahabad	1031
15	Osmania University	940
16	Sri Venkateswara University	931
17	University of Kalyani	906
18	University of Mysore	811
19	Karnatak University	761
20	Andhra University	751
21	Bangalore University	696
22	University of Pune	688
23	Maharaja Sayajirao University	672
24	Kakatiya University	631
25	University of Lucknow	627
26	University of Bombay	577

Based on the publications output of the total of 26 institutions were identified as major collaborating universities in chemical science literature in India. The table - 8 explores that out of these universities the Jadavapur University has published highest number of papers i.e. 2764, followed by University of Delhi has published 2,444 papers, 2,121 papers are produced by Banaras Hindu University, the University of Hyderabad has published 1,972 papers, University of Calcutta published 1,808 papers, Aligarh Muslim University published 1444, Anna University published 1373, Guru Nanak Dev University published 1330Panjab University published 1255, University of Rajasthan published 1189, University of Madras published 1177, Annamalai University published 1148, Shivaji University published 1063, University of Allahabad published 1031, Osmania University published 940, Sri Venkateswara University published 931,University of Kalyani published 906, University of Mysore published 811 papers, Karnatak University has published 761 papers, Andhra University published 751, Bangalore University published 696, University of Pune published 688, Maharaja Sayajirao University published 672, Kakatiya University published 631, University of Lucknow published 627 and University of Bombay published 577 articles published.

4.11. Highly productive Research & Development Organizations

According to productivity of papers it has been listed the top ten research and development institutions. The table 9 indicates that the Indian Institute of Technology, Delhi has in top position with 13,297 papers followed by Bhabha Atomic Research Centre with 4,898 articles, Indian Institute of Chemical Technology with

4,888 articles, Indian Institute of Science with 4,867 articles, Council of Scientific & Industrial Research has published 4,011 articles and Indian Association for the Cultivation of Science has published 3,321 papers.

Table - 9: Highly productive R & D Organizations

Sl. No.	Research Institutions	Records
1	Indian Institute of Technology, Delhi	13297
2	Bhabha Atomic ResearchCentre	4898
3	Indian Institute of Chemical Technology	4888
4	Indian Institute of Science	4867
5	Council of Scientific & Industrial Research	4011
6	Indian Association for the Cultivation of Science	3321
7	National Chemical Laboratory	3067
8	National Institutes of Technology	1693
9	Jawaharlal Nehru Centre for Advanced Scientific Research	1338
10	Central Drug Research Institute	1016

4.12. Subject-Wise Productivity of Indian Chemical Science Research

Table - 10 indicates the subject-wise productivity of chemical science research in India. Materials Science with 16316 (12.434%) publications, Biochemistry Molecular Biology with 6922 (5.275%) publications with 89357 citations, Science Technology other Topics 6891 (5.251%) publications with 121545 citations, Pharmacology Pharmacy 5619 (4.282%) publications with 90529 citations, Engineering 5593 (4.262%) publications with 69934 citations, Electrochemistry 3888 (2.963%) publications with 74479 citations, Crystallography 3623 (2.761%) publications with 54103 citations, Metallurgy Metallurgical Engineering 2950 (2.248%) publications with 36214 citations, Polymer Science 2791 (2.127%) publications with 48148 citations, Food Science Technology 2750 (2.096%) publications with 42802 citations, Thermodynamics 2429 (1.851%) publications with 25652 citations , Energy Fuels 2160 (1.646%) publications with 41837 citations, Nuclear Science Technology 1958 (1.492%) publications with 11682 citations, Biophysics 1741 (1.327%) publications with 37336 citations, Instruments Instrumentation 1396 (1.064%) publications with 27375 citations, Environmental Sciences Ecology 1226 (0.934%) publications with 18645 citations were considered on the basis of the total number of publications.

Table - 10: Subject-Wise Productivity of Indian Chemical Science Research

Sl. No.	Research Areas	TP	% 131221	TC	ACP	H-index
1	Materials Science	16316	12.434	---	---	---
2	Biochemistry Molecular Biology	6922	5.275	89357	12.91	92
3	Science Technology Other Topics	6891	5.251	121545	17.64	119
4	Pharmacology Pharmacy	5619	4.282	90529	16.11	97
5	Engineering	5593	4.262	69934	12.5	90
6	Electrochemistry	3888	2.963	74479	19.16	90
7	Crystallography	3623	2.761	54103	14.93	72
8	Metallurgy Metallurgical Engineering	2950	2.248	36214	12.28	57
9	Polymer Science	2791	2.127	48148	17.25	79
10	Food Science Technology	2750	2.096	42802	15.56	78

11	Thermodynamics	2429	1.851	25652	10.56	49
12	Energy Fuels	2160	1.646	41837	19.37	75
13	Nuclear Science Technology	1958	1.492	11682	5.97	32
14	Biophysics	1741	1.327	37336	21.45	73
15	Instruments Instrumentation	1396	1.064	27375	19.61	69
16	Environmental Sciences Ecology	1226	0.934	18645	15.21	62
17	Agriculture	1164	0.887	13693	11.76	48
18	Spectroscopy	922	0.703	7629	8.27	33
19	Nutrition Dietetics	761	0.58	20090	26.4	64
20	Computer Science	722	0.55	8002	11.08	36
21	Plant Sciences	680	0.518	4186	6.16	27
22	Biotechnology Applied Microbiology	655	0.499	15135	23.11	55
22	Mathematics	463	0.353	3750	8.1	25
23	Radiology Nuclear Medicine Medical Imaging	324	0.247	2321	7.16	21
24	Toxicology	310	0.236	2778	8.96	25
25	Acoustics	287	0.219	6561	22.86	43

TP = Total Publications, TC= Total Citations, ACP = Avarage Citations of Publications

4.13. High Productive Subject Areas in chemical science(World and India)

It is observed from the table - 11 that Pharmacology Pharmacy, Electrochemistry and Crystallography have been identified as the three high priority research areas of Indian chemical science with each contributing publication share 4.28%, 2.96% and 2.77% in the national publication output during 2002-2016. High productive subject areas in chemical science Pharmacology Pharmacy had increased from 1,380 publications during 2002-2006 to 2,036 publications during 2007-2011, and 2,203 publications during

2012-2016, Electrochemistry had increased from 544 publications during 2002-2006 to 1,210 publications during 2007-2011, and 2,134 publications during 2012-2016 and Crystallography had increased from 733 publications during 2002-2006 to 1,107 publications during 2007-2011, and 1,792 publications during 2012-2016. With regard to world Pharmacology Pharmacy, Electrochemistry and Energy Fuels are identified as the three high priority areas of world's chemical science research.

Table - 11: High Productive Subject Areas in Chemical Science (World and India)

Highest Productive Sub-fields in Indian Chemical Science Literature									
	Pharmacology Pharmacy			Electrochemistry			Crystallography		
Year	**TP**	**TC**	**ACPP**	**TP**	**TC**	**ACPP**	**TP**	**TC**	**ACPP**
2002-2006	1380	38294	27.75	544	20103	36.95	733	18712	25.53
2007-2011	2036	38183	18.75	1210	33934	28.04	1107	21424	19.35
2012-2016	2203	15175	6.89	2134	21578	10.11	1792	14635	8.17
2002-2016	**5619**	**91652**	**16.31**	**3888**	**75615**	**19.45**	**3632**	**54771**	**15.08**
Highest Productive Sub-fields in World Chemical Science Literature									
	Pharmacology Pharmacy			**Electrochemistry**			**Energy Fuels**		
Year	**TP**	**TC**	**ACPP**	**TP**	**TC**	**ACPP**	**TP**	**TC**	**ACPP**
2002-2006	30920	722700	23.37	13243	530962	40.09	6169	277645	45.01
2007-2011	36683	679832	18.53	27050	767619	28.38	16240	561222	34.56
2012-2016	37175	249732	6.72	43278	464175	10.73	37349	605854	16.22
2002-2016	**104778**	**1652264**	**15.77**	**83571**	**1762756**	**21.09**	**59758**	**1444721**	**24.18**

4.14. Medium Productive Subject Areas in chemical science(World and India)

The table - 12 reveals that Polymer Science, Thermodynamics, Energy Fuels and Nuclear Science Technology have been identified as the medium productive subject areas of Indian chemical science with each contributing publication share 2.13%, 1.85%, 1.65% and 1.49% in the national publication output during 2002-2016. Medium productive subject areas in chemical science Polymer Science had increased from 328 publications during 2002-2006 to 605 publications during 2007-2011, and 1,858 publications during 2012-2016, Thermodynamics had increased from 450publications during 2002-2006 to 803 publications during 2007-2011 and 1,176 publications during 2012-2016, Energy Fuelshad increased from 232 publications during 2002-2006 to 588 publications during 2007-2011 and 1,340 publications during 2012-2016 andNuclear Science Technology had increased from 420 publications during 2002-2006 to 547 publications during 2007-2011, and 991 publications during 2012-2016. In the same manner in world’s chemical science literature Crystallography (1.89% of total output), Polymer Science (1.61%),Thermodynamics (1.45%) and Instruments Instrumentation (1.38%) subjects are identified as the medium productive sub-fields.

