Project Completion Report

Research Performance of Indian Women Scientists in Research Laboratories: A Scientometric Study

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The National Science and Technology Management Information System (NSTMIS), a division of Department of Science and Technology (DST) has been entrusted with the task building the information base on a continuous basis on resources devoted to scientific and technological activities for policy planning in the country.

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Preface

The issue of women and science is at the core of any nation's scientific policy. In reality science, engineering and technology are vital to developments in most industrial sectors. Currently, women represent almost 50% of India's university graduates but they remain under-represented in research and career related to natural science, engineering and technology. Indeed, the under-representation of women in science is preventing the full realization of the nation's potential and achievement. Furthermore, the exclusion of women in science, especially in mathematical, computational and engineering fields is unacceptable and unaffordable waste of human resources and distortion of the relationship between science and society. Until now, not one country has been successful in attracting enough young women mind to a career in the natural, computational, engineering and mathematics field. Initiative at the national and regional level is now needed to keep women with a completed science education active in scientific careers and to allow newcomers to enter.

Industry plays an important role in research, innovation and development. In India, mainly four types of industrial research sectors exists: agricultural, scientific & technological, health care (medical) and space, atomic & defense industry. A large number of the workforce including women are engaged in all these industrial research sectors. Although analysis of overall research activities has been carried out before, the research productivity exclusively for women in industrial research organizations in India has never been analysed before. We will not succeed in the overall improvement of science if the research performance by women scientists remains unknown to us.

This study is an attempt in bringing together information about women researchers in the S&T industry from various sources and evaluate the research performance by the women presently working in various research laboratories of Ministry & Science and Technology, Government of India. It constitutes a starting point in terms of outlining actions to be taken and identifying areas for further investigation. The report has been prepared by senior researcher Dr. Bhaskar Mukherjee, Department of Library & Information Science, Banaras Hindu University, Varanasi with financial assistance from the National Science & Technology Management Information System division of the Department of Science & Technology, Government of India.

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LIST OF ABBREVIATIONS

4PI	CSIR Fourth Paradigm Institute, Bengaluru
AMPRI	Advanced Materials and Processes Research Institute, Bhopal
ARCI/IARCPMNM	International Advanced Research Centre for Powder Metallurgy and New Materials, Hyderabad
ARI	Agharkar Research Institute, Pune
ARIES/ARIOS	Aryabhata Research Institute of Observational Sciences, Nainital
BI	Bose Institute, Kolkata
BSIP	Birbal Sahni Institute of Palaeobotany, Lucknow
CA	Close Access
CBRI	Central Building Research Institute, Roorkee
CCMB	Centre for Cellular Molecular Biology, Hyderabad
CDFD	Centre for DNA Fingerprinting and Diagnostics, Hyderabad
CDRI	Central Drug Research Institute, Lucknow
CECRI	Central Electrochemical Research Institute, Karaikudi
CEERI	Central Electronics Engineering Research Institute, Pilani
CeNS/CNSMS	Centre for Nano and Soft Matter Sciences, Bengaluru
CFTRI	Central Food Technological Research Institute, Mysore
CGCRI	Central Glass Ceramic Research Institute, Kolkata
CIAB	Centre of Innovative and Applied Bioprocessing (formerly Bio-Processing Unit), Mohali
CIMAP	Central Institute of Medicinal Aromatic Plants, Lucknow
CIMFR	Central Institute of Mining and Fuel Research, Dhanbad
CLRI	Central Leather Research Institute, Chennai
CMC	CSIR Madras Complex, Chennai
CMERI	Central Mechanical Engineering Research Institute, Durgapur
CPT	Citations/Publications/Time
CRRI	Central Road Research Institute, New Delhi
CSIO	Central Scientific Instruments Organisation, Chandigarh
CSIR	Council of Scientific and Industrial Research
CSMCRI	Central Salt Marine Chemicals Research Institute, Bhavnagar
DBT	Department of Biotechnology
DOI	Digital Object Identifier
DST	Department of Science and Technology