Table - 12: Medium Productive Subject Areas in chemical science (World and India)

Medium Productive Sub-fields in Indian Chemical Science Literature												
	Polymer Science			Thermodynamics			Energy Fuels			Nuclear Science Technology		
Year	**TP**	**TC**	**ACPP**	**TP**	**TC**	**ACPP**	**TP**	**TC**	**ACPP**	**TP**	**TC**	**ACPP**
2002-2006	328	11664	35.56	450	8761	19.47	232	8136	35.07	420	4549	10.83
2007-2011	605	18684	30.88	803	10350	12.89	588	17284	29.39	547	4394	8.03
2012-2016	1858	18422	9.91	1176	6851	5.83	1340	17153	12.80	991	2860	2.89
2002-2016	**2791**	**48770**	**17.47**	**2429**	**25962**	**10.69**	**2160**	**42573**	**19.71**	**1958**	**11803**	**6.03**
Medium Productive Sub-fields in World Chemical Science Literature												
	Crystallography			**Polymer Science**			**Thermodynamics**			**Instruments Instrumentation**		
Year	**TP**	**TC**	**ACPP**	**TP**	**TC**	**ACPP**	**TP**	**TC**	**ACPP**	**TP**	**TC**	**ACPP**
2002-2006	10441	223813	21.44	6473	228545	35.31	9061	165260	18.24	5726	141702	24.75
2007-2011	15175	339954	22.40	11920	352206	29.55	11775	159345	13.53	10282	193711	18.84
2012-2016	19732	155256	7.87	20415	207420	10.16	13997	73639	5.26	17261	133382	7.73
2002-2016	**45348**	**719023**	**15.86**	**38808**	**788171**	**20.31**	**34833**	**398244**	**11.43**	**33269**	**468795**	**14.09**

4.15. Low Productive Subject Areas in chemical science(World and India)

The table - 13 reveals that Instruments Instrumentation, Spectroscopy, Toxicology have been identified as the low productive subject areas of Indian chemical science with each contributing publication share 1.06%, 0.70% and 0.24% in the national publication output during 2002-2016. Low productive subject areas in chemical science Instruments Instrumentation had increased from 184 publications during 2002-2006 to 416 publications during 2007-2011, and 796 publications during 2012-2016, Spectroscopy had increased from 135 publications during 2002-2006 to 264 publications during 2007-2011 and 523 publications during 2012-2016 and Toxicology had increased from 67 publications during 2002-2006 to 94 publications during 2007-2011, and 149 publications during 2012-2016. Spectroscopy, Nuclear Science Technology and Toxicology are the three low productive subject fields in world's chemical science literature.

Table - 13: Low Productive Subject Areas in chemical science (World and India)

Low Productive Sub-fields in Indian Chemical Science Literature									
	Instruments Instrumentation			Spectroscopy			Toxicology		
Year	**TP**	**TC**	**ACPP**	**TP**	**TC**	**ACPP**	**TP**	**TC**	**ACPP**
2002-2006	184	7041	38.27	135	1812	13.42	67	945	14.10
2007-2011	416	11115	26.72	264	2952	11.18	94	1209	12.86
2012-2016	796	10663	13.40	523	2979	5.70	149	682	4.58
2002-2016	**1396**	**28819**	**20.64**	**922**	**7743**	**8.40**	**310**	**2836**	**9.15**
Low Productive Sub-fields in World Chemical Science Literature									
	Spectroscopy			Nuclear Science Technology			Toxicology		
Year	**TP**	**TC**	**ACPP**	**TP**	**TC**	**ACPP**	**TP**	**TC**	**ACPP**
2002-2006	8681	216067	24.89	5684	57659	10.14	3579	74573	20.84
2007-2011	10041	179785	17.91	6071	49272	8.12	3864	62036	16.05
2012-2016	14451	83019	5.74	8149	23947	2.94	3997	23618	5.91
2002-2016	**33173**	**478871**	**14.44**	**19904**	**130878**	**6.58**	**11440**	**160227**	**14.01**

4.16. Source wise Distribution of Indian Contributions in Chemical Science Literature

Bradford's law of scattering is employed to identify core journals. 25 core journals are identified which contains 1/3 of the total articles. Among 25 journals 19 journals are published outside India. Impact factor of the journals shows that Indian cancer related research publish in low impact journals. Further impact of journals of Indian contributions with more than 1000 publications in chemical science has been shown in the table - 14. The impact factor is a measure of the frequency with which the "average article" in journal has been cited in a given period of time. The journal impact factor is calculated based on a 3 years period, and can be the average number of times published papers are cited up to 2 years after publication.

The top most productive journals publishing India's research papers in chemical science research contributed 51,403 papers, which accounts for 39.17% share in the cumulative publications output of India during 2002 to 2016.In these top most productive journals 7 journals are published from the United Kingdom and the United States of America, 6 journals are published from India and 5 journals are published from Netherlands.

Based on the publications the *RSC Advances* journal from United Kingdom published the highest publications i.e. 6,650 articles and received 50, 236 citations, followed by *Asian Journal of Chemistry* (India) published 4,633 articles and received 40,459 citations, *Tetrahedron Letters* (United Kingdom) published 4,424 articles and received 5,262 citations, *Journal of The Indian Chemical Society* (India) contributed 3,417 papers and received 81,428 citations, *Journal of Alloys and Compounds*from Netherlands published 2,639 papers and received 5,894 citations, *Indian Journal of Chemistry Section B Organic Chemistry Including Medicinal Chemistry* published 2,324 articles and received 34,040 citations, *Journal of Physical Chemistry B* published 1,728 articles and received 10,121 citations, *Synthetic Communications*published 1,723 articles and received 40,925 citations, *Indian Journal of Chemistry Section A Inorganic Bio Inorganic Physical Theoretical Analytical Chemistry* published 1,623 articles and received 12,775citations and *Indian Journal of Heterocyclic Chemistry* published 1,475 articles and received 7,329 citations (Table – 14).

Table - 14: Source wise distribution of Indian contributions in chemical science literature

Sl. No.	Source Titles	TP	TC	ACP	H-index	% of 131221	Country
1	RSC Advances	6650	50236	7.55	52	5.07	UK
2	Asian Journal of Chemistry	4633	40459	8.73	47	3.53	India
3	Tetrahedron Letters	4424	5262	1.19	16	3.37	UK
4	Journal of The Indian Chemical Society	3417	81428	23.83	84	2.60	India
5	Journal of Alloys And Compounds	2639	5894	2.23	19	2.01	Netherlands
6	Indian Journal of Chemistry Section B Organic Chemistry Including Medicinal Chemistry	2324	34040	14.65	56	1.77	India
7	Journal of Physical Chemistry B	1728	10121	5.86	27	1.32	USA
8	Synthetic Communications	1723	40925	23.75	81	1.31	USA

9	Indian Journal of Chemistry Section A Inorganic Bio Inorganic Physical Theoretical Analytical Chemistry	1623	12775	7.87	36	1.24	India
10	Indian Journal of Heterocyclic Chemistry	1475	7329	4.97	23	1.12	India
11	Journal of Molecular Structure	1454	2939	2.02	16	1.11	Netherlands
12	Dalton Transactions	1401	11845	8.45	36	1.07	UK
13	Journal of Nanoscience And Nanotechnology	1381	22399	16.22	53	1.05	USA
14	Journal of Physical Chemistry C	1369	9616	7.02	34	1.04	USA
15	Tetrahedron	1368	31965	23.37	78	1.04	UK
16	Applied Surface Science	1364	31180	22.86	68	1.04	Netherlands
17	Bioorganic Medicinal Chemistry Letters	1360	19857	14.60	53	1.04	UK
18	Chemical Communications	1358	24768	18.24	58	1.03	UK
19	Journal of Chemical Physics	1341	34271	25.56	76	1.02	USA
20	Polyhedron	1235	17752	14.37	49	0.94	UK
21	Journal of Organic Chemistry	1218	18128	14.88	50	0.93	USA
22	Abstracts of Papers of The American Chemical Society	1210	31060	25.67	71	0.92	USA
23	Journal of Molecular Liquids	1197	7578	6.33	32	0.91	Netherlands
24	Chemical Physics Letters	1197	8839	7.38	33	0.91	Netherlands
25	Journal of Chemical Sciences	1182	17100	14.47	54	0.90	India

4.17. Application of Bradford' law

In order to observe the appropriateness of the distribution of journals using the verbal formulation of Bradford law, the following explanations are made and the results are presented. The first part deals with the verbal formulation of the theory based on data consisting whole periodical references, arranged by their decreasing frequency of citations while the second part examines the graphical representations based on the same data.

4.17.1 Verbal Formulation

Table - 15 presents details of highly productive journals to test the verbal formulation of Bradford's law. The table consits of rank number of journals, Cumulative number of Journals, number of articles, Cumulative number of articles, log of Cumulative number of Journals are given to test the verbal formulation of Bradford's law. Bradford's technique is used to group the journals in to three zones of productivity and Bradford's law of scattering is applied to test the verbal formulation.

Table - 15presents several details of journal citations to test the verbal formulation of Bradford's law. The number of cited journals has been arranged by decreasing number of articles to test the verbal formulation of Bradford's law, the Zone number of journals, number of articles, cumulative articles, log of cumulative journals are given in the table - 16.

For testing the algebraic interpretation of the Law, the 131221 journal titles were divided into three zones. The Bradford's multiplier factor was arrived at by dividing periodical titles of a zone by its preceding zone. Bradford multiplier is expressed as the ratio of the number of periodical titles in any group to the number of periodical titles in any immediately preceding group. The basis for choosing the three zones was that the percentage error in distribution of citations, among the three zones should be minimum.

The distribution of journals and corresponding number of citations in the three zones along with the value of Bradford multipliers are shown in the Table - 16.

In the present data set, 20 journals covered 44267 articles, next 56 journals covered 43984 articles and next 513 journals covered 42970 articles. In other words, one third of the total articles have been covered by each group of the journals.

According to Bradford, the zones, thus identified will form an approximately geometric series in the form 1: n: n^2. But it is found that the relationship of each zone in the present study is 20: 56: 513. This does not fit into the Bradford's distribution.

Here, 20 represent the number of periodicals in the nucleus and n= 5.92 is a multiplier. The mean value of multiplier is 5.92.

Therefore $20:20X5.92:20X5.92^2 :: 1 : n : n^2$

20: 118.4: 700.928 ≈ 839.328

Percentage of error = $\frac{839.328-589}{589}$ X 100 = 42.50%

Since the percentage of error is high 42.50% data does not fit the Bradford's law.

4.17.2 Leimkuhler Model

For application of Bradford's law, divide the citation distribution in three or more approximately equal zones (p). Since Bradford assumes that there should be minimum 3 zones, here also p is assumed to be 3. Then by using the mathematical formula, the value of the Bradford's multiplier k is calculated as

$k = (e^{\Upsilon} X y_m)^{1/p} = (1.781 * 6650)^{1/3} = 22.794$

$Y_o = A/P = 131221/3 = 43740.33$

$r_o = T(k-1)/(k^p-1) = 589(22.794-1)/(22.794^3-1)$

$= 1.084$

$a = Y_o / \log k = 43740.33/ \log 22.794 = 32213.63$

$b = k-1/ r_o = 22.794-1/1.08 = 20.18$

The findings of the calculation are shown in Table. From the table the nucleus zone is found to be 1 and $k= 23.76$ is a multiplier. Therefore, the Bradford distribution is:

$1:1X23.76:1X23.76^2 \approx 1: n: n^2$

$1: 23.76: 564.5376 \approx 589.2976$

Percentage of error = $\frac{589.2976-589}{589}$ X 100= 0.05%

Hence, it can be noted from the above calculations that the percentage of error is very negligible and Bradford's Law of Scattering fits very well in the present data set for Bradford multiplier k = 23.76. It can also be noted from Table that the three zones are not exactly the 1/3rd of total citations and analysis proves the hypothesis, **Bradford's law of scattering positively fitted with Chemical Science Literature.**

Table - 15: Bradford distribution

Rank	No. of Journals	Cum no. Journals	Articles	Total no. of Articles	Cum. No. of Articles	Log (n)	% of Articles	% of Journals
1	1	1	6650	6650	6650	0	5.07	0.17
2	1	2	4633	4633	11283	0.69	8.60	0.34
3	1	3	4424	4424	15707	1.10	11.97	0.51
4	1	4	3417	3417	19124	1.39	14.57	0.68
5	1	5	2639	2639	21763	1.61	16.58	0.85
6	1	6	2324	2324	24087	1.79	18.36	1.02
7	1	7	1728	1728	25815	1.95	19.67	1.19
8	1	8	1723	1723	27538	2.08	20.99	1.36
9	1	9	1623	1623	29161	2.20	22.22	1.53
10	1	10	1475	1475	30636	2.30	23.35	1.70
11	1	11	1454	1454	32090	2.40	24.45	1.87
12	1	12	1401	1401	33491	2.49	25.52	2.04
13	1	13	1381	1381	34872	2.57	26.58	2.21
14	1	14	1369	1369	36241	2.64	27.62	2.38
15	1	15	1368	1368	37609	2.71	28.66	2.55
16	1	16	1364	1364	38973	2.77	29.70	2.72
17	1	17	1360	1360	40333	2.83	30.74	2.89
18	1	18	1358	1358	41691	2.89	31.77	3.06
19	1	19	1341	1341	43032	2.94	32.79	3.23
20	1	20	1235	1235	44267	3.00	33.73	3.40
21	1	21	1218	1218	45485	3.04	34.66	3.57
22	1	22	1210	1210	46695	3.09	35.59	3.74
23	2	24	1197	2394	49089	3.18	37.41	4.07
24	1	25	1182	1182	50271	3.22	38.31	4.24

25	1	26	1132	1132	51403	3.26	39.17	4.41
26	1	27	1120	1120	52523	3.30	40.03	4.58
27	1	28	1104	1104	53627	3.33	40.87	4.75
28	1	29	1063	1063	54690	3.37	41.68	4.92
29	1	30	1062	1062	55752	3.40	42.49	5.09
30	1	31	993	993	56745	3.43	43.24	5.26
31	1	32	971	971	57716	3.47	43.98	5.43
32	1	33	969	969	58685	3.50	44.72	5.60
33	1	34	966	966	59651	3.53	45.46	5.77
34	2	36	913	1826	61477	3.58	46.85	6.11
35	1	37	904	904	62381	3.61	47.54	6.28
36	1	38	897	897	63278	3.64	48.22	6.45
37	1	39	885	885	64163	3.66	48.90	6.62
38	1	40	881	881	65044	3.69	49.57	6.79
39	1	41	872	872	65916	3.71	50.23	6.96
40	1	42	867	867	66783	3.74	50.89	7.13
41	1	43	829	829	67612	3.76	51.53	7.30
42	1	44	797	797	68409	3.78	52.13	7.47
43	1	45	780	780	69189	3.81	52.73	7.64
44	1	46	765	765	69954	3.83	53.31	7.81
45	1	47	763	763	70717	3.85	53.89	7.98
46	1	48	738	738	71455	3.87	54.45	8.15
47	1	49	728	728	72183	3.89	55.01	8.32
48	1	50	718	718	72901	3.91	55.56	8.49
49	1	51	695	695	73596	3.93	56.09	8.66
50	1	52	693	693	74289	3.95	56.61	8.83
51	1	53	673	673	74962	3.97	57.13	9.00

52	1	54	641	641	75603	3.99	57.62	9.17
53	1	55	639	639	76242	4.01	58.10	9.34
54	1	56	638	638	76880	4.03	58.59	9.51
55	1	57	624	624	77504	4.04	59.06	9.68
56	1	58	613	613	78117	4.06	59.53	9.85
57	1	59	599	599	78716	4.08	59.99	10.02
58	1	60	574	574	79290	4.09	60.42	10.19
59	1	61	540	540	79830	4.11	60.84	10.36
60	1	62	538	538	80368	4.13	61.25	10.53
61	1	63	524	524	80892	4.14	61.65	10.70
62	2	65	511	1022	81914	4.17	62.42	11.04
63	1	66	497	497	82411	4.19	62.80	11.21
64	1	67	492	492	82903	4.21	63.18	11.38
65	1	68	490	490	83393	4.22	63.55	11.54
66	1	69	488	488	83881	4.23	63.92	11.71
67	1	70	483	483	84364	4.25	64.29	11.88
68	1	71	458	458	84822	4.26	64.64	12.05
69	1	72	452	452	85274	4.28	64.99	12.22
70	1	73	440	440	85714	4.29	65.32	12.39
71	1	74	437	437	86151	4.30	65.65	12.56
72	1	75	435	435	86586	4.32	65.98	12.73
73	1	76	421	421	87007	4.33	66.31	12.90
74	1	77	420	420	87427	4.34	66.63	13.07
75	1	78	413	413	87840	4.36	66.94	13.24
76	1	79	411	411	88251	4.37	67.25	13.41
77	1	80	409	409	88660	4.38	67.57	13.58
78	1	81	406	406	89066	4.39	67.87	13.75