ESS	Electronic Submission System
GoI	Government of India
GS	Google Scholar
HRDC UNIT	Human Resource Development Centre, Ghaziabad
IACS	Indian Association for the Cultivation of Science, Kolkata
IASST	Institute for Advanced Studies in Science Technology, Guwahati
IBSD	Institute of Bio resources and Sustainable development, Imphal
IF	Impact Factor
IGIB	Institute of Genomics and Integrative Biology, Delhi
IHBT	Institute of Himalayan Bioresource Technology, Palampur
IIA	Indian Institute of Astrophysics, Bengaluru
IICB	Indian Institute of Chemical Biology, Kolkata
IICT	Indian Institute of Chemical Technology, Hyderabad
IIG	Indian Institute of Geomagnetism, Mumbai
IIIM	Indian Institute of Integrative Medicine, Jammu
IIP	Indian Institute of Petroleum, Dehradun
IITR	Indian Institute of Toxicology Research, Lucknow
ILS	Institute of Life Sciences, Bhubneshwar
IMMT	Institute of Minerals and Materials Technology, Bhubaneswar
IMT/IMTech	Institute of Microbial Technology, Chandigarh
INST	Institute of Nano Science and Technology, Mohali
InSTEM/ISCSRM	Institute for stem cell science and regenerative medicine, Bangalore/ Institute for Stem Cell Biology and Regenerative Medicine
ISI	Institute for Scientific Information
JCR	Journal Citation Report
JNCASR	Jawaharlal Nehru Centre for Advanced Scientific Research, Bengaluru
Jr.	Journal
NA	Not Available
NABI	National Agri-Food Biotechnology Institution, Mohali
NAIB	National Institute of Animal Biotechnology, Hyderabad
NAL	National Aerospace Laboratories, Bengaluru
NBRC	National Brain Research Centre, Gurgaon
NBRI	National Botanical Research Institute, Lucknow
NCCS	National Centre for Cell Science, Pune
NCL	National Chemical Laboratory, Pune
NEERI	National Environmental Engineering Research Institute, Nagpur
NEIST	North - East Institute of Science and Technology, Jorhat
NGRI	National Geophysical Research Institute, Hyderabad

NIBG	National Institute of Biomedical Genomics, Kalyani, West Bengal
NIF	National Innovation Foundation
NII	National Institute of Immunology, New Delhi
NIIST	National Institute For Interdisciplinary Science and Technology, Thiruvananthapuram
NIO	National Institute of Oceanography, Goa
NIPGR	National Institute of Plant Genome Research, New Delhi
NISCAIR	National Institute of Science Communication and Information Resource
NISCAIR	National Institute of Science Communication And Information Resources, New Delhi
NISTADS	National Institute of Science, Technology And Development Studies, New Delhi
NML	National Metallurgical Laboratory, Jamshedpur
No.	Number
NPL	National Physical Laboratory, New Delhi
NSTMIS	National Science and Technology Management Information System
OA	Open Access
OSDD UNIT	Open Source Drug Discovery, New Delhi
RCB	Regional Centre for Biotechnology, Faridabad
RGCB	Rajiv Gandhi Centre for Biotechnology Institution, Thiruvananthapuram
RRI	Raman Research Institute, Bengaluru
SCI	Science Citation Index
SCTIMST	Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram
SERC	Structural Engineering Research Centre, Chennai
SNBNCBS	S.N. Bose National Centre for Basic Sciences, Kolkata
STEM	Science Technology Engineering & Medicine
THSTI	Translational Health Science and Technology Institute, Faridabad
TIFAC	Technology Information, Forecasting and Assessment Council, New Delhi
TKDL UNIT	Traditional Knowledge Digital Library, New Delhi
TRISUTRA UNIT	Translational Research and Innovative Science Through Ayurveda, New Delhi
URDIP UNIT	Unit for Research and Development of Information Products, Pune
VP	Vigyan Prasar, New Delhi
WIHG	Wadia Institute of Himalayan Geology, Dehradun
WoS	Web of Science

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Executive Summary

According to the All India Survey of Higher Education, AISHE 2019-20, the total female enrolment in higher education, including diploma, graduate, post-graduate and Ph.D. were 18.9 million. Female constitute 49% of the total enrolment (p. ii). In contrast, as per Research and Development Statistics, 2019-20, DST, GoI, as on 1 April 2018, of the total 3,41,818 S&T personnel employed directly in R&D or creating new knowledge, 16.6% or 56747 women are directly engaged in R&D activities. Of these, almost 44705 female personnel were employed in Industrial Sector R&D establishment in the country and 54.5% (24,368) of them were employed in Industrial Sector R&D work.

The Ministry of Science and Technology, the Government of India was established in 1971 with a motto to formulate science policy and to promote science and technological activities in India. The ministry currently has three major departments including the Council of Scientific and Industrial Research (CSIR), the Department of Biotechnology (DBT) and the Department of Science and Technology (DST).

In the Union Budget of 2019, the Government of India announced a provision for increasing the funds allocated for scientific research. With government support, the R&D sector is expected to exhibit robust growth. As in 2020, the Global Innovative index (GII) ranked India in the 48th position and with such government support, it is expected that India will likely rank 25th within the next 10 years. To reach the goal, the government of India during the last few years has introduced various policies and started various women scientist schemes/programmes. How such policies are translating into research productivity is important to analyse. We have, therefore, primarily taken up the research productivity issue focusing on the women scientists working in various research organizations of the Ministry and to assess the pattern of contribution in terms of quantity, authorship, collaboration, age, position and subjects.