79	1	82	401	401	89467	4.41	68.18	13.92
80	1	83	392	392	89859	4.42	68.48	14.09
81	1	84	384	384	90243	4.43	68.77	14.26
82	1	85	373	373	90616	4.44	69.06	14.43
83	1	86	370	370	90986	4.45	69.34	14.60
84	1	87	368	368	91354	4.47	69.62	14.77
85	1	88	364	364	91718	4.48	69.90	14.94
86	2	90	363	726	92444	4.50	70.45	15.28
87	1	91	362	362	92806	4.51	70.72	15.45
88	1	92	361	361	93167	4.52	71.00	15.62
89	1	93	357	357	93524	4.53	71.27	15.79
90	1	94	356	356	93880	4.54	71.54	15.96
91	1	95	352	352	94232	4.55	71.81	16.13
92	1	96	348	348	94580	4.56	72.08	16.30
93	2	98	340	680	95260	4.59	72.60	16.64
94	1	99	336	336	95596	4.60	72.85	16.81
95	1	100	332	332	95928	4.61	73.10	16.98
96	1	101	328	328	96256	4.62	73.35	17.15
97	1	102	323	323	96579	4.63	73.60	17.32
98	1	103	312	312	96891	4.64	73.84	17.49
99	1	104	310	310	97201	4.64	74.07	17.66
100	1	105	306	306	97507	4.65	74.31	17.83
101	1	106	301	301	97808	4.66	74.54	18.00
102	1	107	299	299	98107	4.67	74.76	18.17
103	1	108	292	292	98399	4.68	74.99	18.34
104	1	109	291	291	98690	4.69	75.21	18.51
105	1	110	290	290	98980	4.70	75.43	18.68

106	2	112	288	576	99556	4.72	75.87	19.02
107	2	114	287	574	100130	4.74	76.31	19.35
108	1	115	286	286	100416	4.75	76.52	19.52
109	2	117	285	570	100986	4.76	76.96	19.86
110	1	118	281	281	101267	4.77	77.17	20.03
111	2	120	279	558	101825	4.79	77.60	20.37
112	1	121	267	267	102092	4.80	77.80	20.54
113	2	123	265	530	102622	4.81	78.21	20.88
114	1	124	263	263	102885	4.82	78.41	21.05
115	1	125	260	260	103145	4.83	78.60	21.22
116	2	127	259	518	103663	4.84	79.00	21.56
117	1	128	258	258	103921	4.85	79.20	21.73
118	2	130	256	512	104433	4.87	79.59	22.07
119	1	131	253	253	104686	4.88	79.78	22.24
120	2	133	248	496	105182	4.89	80.16	22.58
121	1	134	246	246	105428	4.90	80.34	22.75
122	1	135	241	241	105669	4.91	80.53	22.92
123	2	137	236	472	106141	4.92	80.89	23.26
124	3	140	235	705	106846	4.94	81.42	23.77
125	1	141	234	234	107080	4.95	81.60	23.94
126	3	144	229	687	107767	4.97	82.13	24.45
127	1	145	222	222	107989	4.98	82.30	24.62
128	1	146	218	218	108207	4.98	82.46	24.79
129	1	147	217	217	108424	4.99	82.63	24.96
130	1	148	215	215	108639	5.00	82.79	25.13
131	1	149	214	214	108853	5.00	82.95	25.30
132	1	150	213	213	109066	5.01	83.12	25.47

133	1	151	209	209	109275	5.02	83.28	25.64
134	1	152	208	208	109483	5.02	83.43	25.81
135	1	153	206	206	109689	5.03	83.59	25.98
136	1	154	205	205	109894	5.04	83.75	26.15
137	1	155	204	204	110098	5.04	83.90	26.32
138	1	156	194	194	110292	5.05	84.05	26.49
139	2	158	191	382	110674	5.06	84.34	26.83
140	1	159	185	185	110859	5.07	84.48	26.99
141	1	160	184	184	111043	5.08	84.62	27.16
142	1	161	183	183	111226	5.08	84.76	27.33
143	1	162	182	182	111408	5.09	84.90	27.50
144	1	163	181	181	111589	5.09	85.04	27.67
145	2	165	179	358	111947	5.11	85.31	28.01
146	1	166	176	176	112123	5.11	85.45	28.18
147	3	169	173	519	112642	5.13	85.84	28.69
148	1	170	172	172	112814	5.14	85.97	28.86
149	1	171	171	171	112985	5.14	86.10	29.03
150	2	173	167	334	113319	5.15	86.36	29.37
151	2	175	163	326	113645	5.17	86.61	29.71
152	1	176	161	161	113806	5.17	86.73	29.88
153	1	177	159	159	113965	5.18	86.85	30.05
154	1	178	158	158	114123	5.18	86.97	30.22
155	1	179	151	151	114274	5.19	87.09	30.39
156	1	180	149	149	114423	5.19	87.20	30.56
157	1	181	146	146	114569	5.20	87.31	30.73
158	1	182	143	143	114712	5.20	87.42	30.90
159	3	185	142	426	115138	5.22	87.74	31.41

160	1	186	140	140	115278	5.23	87.85	31.58
161	1	187	137	137	115415	5.23	87.95	31.75
162	2	189	136	272	115687	5.24	88.16	32.09
163	2	191	135	270	115957	5.25	88.37	32.43
164	2	193	134	268	116225	5.26	88.57	32.77
165	1	194	133	133	116358	5.27	88.67	32.94
166	2	196	131	262	116620	5.28	88.87	33.28
167	5	201	130	650	117270	5.30	89.37	34.13
168	1	202	129	129	117399	5.31	89.47	34.30
169	1	203	127	127	117526	5.31	89.56	34.47
170	2	205	126	252	117778	5.32	89.76	34.80
171	2	207	124	248	118026	5.33	89.94	35.14
172	1	208	123	123	118149	5.34	90.04	35.31
173	1	209	122	122	118271	5.34	90.13	35.48
174	1	210	121	121	118392	5.35	90.22	35.65
175	2	212	120	240	118632	5.36	90.41	35.99
176	3	215	118	354	118986	5.37	90.68	36.50
177	1	216	117	117	119103	5.38	90.77	36.67
178	1	217	115	115	119218	5.38	90.85	36.84
179	2	219	114	228	119446	5.39	91.03	37.18
180	2	221	113	226	119672	5.40	91.20	37.52
181	1	222	112	112	119784	5.40	91.28	37.69
182	3	225	110	330	120114	5.42	91.54	38.20
183	2	227	109	218	120332	5.43	91.70	38.54
184	2	229	108	216	120548	5.43	91.87	38.88
185	2	231	107	214	120762	5.44	92.03	39.22
186	3	234	106	318	121080	5.46	92.27	39.73

187	1	235	103	103	121183	5.46	92.35	39.90
188	1	236	98	98	121281	5.46	92.42	40.07
189	1	237	97	97	121378	5.47	92.50	40.24
190	1	238	96	96	121474	5.47	92.57	40.41
191	1	239	93	93	121567	5.48	92.64	40.58
192	3	242	92	276	121843	5.49	92.85	41.09
192	2	244	91	182	122025	5.50	92.99	41.43
193	1	245	90	90	122115	5.50	93.06	41.60
194	4	249	89	356	122471	5.52	93.33	42.28
195	2	251	88	176	122647	5.53	93.47	42.61
196	1	252	87	87	122734	5.53	93.53	42.78
197	4	256	86	344	123078	5.55	93.79	43.46
198	2	258	84	168	123246	5.55	93.92	43.80
199	3	261	83	249	123495	5.57	94.11	44.31
200	1	262	81	81	123576	5.57	94.17	44.48
201	3	265	80	240	123816	5.58	94.36	44.99
202	2	267	79	158	123974	5.59	94.48	45.33
203	2	269	78	156	124130	5.60	94.60	45.67
204	4	273	77	308	124438	5.61	94.83	46.35
205	3	276	76	228	124666	5.62	95.00	46.86
206	3	279	74	222	124888	5.63	95.17	47.37
207	2	281	73	146	125034	5.64	95.29	47.71
208	4	285	72	288	125322	5.65	95.50	48.39
209	2	287	71	142	125464	5.66	95.61	48.73
210	2	289	69	138	125602	5.67	95.72	49.07
211	3	292	68	204	125806	5.68	95.87	49.58
212	2	294	67	134	125940	5.68	95.98	49.92

213	2	296	66	132	126072	5.69	96.08	50.25
214	2	298	65	130	126202	5.70	96.18	50.59
215	1	299	64	64	126266	5.70	96.22	50.76
216	1	300	63	63	126329	5.70	96.27	50.93
217	1	301	62	62	126391	5.71	96.32	51.10
218	2	303	61	122	126513	5.71	96.41	51.44
219	1	304	60	60	126573	5.72	96.46	51.61
220	2	306	59	118	126691	5.72	96.55	51.95
221	3	309	57	171	126862	5.73	96.68	52.46
222	1	310	55	55	126917	5.74	96.72	52.63
223	3	313	54	162	127079	5.75	96.84	53.14
224	3	316	53	159	127238	5.76	96.96	53.65
225	3	319	52	156	127394	5.77	97.08	54.16
226	4	323	51	204	127598	5.78	97.24	54.84
227	1	324	50	50	127648	5.78	97.28	55.01
228	2	326	49	98	127746	5.79	97.35	55.35
229	1	327	48	48	127794	5.79	97.39	55.52
230	4	331	47	188	127982	5.80	97.53	56.20
231	2	333	46	92	128074	5.81	97.60	56.54
232	1	334	44	44	128118	5.81	97.64	56.71
234	3	337	43	129	128247	5.82	97.73	57.22
235	2	339	42	84	128331	5.83	97.80	57.56
236	1	340	40	40	128371	5.83	97.83	57.72
237	4	344	39	156	128527	5.84	97.95	58.40
238	5	349	38	190	128717	5.86	98.09	59.25
239	1	350	37	37	128754	5.86	98.12	59.42
240	1	351	36	36	128790	5.86	98.15	59.59
241	2	353	35	70	128860	5.87	98.20	59.93
242	2	355	34	68	128928	5.87	98.25	60.27

243	4	359	33	132	129060	5.88	98.35	60.95
244	2	361	32	64	129124	5.89	98.40	61.29
245	2	363	31	62	129186	5.90	98.45	61.63
246	1	364	29	29	129215	5.90	98.47	61.80
247	4	368	28	112	129327	5.91	98.56	62.48
248	6	374	27	162	129489	5.92	98.68	63.50
249	1	375	26	26	129515	5.93	98.70	63.67
250	3	378	25	75	129590	5.94	98.76	64.18
251	2	380	24	48	129638	5.94	98.79	64.52
252	11	391	23	253	129891	5.97	98.99	66.38
253	3	394	22	66	129957	5.98	99.04	66.89
254	2	396	21	42	129999	5.98	99.07	67.23
255	5	401	20	100	130099	5.99	99.14	68.08
256	6	407	19	114	130213	6.01	99.23	69.10
257	4	411	18	72	130285	6.02	99.29	69.78
258	5	416	17	85	130370	6.03	99.35	70.63
259	1	417	16	16	130386	6.03	99.36	70.80
260	7	424	15	105	130491	6.05	99.44	71.99
261	5	429	14	70	130561	6.06	99.50	72.84
262	4	433	13	52	130613	6.07	99.54	73.51
263	7	440	12	84	130697	6.09	99.60	74.70
264	6	446	11	66	130763	6.10	99.65	75.72
265	4	450	10	40	130803	6.11	99.68	76.40
266	4	454	9	36	130839	6.12	99.71	77.08
267	5	459	8	40	130879	6.13	99.74	77.93
268	7	466	7	49	130928	6.14	99.78	79.12
269	11	477	6	66	130994	6.17	99.83	80.98
270	11	488	5	55	131049	6.19	99.87	82.85
271	8	496	4	32	131081	6.21	99.89	84.21
272	9	505	3	27	131108	6.23	99.91	85.74
273	29	534	2	58	131166	6.28	99.96	90.66
274	55	589	1	55	131221	6.38	100.00	100.00

Table - 16: Bradford zones of Scattering

Zone	Journals	% of Journals	Articles	% of Articles	*k*
1	20	3.39	44267	33.73	-
2	56	9.51	43984	33.52	25
3	513	87.1	42974	32.75	22.52
	589	100	131221	100	23.76

4.18. International Collaboration

Due to the interdisciplinary growth of subject, the universe of knowledge is ever dynamic and is ever-growing. More and more specialization in the subjects is achieved by the scientists, which is a result of increased participation of group of researchers from different dicipline. It has been found from earlier studies that collaboration in research varies from discipline to discipline and for the same discipline from time to time and from one country to country.

Collaborative research has become a well established feature in the field of chemical science. It is observed that there is consistently increasing trend towards collaboration among various branches of chemical science which leads to collaborative authorship in literature.

Table - 17 depicts the international collaborative papers of India with top 25 countries during 2002-2016. The largest number of collaborative publications (5,255) of India in chemical science research was with United States with 4.005% share, followed by Germany contributed 2,597 papers with 1.979% of total share, South Korea published 2,461 (1.875%) papers, Japan produced 2,062 papers, England published 1,549 (1.18%) articles, France contributes 1,484 (1.13%) papers, Spain published 1,224 (0.933%) papers and Saudi Arabia has contributed with India in chemical science research i.e. 1,188 (0.905%) papers. Many countries are contributed with below 1% share with India in chemical science research during 2002 to 2016 (Table-17). Hence the analysis proves hypothesis **the share of international collaborative papers in the Chemical Science have increased over the years**.

Table - 17: International Collaboration

Sl. No.	Countries	TP	% of 131221
1	USA	5255	4.005
2	Germany	2597	1.979
3	South Korea	2461	1.875
4	Japan	2062	1.571
5	England	1549	1.18
6	France	1484	1.131
7	Spain	1224	0.933
8	Saudi Arabia	1188	0.905
9	Italy	1040	0.793
10	Taiwan	1028	0.783
11	Canada	777	0.592
12	Peoples R China	699	0.533
13	Australia	691	0.527
14	Malaysia	663	0.505

15	South Africa	545	0.415
16	Switzerland	433	0.33
17	Singapore	400	0.305
18	Portugal	396	0.302
19	Poland	342	0.261
20	Belgium	322	0.245
21	Czech Republic	302	0.23
22	Sweden	301	0.229
23	Iran	276	0.21
24	Israel	275	0.21
25	Scotland	274	0.209

4.19. Publication Efficiency Index (PEI)

To determine the impact of publications produced by a given country is significantly related to the research effort. Chen and Guan (2011) propose Publication Efficiency Index (PEI). If PEI >1(greater than), this indicates that the impact of publications in a given field by a particular country is more than the research effort devoted to it during the period considered. The same formula is employed to calculate the Publication Efficiency Index (PEI) of the Indian chemical scienceliterature during the period 2002 to 2011. Table - 18shows the PEI scores for India.

The study demonstrates that PEI score is not greater than one for all the years. This means that for all the years the Indian chemical research performance is not more than the research effort devoted to it during 2002-2011. All the researchers are active in the chemical science research publications during 2002 to 2011 (except during 2002 to 2007 in these years the PEI score is less than one). It is observed that the highest PEI is 1.29in Indian chemical science research in the year 2011 (Table – 18).

Table - 18: Publication Efficiency Index (PEI)

Year	TC	PEI
2002	4522	0.87
2003	4930	0.89
2004	5539	0.84
2005	5859	0.85
2006	6763	0.89
2007	7348	0.95
2008	7503	1.04
2009	8238	1.09
2010	8760	1.19
2011	9844	1.29
	69306	1
		Mean 0.99

4.20. Relative Citation Index (RCI)

The indicator was developed by Institute of Scientific Information (now Thomson Reuters, USA) to calculate science and scientific indicators. RCI measures both the influence and visibility of a nation’s research in global perspective. RCI is a ratio of a country’s share of world citations (percent citations) to country’s share of world publications (percent publications). RCI = 1 indicates that country’s citation rate is equal to world citation rate; RCI > 1 indicates that country's citation rate is higher than world's citation rate and RCI < 1 indicate that country's citation rate is less than world's citation rate (Table - 19).

Table - 19: Relative Citation Index (RCI) of Indian Chemical Science Research

Year	TNP	TNC	ACP	RCI
2002	4522	94726	20.95	1.14
2003	4930	102072	20.70	1.13
2004	5539	120603	21.77	1.19
2005	5859	126800	21.64	1.18
2006	6763	138815	20.53	1.12
2007	7348	142009	19.33	1.05
2008	7503	131716	17.56	0.96
2009	8238	138103	16.76	0.91
2010	8760	135258	15.44	0.84
2011	9844	140215	14.24	0.78
	69306	1270317	18.33	1

TNP = Total number of Publications, TNC = Total Number of Citations, ACP = Average citations per paper; RCI = Relative Citations Index

Table - 19 deals with relative citation index. Table data clearly indicates that from 2002 to 2007 country's citation rate is higher than the world's citation rate. Further it is also observed that from 2008 to 2011 country's citation rate is less than world citation rate.

4.21. Activity Index

The table - 20 shows that the highest Activity Index in various subject categories in different years were: Pharmacology Pharmacy the highest activity index i.e. 127.32 in 2012, Electrochemistry 113.96 (2016), Energy Fuels 149.98 (2002), Crystallography 129.32 (2014), Polymer Science 145.56 (2015), Thermodynamics 143.03 (2012), Spectroscopy 152.91 (2014), Instruments Instrumentation 127.49 (2013), Nuclear Science Technology 154.43 (2014) and Toxicology 166.48 in 2014.

It is observed from the data that the Toxicology subject scored highest Activity Index (166.48), followed by Nuclear Science Technology (154.43), Spectroscopy (152.91), Energy Fuels (149.98), Polymer Science (145.56) etc., in fifteen years period. It indicates India's research efforts in these subjects correspond to the world's average.