To accomplish the work, we first identified the working women from the official website of the concerned laboratories of the Ministry and further excavated the publications from the Web of Science and Scopus database. The overall observation of our study is explained in various chapters.

- During our investigation, we observed a considerable number of women have contributed significantly to the enrichment and enhancement of science and technology. In Chapter II, we have enlisted twenty of such women scientists who have a very highly decorated research career in terms of publication, patents, or have received the most recognised and prestigious national as well as international awards or may have served at the highest position of their organisations.
- While searching publications in international databases like Web of Science, we observed various anomalies in search results. We have taken up a study, in Chapter III, by using almost 50 sample author names from various regions, to track how far such results are complete, in what ways anomalies exist and in what way searching leads to best results. We found search results differ considerably for 'Author Search' and 'Basic Search'. For some names 'author search' displayed

exhaustive results while in a few cases 'basic search' displayed more comprehensive results. Furthermore, while searching the name through the 'author search' it was seen that authors have been indexed more than one time, despite both the author belong to the same name and organization. In several cases where the date of publication was before 2009, the author's first name is indexed in initial and as a result publication by other similar initial named authors appeared. Based on our experience we, therefore, recommend that for getting the best results one should first identify at least a few titles written by that author and place any latest publication detail in the 'basic search' tab. In the results of the 'basic search' every author's names are available in hyperlinked. By clicking the hyperlink of the desired author name, the exhaustive publications of that author in his/her lifetime are possible to track. However, the greatest challenge by this method is to identify any correct publication by an author as in several cases it was observed that the official website of the authors does not contain any publication profile. Therefore it is highly recommended that organizations must prepare a dynamic website of their organizations and insist authors update publications regularly.

- In Chapter IV we analyzed the publication details of women presently working in various research organizations under the Ministry of Science & Technology, GoI. Women who did not hold any scientific post throughout the entire observation period (i.e. 2018 to 2019) in these organizations were not included in our dataset, eliminating all those who had superannuated before 2018 but we included those who retired during 2019.
- As of December 2019, 618 women scientists are working in a permanent position (junior scientists and upward) under 44 organizations of CSIR followed by 178 scientists in 19 organizations of DST and 106 scientists in 15 organizations of DBT, excluding Ph.D. scholars, ad-hoc scientists, guest faculty-cum-scientists, project scientists. The Male-Female ratio of these organizations is 81:19 in CSIR, 76:24 in DST, and 71:29 in DBT.
- CSIR has a large number of women scientists per organization (14 women scientists/organization) as compared to DST (9 women scientist/organization) & DBT (7 women scientist/organization). However, the percentage of women scientists as compared to the male scientists is higher in the organizations of DBT (29%) followed by DST (24%).
- As far as publications of these women scientists are concerned, we found 21203 publications in the WoS database and 23012 publications in the Scopus database by all 902 women scientists up to December 2019. Interestingly it was observed in some cases that the searched records against an individual scientist's name in WoS is higher than Scopus, in spite Scopus database have larger coverage. We, therefore, considered only the unique and highest publications of a scientist from both the two databases, a total of 22617 publications are considered for final analysis that appeared as Articles, Conference Proceedings, Books, and Chapters in Books.
- It was seen on average DST women authors produced more articles per scientist (34 articles) than DBT (24 articles) and CSIR authors (23 articles).