Table - 20: Activity Index

Year	Pharmacology Pharmacy	Electrochemistry	Energy Fuels	Crystallography	Polymer Science	Thermodynamics	Spectroscopy	Instruments Instrumentation	Nuclear Science Technology	Toxicology
2002	76.37	110.17	**149.98**	78.86	66.36	52.03	19.38	78.66	90.58	45.25
2003	80.49	57.85	60.52	83.70	64.67	72.84	49.40	59.30	70.70	63.72
2004	96.22	107.08	85.37	74.90	52.25	83.34	52.26	59.91	50.83	49.06
2005	90.60	78.43	116.33	83.08	77.87	65.51	75.68	68.46	72.75	58.89
2006	75.53	91.37	109.37	114.04	82.70	80.36	74.76	107.66	95.44	127.96
2007	87.46	105.24	110.32	105.19	66.59	61.07	77.30	114.02	84.41	46.77
2008	92.86	99.84	113.52	92.81	55.92	81.30	77.17	101.06	64.50	78.52

2009	108.62	93.51	99.59	80.67	61.18	103.73	51.43	88.83	61.87	83.16
2010	114.30	85.96	88.77	83.66	68.57	126.11	107.22	85.16	106.87	123.77
2011	111.38	98.35	96.56	93.72	87.27	105.75	151.06	95.89	143.28	118.88
2012	**127.32**	98.10	103.38	101.40	96.13	**143.03**	125.69	100.93	137.86	97.85
2013	89.84	96.35	92.97	113.72	112.08	141.88	123.97	**127.49**	111.09	134.54
2014	118.71	108.48	103.02	**129.32**	131.91	113.12	**152.91**	119.67	**154.43**	**166.48**
2015	108.01	109.20	92.65	115.22	**145.56**	107.32	115.84	104.29	101.79	147.44
2016	112.03	**113.96**	104.92	106.03	144.34	96.83	131.32	100.23	109.07	140.49

4.22. Highly Cited Papers in the field Indian Chemical Science

Table - 21shows characteristics of selected highly cited papers of India in chemical science. The list of such highly cited papers is presented based on publication output of India in this area and 25 papers are identified as highly cited ones, who have received citations from 743 to 2,132 during 2002 to 2016. These 25 high cited papers were published in 14 journals including 6 papers in *Chemical Reviews*, 3 in *Angewandte Chemie-International Edition*,2 in *Advanced Materials* and 1 paper each in 3 journals. Citations received by these top 25 cited papers accumulated to 27,445 (2.16%) of all citations. Most of the papers are having multiple authors (Three or more authors), two papers are single author and seven papers are having two authors. The top cited paper was ‘Graphene: The New Two-Dimensional Nanomaterial’, authored by Rao, CNR; Sood, AK; Subrahmanyam, KS; and Govindaraj, A. published in *Angewandte Chemie-International Edition* in the year 2009 and this paper has received 2132 citations, followed by ‘Metal carboxylates with open architectures’, authored by Rao, CNR; Natarajan, S; Vaidhyanathan, R. published in *Angewandte Chemie-*

International in the year 2004, and this paper received 1754 citations, ‘Hydrogen bridges in crystal engineering: Interactions without borders’ authored by Desiraju, GR. published in *Accounts of Chemical Research* in the year 2002 and this paper received 1512 citations, ‘Recent advances in the Baylis-Hillman reaction and applications’ authored by Basavaiah, D; Rao, AJ; Satyanarayana, T. published in *Chemical Reviews* in the year 2003 this paper received 1438 citations. Further, ‘Chitosan chemistry and pharmaceutical perspectives’, authored by Kumar, MNVR; Muzzarelli, RAA; Muzzarelli, C; Sashiwa, H; Domb, AJ, published in *Chemical Reviews* received 1391 citations, ‘Recent applications of the Suzuki-Miyaura cross-coupling reaction in organic synthesis’, authored by Kotha, S; Lahiri, K; Kashinath, D. published in *Tetrahedron* in the year 2002 paper received 1381 citations, ‘Inter particle coupling effect on the surface plasmon resonance of gold nanoparticles: From theory to applications’ authored by Ghosh, SK; Pal, T. published in *Chemical Reviews* in the year 2007 this paper received 1262 citations. While, ‘Supra molecular gels: Functions and uses’ authored by Sangeetha, NM; Maitra, U. published in *Chemical Society Reviews* in the year 2005 received 1225 citations, this shows that more research activities are being carried out in newly developing fields.

Table - 21: Highly Cited Papers in the field Indian Chemical Science

Sl. No	Citations Received	Title of the Article	Authors	Source	Country	Year of Publication
1	2132	Graphene: The New Two-Dimensional Nanomaterial	Rao, CNR; Sood, AK; Subrahmanyam, KS; Govindaraj, A	*Angewandte Chemie-International Edition*, *48*(42), 7752-7777	India	2009
2	1754	Metal carboxylates with open architectures	Rao, CNR; Natarajan, S; Vaidhyanathan, R	*Angewandte Chemie-International Edition*, *43*(12), 1466-1496	India	2004
3	1512	Hydrogen bridges in crystal engineering: Interactions without borders	Desiraju, GR	*Accounts of Chemical Research*, *35*(7), 565-573	India	2002
4	1438	Recent advances in the Baylis-Hillman reaction and applications	Basavaiah, D; Rao, AJ; Satyanarayana, T	*Chemical Reviews,103(*3), 811-891	India	2003
5	1391	Chitosan chemistry and pharmaceutical perspectives	Kumar, MNVR; Muzzarelli, RAA; Muzzarelli, C; Sashiwa, H; Domb, AJ	*Chemical Reviews*, *104*(12), 6017-6084	India	2004
6	1381	Recent applications of the Suzuki-Miyaura cross-coupling reaction in organic synthesis	Kotha, S; Lahiri, K; Kashinath, D	*Tetrahedron*, *58*(48), 9633-9695	India	2002

7	1262	Interparticle coupling effect on the surface plasmon resonance of gold nanoparticles: From theory to applications	Ghosh, SK; Pal, T	*Chemical Reviews*, *107*(11), 4797-4862	India	2007
8	1225	Supramolecular gels: Functions and uses	Sangeetha, NM; Maitra, U	*Chemical Society Reviews*, *34*(10), 821-836	India	2005
9	1186	Recent advances on chitosan-based micro- and nanoparticles in drug delivery	Agnihotri, SA; Mallikarjuna, NN; Aminabhavi, TM	*Journal of Controlled Release*, *100*(1), 5-28	India	2004
10	1116	Supramolecular Coordination: Self-Assembly of Finite Two- and Three-Dimensional Ensembles	Chakrabarty, R; Mukherjee, PS; Stang, PJ	*Chemical Reviews*, *111*(11), 6810-6918	India	2011
11	1050	Biodegradable polymeric nanoparticles-based drug delivery systems	Kumari, A; Yadav, SK; Yadav, SC	*Colloids and Surfaces B-Biointerfaces*,*75*(1), 1-18	India	2010
12	1015	Controlling the aspect ratio of inorganic nanorods and nanowires	Murphy, CJ; Jana, NR	*Advanced Materials*,*14*(1), 80-82	India	2002
13	988	Recent developments in ring opening polymerization of lactones for biomedical applications	Albertsson, AC; Varma, IK	*Biomacromolecules*, *4*(6), 1466-1486	India	2003
14	956	Recent advances in transition metal catalyzed oxidation of organic substrates with molecular oxygen	Punniyamurthy, T; Velusamy, S; Iqbal, J	Chemical Reviews, 105(6), 2329-2363	India	2005

15	910	Application of conducting polymers to biosensors	Gerard, M; Chaubey, A; Malhotra, BD	*Biosensors & Bioelectronics, 17*(5), 345-359	India	2002
16	906	Rapid synthesis of Au, Ag, and bimetallic Au core-Ag shell nanoparticles using Neem (Azadirachta indica) leaf broth	Shankar, S. S., Rai, ,A., Ahmad, A., & Sastry, M.	*Journal of Colloid and Interface Science*, *275*(2), 496-502	India	2004
17	897	Biological synthesis of triangular gold nanoprisms	Shankar, SS; Rai, A; Ankamwar, B; Singh, A; Ahmad, A; Sastry, M	*Nature Materials, 3*(7), 482-488	India	2004
18	845	Structure, and Properties of Boron- and Nitrogen-Doped Graphene	Panchokarla, LS; Subrahmanyam, KS; Saha, SK; Govindaraj, A; Krishnamurthy, HR; Waghmare, UV; Rao, CNR	*Advanced Materials*, *21*(46), 4726-+	India	2009
19	813	Biocompatibility of gold nanoparticles and their endocytotic fate inside the cellular compartment: A microscopic overview	Shukla, R; Bansal, V; Chaudhary, M; Basu, A; Bhonde, R); Sastry, M	*Langmuir*, *21*(23), 10644-10654	India	2005
20	804	Core/Shell Nanoparticles: Classes, Properties, Synthesis Mechanisms, Characterization, and Applications	Chaudhuri, RG; Paria, S	*Chemical Reviews*, *112*(4), 2373-2433	India	2012

21	797	Graphene Quantum Dots Derived from Carbon Fibers	Peng, J; Gao, W; Gupta, BK; Liu, Z; Romero-Aburto, R; Ge, LH; Song, L; Alemany, LB; Zhan, XB; Gao, GH; Vithayathil, SA; Kaipparettu, BA; Marti, AA; Hayashi, T; Zhu, JJ; Ajayan, PM	*Nano Letters*, *12*(2), 844-849	India	2012
22	793	Crystal engineering: A holistic view	Desiraju, GR	Angewandte Chemie-International Edition, 46(44), 8342-8356.	India	2007
23	775	Polyionic hydrocolloids for the intestinal delivery of protein drugs: Alginate and chitosan - a review	George, M; Abraham, TE	Journal of Controlled Release,114(1), 1-14	India	2006
24	756	Removal of Congo Red from water by adsorption onto activated carbon prepared from coir pith, an agricultural solid waste	Namasivayam, C; Kavitha, D	Dyes and Pigments, 54(1), 47-58	India	2002
25	743	Structural diversity and chemical trends in hybrid inorganic-organic framework materials	Cheetham, AK; Rao, CNR; Feller, RK	Chemical Communications, 46, 4780-4795	India	2006

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CHAPTER – 5

FINDINGS SUGGESTIONS AND CONCLUSION

5.1 Introduction

The present study has explored that the Indian chemical science literature covered in Web of Science database. It analyses India's publication activity in terms of global share, share of international collaborative publications, and visibility and citation impact for the period 2002-2016. It explores how far the trends in Indian chemical science output mirror those of the other upcoming countries and what are the main differences among those countries. It discusses the findings in the light of the above-mentioned ongoing discussion on decline or emergence of chemical science literature.

The present study "Mapping of Chemical Science Literature with Reference to Web of Science Citation Database: A Scientometric Study" has been undertaken to understand the characteristics of Indian chemical science literature by identifying the growth of literature, productivity and collaboration trend, assessing the productivity of scientific institutions and journals of science literature with the help of 3 data sets (2002-2006, 2007-20011 and 2012-2016). This chapter reports the findings of the analysis of Indian chemical science research. Different data sets have been used for application of different indicators, and presented under different sub-headings.

5.2 Major Findings of the Study

The major findings of the study are:

5.2.1 Status of World Chemical Science Literature

- India has produced 1,31,221 papers, and received 12,70,317 citations during the period 2002-2016, Average Citations per Paper is 9.68.
- The world has produced 24,04,444 publications in chemical science and had increased its publications from 1,14,912 in 2002 to 1,93,822 in 2016.
- As per the Web of Science data, the cumulative publications growth of chemical science research output of India had increased from 27,613 publications during 2002-2006 to 41,693 publications during 2007-2011, and 61,915 publications during 2012-2016 (Table 1).
- The publication trend shows a higher steepness, indicating a faster increase in research output in respect of the global research output.
- India has produced the highest publication i.e. 13,544 papers in 2016. The lowest publication is 4,522 in 2002 (Table 2).
- Chemical science publications are gradually increased year by year, the publications share of chemical science which has increased from 3.94% in 2002 to 6.99% in 2016.
- According to the data the trend line shows that there is a steady and significant increase in the publications in chemical science
- India’s publication has gradually increased year by year. The global publications share of India during 2002-2016 was 5.46%, which has increased from 3.94 in 2002 to 6.99 in 2016.

5.2.2. Relative Growth Rate and doubling time

- The table- 3 shows that the relative growth rate of world output decreases gradually from 0.72 to 0.08 in fifteen year's periods (2002-2016). The doubling time (Dt) correspondingly increases from 0.96 to 8.25 in this period. The mean growth rate and doubling time for the world is 1.13 and 1.17 respectively.
- Indian growth rate decreases gradually from 0.74 to 0.11 during fifteen years period (2002-2016). This growth may be due to the establishment of major scientific institutions like DST, CSIR, NPL, NCL, etc., which resulted into more scientific research in chemical science. Correspondingly, the doubling time increases from 0.94 to 6.36 in the same period. The mean growth rate and doubling time for Indian output is 0.12 and 0.93.
- But the year-wise analysis of growth rate and doubling time for world and India indicates a different finding. The growth rate of World is comparatively more than that of India.
- The average growth rate of world and India is 0.22 and 0.24 respectively. Correspondingly, the doubling time of world is 4.58 and India is 3.83 respectively.
- Publications by broad subjects have substantially increased during the period under study.

5.2.3. Most Productive Authors in Indian Chemical Science Research

- The top 25 authors having been identified as most productive authors in Indian chemical science research, the publications profile of these 25 authors along with their research output, citations received and h-index values are presented in (Table 4).
- These 25 authors together contributed 21,257 papers with an average of 817.58 papers per author and account for 16.20% share in the cumulative Indian publications output during 2002-2016.
- According to highest publications, Kumar, A, occupies first rank with 2,227 articles (29,647 citations) with 13.31 of aveage citations per paper and his h-index is 65, followed by Kumar, S. published 1,674 papers and received 19,748 citations with an average of 11.8 citations prepare and his h-index is 52, Ghosh, S. published 1,253 papers (16,984 citations), Singh, S. produced 1,121 papers and received 12,222 citations (h-index 45), Kumar, R. published 1,101 articles and received 15,068 citations.
- Yadav, J. S. has published 914 articles and received 17,521 citations with an average of 19.17 citations prepare and his h-index is 54 and Das, S. published 897 articles.

5.2.4. Channels used for Communicating Cheimical Science Research

- It has been observed from the table - 5 there are many communicating channels are used by scientists to publish their research articles in Indian chemical science literature. The majority of publications are published in Journals i.e. 1,22,712 (95.62),
- 3,150 (2.40%) review publications, 2,692 (2.05%) of papers published in Proceedings, 1,317 are as published as meeting abstracts and less than 1% of articles are published in other communication channels (Table 5).

5.2.5. Organizational / Institution Productivity in the Field of Chemical Science Literature

- The study reveals that the ranking list of top 25 highly productive Research Institutions in India based on their highest publications, citations, average citations per publication and h-index.
- According to the web of science database Indian Institute of Technology (IIT), Delhi contributed the highest publications to the field of chemical science, i.e. 13,297 publications, followed by Bhabha Atomic Research Centre published 4.02 % i.e. 5,273 articles and received 1,00,899 citations with an average (average citations per paper) 19.14 and h-index is 102, Indian Institute of Chemical Technology produced 5,078 papers and received 61,095 citations next to this Indian Institute of Science published 3.73% of papers (4,888 papers and received 1,04,872 citations) (Table 7).

- National Chemical Laboratory published 3,992 papers University of Delhi produced 3,373 articles and received 63,109 citations and average citations per paper is 18.71, Banaras Hindu University produced 3,306 articles and received 61,905 citations and University of Hyderabad published 3,008 papers with 16.08 average citations per paper.

- Based on the publications output of the total of 25 institutions were identified as major collaborating universities in chemical science literature in India.

- The table 8 explores that out of these universities the Jadavapur University has published highest number of papers i.e. 2764, followed by University of Delhi has published 2,444 papers, 2,121 papers are produced by Banaras Hindu University, the University of Hyderabad has published 1,972 papers, University of Calcutta published 1,808 papers, University of Mysore published 811 papers, Karnatak University has published 761 papers, Bangalore University published 696 articles and Mangalore University has published 406 papers.

- The table- 9 indicates that the Indian Institute of Technology, Delhi has in top position with 13,297 papers followed by Bhabha Atomic Research Centre with 4,898 articles, Indian Institute of Chemical Technology with 4,888 articles, Indian Institute of Science with 4,867 articles, Council of Scientific & Industrial Research has published 4,011 articles and Indian Association for the Cultivation of Science has published 3,321 papers.

5.2.6. Subject-Wise Productivity of Indian Chemical Science Research

5.2.6.1.High Productive Subject Areas in Chemical Science

- It is observed from the table - 11 Pharmacology Pharmacy, Electrochemistry and Crystallography have been identified as the three high priority research areas of Indian chemical science with each contributing publication share 4.28%, 2.96% and 2.77% in the national publication output during 2002-2016.
- High productive subject areas in chemical science Pharmacology Pharmacy had increased from 1,380 publications during 2002-2006 to 2,036 publications during 2007-2011, and 2,203 publications during 2012-2016, Electrochemistry had increased from 544 publications during 2002-2006 to 1,210 publications during 2007-2011, and 2,134 publications during 2012-2016 and Crystallography had increased from 733 publications during 2002-2006 to 1,107 publications during 2007-2011, and 1,792 publications during 2012-2016.
- With regard to world Pharmacology Pharmacy, Electrochemistry and Energy Fuels are identified as the three high priority areas of world's chemical science research.

5.2.6.2. Medium Productive Subject Areas in Chemical Science

- The table reveals that Polymer Science, Thermodynamics, Energy Fuels and Nuclear Science Technology have been identified as the medium productive subject areas of Indian chemical science with each contributing publication share 2.13%, 1.85%, 1.65% and 1.49% in the national publication output during 2002-2016 (Table 12).

- Medium productive subject areas in chemical science are Polymer Science which had increased from 328 publications during 2002-2006 to 605 publications during 2007-2011, and 1,858 publications during 2012-2016, Thermodynamics had increased from 450 publications during 2002-2006 to 803 publications during 2007-2011 and 1,176 publications during 2012-2016, Energy Fuels had increased from 232 publications during 2002-2006 to 588 publications during 2007-2011 and 1,340 publications during 2012-2016 and Nuclear Science Technology had increased from 420 publications during 2002-2006 to 547 publications during 2007-2011, and 991 publications during 2012-2016.
- In the same manner in world’s chemical science literature Crystallography (1.89% of total output), Polymer Science (1.61%), Thermodynamics (1.45%) and Instruments Instrumentation (1.38%) subjects are identified as the medium productive sub-fields.

5.2.6.3. Low Productive Subject Areas in chemical science

- The table- 13 reveals that Instruments Instrumentation, Spectroscopy, Toxicology have been identified as the low productive subject areas of Indian chemical science with each contributing publication share 1.06%, 0.70% and 0.24% in the national publication output during 2002-2016.
- Low productive subject areas in chemical science Instruments Instrumentation had increased from 184 publications during 2002-2006 to 416 publications during 2007-2011, and 796 publications during 2012-2016,

Spectroscopy had increased from 135 publications during 2002-2006 to 264 publications during 2007-2011 and 523 publications during 2012-2016 and Toxicology had increased from 67 publications during 2002-2006 to 94 publications during 2007-2011, and 149 publications during 2012-2016 (Table 13).

- Spectroscopy, Nuclear Science Technology and Toxicology are the three low productive subject fields in world's chemical science literature.

5.2.7. Source wise distribution of Indian contributions in chemical science literature

- Among 25 journals 20 journals are published abroad. Impact factor of the journals shows that Indian cancer related research is publish in low impact journals.
- Further impact of journals of Indian contributions with more than 1000 publications in chemical science has been shown in the table -14.
- The top most productive journals publishing India's research papers in chemical science research contributed 51,403 papers, which accounts for 39.17% share in the cumulative publications output of India during 2002 to 2016.
- In these top most productive journals 7 journals each are published from the United Kingdom and the United States of America, 6 journals are published from India and 5 journals are published from Netherlands.

- Based on the publications the *RSC Advances* journal from United Kingdom published the highest publications i.e. 6,650 articles and received 50, 236 citations, followed by *Asian Journal of Chemistry* (India) published 4,633 articles and received 40,459 citations,
- *Tetrahedron Letters* (United Kingdom) published 4,424 articles and received 5,262 citations, *Journal of The Indian Chemical Society* (India) contributed 3,417 papers and received 81,428 citations,
- *Journal of Alloys and Compounds* from Netherlands published 2,639 papers and received 5,894 citations, *Indian Journal of Chemistry Section B Organic Chemistry Including Medicinal Chemistry* published 2,324 articles and received 34,040 citations, *Journal of Physical Chemistry B* published 1,728 articles and received 10,121 citations,
- *Synthetic Communications* published 1,723 articles and received 40,925 citations, *Indian Journal of Chemistry Section A Inorganic Bio Inorganic Physical Theoretical Analytical Chemistry* published 1,623 articles and received 12,775 citations and *Indian Journal of Heterocyclic Chemistry* published 1,475 articles and received 7,329 citations.

5.2.8. International Collaboration

- Collaborative research has become a well established feature in the field of chemical science literature. It is observed that there is a consistently increasing trend towards collaboration among various branches of chemical science which leads to collaborative authorship in literature.

- Table 17 depicts the international collaborative papers of India with top with 25 countries during 2002-2016. The share of International collaborative publications in the Indian chemical science research output was 20.26% during 2002-2016.
- The largest number of collaborative publications (5,255) of India in chemical science research was with United States with 4.005% share, followed by Germany contributed 2,597 papers with 1.979% of total share, South Korea published 2,461 papers, Japan produced 2,062 papers, England published 1,549 articles,
- France contributes 1,484 papers, Spain published 1,224 papers and Saudi Arabia has contributed with India in chemical science research i.e. 1,188 papers. Many countries are contributed with below 1% share with India in chemical science research during 2002 to 2016

5.2.9. Publication Efficiency Index (PEI)

- The study demonstrates that PEI score is not greater than one for all the years. This means that for all the years the indian chemical research performance is not more than the research effort devoted to it during 2002-2011.
- All the researchers are active in the chemical science research publications during 2002 to 2011 (except during 2002 to 2007 in these years the PEI score is less than one). It is observed that the highest PEI is 1.29 in Indian chemical science research in the year (Table 18).

5.2.10. Relative Citation Impact (RCI)

- RCI is a ratio of a country's share of world citations (percent citations) to country's share of world publications (percent publications). RCI = 1 indicates that country's citation rate is equal to world citation rate; RCI > 1 indicates that country's citation rate is higher than world's citation rate and RCI < 1 indicate that country's citation rate is less than world's citation rate.

5.2.11. Activity Index

- The data shows that the highest Activity Index in various subject categories in different years were: Pharmacology Pharmacy the highest activity index i.e. 127.32 in 2012, Electrochemistry 113.96 (2016), Energy Fuels 149.98 (2002), Crystallography 129.32 (2014), Polymer Science 145.56 (2015), Thermodynamics 143.03 (2012), Spectroscopy 152.91 (2014), Instruments Instrumentation 127.49 (2013), Nuclear Science Technology 154.43 (2014) and Toxicology 166.48 in 2014 (Table 20).
- It is observed from the data that the Toxicology subject scored highest Activity Index (166.48), followed by Nuclear Science Technology (154.43), Spectroscopy (152.91), Energy Fuels (149.98), Polymer Science (145.56) etc., in fifteen years period. It indicates India's research efforts in these subjects correspond to the world's average.

5.3 Suggestions

Based on the outcomes of the study, the following are suggested as measures to improve the research productivity of India in the field of Chemical science literature.

By enhancing the opportunities of researchers to have international collaboration in multidisciplinary research. The exponential growth of scientific literature, inter-disciplinary nature of research and trend towards specialization has posed many problems for both scientists and librarians. Further the development of national and international information systems caused the need for an analysis of literature used by scientists. The extensive investigation and abundance of literature being published to immense escalation of cost for the libraries towards the acquisition of literature published. Further, due to the lack of adequate funds, the libraries are not in a position to acquire all the periodicals, at least in board fields. It is necessary for the librarians to know the characteristics of literature being used by researchers.

5.4 Areas of Further Research

The findings of this research have more scope for further research such as

- Assessment of chemical research output using Scientometric Indicators: A comparative study of India and other countries.
- The extent and pattern of collaboration research in the subfields of Chemical Science research.
- The citation studies in Chemical Science research.
- Application of various growth models to validate the research with regard to chemical science literature.

Research publications are the embodiments of intellectual discoveries primarily aiming to transmit new ideas or information for bringing advancement in knowledge.

The bibliometric and scientometric techniques are increasingly used for the assessment of scientific research. The outcome of these studies helps in enhancing the visibility of institutions, trends of their research productivity, research collaboration, etc. and as a consequence the funding agencies come forward to support their research. The individuals and the team of researchers also get appreciation and inducement for their work. As such scientometric studies influence the research of the institution.

5.5 Conclusion

The present study analyses India's publication activity in terms of global share, share of international collaborative publications, and visibility and citation impact for the period 2002-2016. It explores how far the trends in Indian chemical science output mirror those of the other upcoming countries and what are the main differences among those countries. It discusses the findings in the light of the above-mentioned ongoing discussion on decline or emergence of chemical science literature.

India has produced 1,31,212 papers, and received 12,70,317 citations during the period 2002-2016, in the same manner world has produced 24,04,444 publications in chemical science and had increased its publications from 1,14,912 in 2002 to 1,93,822 in 2016. The study has identified most active institutions engaged in chemical research, areas of research in chemical science, journals used for communication and the impact of the highly cited papers in chemical science research output. The findings of the present study will be beneficial for the scholars and scientists who are engaged in research of various disciplines of chemical science as well as policy makers in the field.

At the national level there is a need to increase the evolving research strategies and delineating specific directions to investigate the recent trends. There is also need to increase international collaboration, which will increase both quality and quantity of research in chemical science literature.