- The publications under fractional authorship as compared to the average article per scientist indicate that DST authors collaborate with a fewer number of authors than women authors of CSIR and DBT collaborate most.
- While looking at publications patterns through the normalized count, it is seen that at least 15% of women authors of DST have quite a good publication record.
- However, the *h-index* of CSIR authors is highest (152) followed by DST (127) and DBT (113), even though the percentage of authors without any publication is highest in CSIR (11%) followed by DST (7%) and DBT (5%). A major portion of authors of all these three organizations having publications between 20 and 49 of their credit, which is quite promising.
- It was seen that articles written by DBT authors received more citations per article (31 citations) than DST authors (20 citations) or CSIR authors (19 citations). As a result of which fractional citation and normalized citation value are a little higher for DBT authors than CSIR or DST authors. While maximum articles of CSIR and DST scientists have IF between 1 and 2.999, maximum articles of DBT authors have IF 3 to 4.999.
- In terms of 'Patents,' we observed female inventor has increased from 4% in 2005 to 17% in 2020 in CSIR, but the increase is quite slow for DST (3% in 2005 to 8% in 2020) and DBT (8% in 2005 to 12% in 2020). On the other hand, the per-scientist award was higher among scientists of DBT (0.55 awards) than DST (0.37 awards) and CSIR (0.24 awards) There are six scientists of DBT who are the recipient of the prestigious National Bio-Science Award, two received NASI-Reliance Award, and three scientists bagged Infosys award in Life Sciences for their seminal contribution to biological sciences. One scientist from CSIR is the recipient of Shanti Swarup Bhatnagar in biology and five scientists are the recipient of the National Geoscience Award of the Government of India.
- The pattern of publication with terms of their highest degree of qualification shows that a larger portion of women scientists of DBT has Post-doctoral degree (59%), a larger portion of CSIR scientists have a doctoral degree (57%) and an almost equal portion of women scientists of DST has a post-doctoral degree (43%) and doctoral degree (46%). Overall, scientists with a doctorate (Ph.D.) or post-doctoral fellows publish more (almost 90%) with marginal variations, but scientists having post-doctoral degrees produced more per-scientist-publication, 44 for DST, 28 for CSIR, and 25 for DBT.
- While correlating publications with the tenure of service the trend is quite similar for women scientists of CSIR and DST but differs for DBT. The maximum percentage (26%) of CSIR scientists belongs to those who have served 10 to 15 years of service, but the maximum percentage of publications (28%) came from the scientists who have served more than 20 years of service. Similarly, in DST maximum (32%) of scientists belong to 10 years of service tenure, whereas, maximum publications (32%) came from the scientists who have served more than 20 years of service. However, in DBT scientists who are comparatively young and served a maximum of 10 years of service contribute more significantly than others.
- While considering publication pattern with (A) service age as well as (B) physical age and percentage of share to the total publications, it was seen that women scientists of CSIR contributed the

maximum percentage of their publications during the first 6 to 10 years of joining but women scientists of DBT and DST contributed most of their publications during the first 5 years of their joining. It was also observed that at the age between 30 and 40, the scientists of all three organizations contributed the highest percentage of publications. To confirm whether publication rate increases or declines with time, it was observed that there are almost 20% scientists of CSIR & DST and 33% scientists of DBT whose publication rate does not decline on attaining age 50 years or more. They have contributed almost 18-19 publications each year.

- In terms of collaboration, it was observed that the pattern of collaboration has changed over time. The figure clearly shows that women authors of CSIR and DST collaborate with authors of small groups and this trend remains the same in the last five decades. In CSIR & DST, the average number of co-authors per article was almost 2 authors in 1972/1975 which reached 5.55 authors and 8.5 authors in 2019 respectively. However, the size of collaboration of women scientists of DBT is increasing, it was almost 3 in 1988 but reached 25 authors-group in 2019. On average maximum number of articles (above 75%) in both the three organizations have appeared under the authors-group consisting of 3 to 9 authors. In DBT almost 15% of publications, however, appeared with mega-group having more than 9 authors per article.
- Our analysis reveals that a larger number (almost 98%) of articles were collaborative, however, their position in multi-authored articles is mostly as a member of the team than that of a leader. The percentage of the last authorship is a little higher, with roughly 27% for CSIR and DBT and 29% for DST. Somewhat lower than this figure is the percentage of women under the first authorship where roughly 20% for CSIR and DST, even lower, only 14% for DBT.
- Women collaborate more with authors of various other similar research industries, a maximum of 62%, but collaborate quite less, a maximum of 4%, with authors of the same organization. Authors of DBT tend to collaborate more (34%) with global authors than DST (29%) or CSIR (16%) and they (DBT women authors) have also collaborated more with authors from academia. The collaboration pattern of CSIR and DST scientists are mostly intra-institutional or with 'academic-industry and their collaboration with the peers of their organizations are negligible.
- In terms of the pattern of collaboration as measured through VOSviewer and Pajek it was observed there are many numbers of different authors clusters exists among scientists and each cluster is loosely connected as they have less relatedness in publications. The highest closeness & betweenness value was observed for Gagandeep Kang, (Former THIRST scientist, DBT).
- The subject analysis of research papers shows that maximum contribution by CSIR science was made in the field of Chemical Sciences (2201 publications) followed by Materials Science (1639 publications). While women scientists of DBT contributed more in Biochemistry & Molecular Biology, Bio-physics, Cell Biology (680 publications) followed by Medical & Health Sciences (537 publications). The DST scientists contributed more to Astronomy, Astrophysics, Space Science (778 publications), followed by Medical & Health Sciences (695 publications). Apoptosis; oxidative stress; cytotoxicity; reactive oxygen species; genetic diversity is the most frequently occurred research terms in the publications and the highest CPT (Citation/Publication/Time) value was

observed in the research which deals "Development, optimization and biological evaluation of hybrid nanoparticles based on **chitosan** and their applications in various medical aspects". Concepts like "**Cytotoxicity** of various foreign elements in human cells" and "Cause and effect of **reactive oxygen species** damaging the DNA, RNA, and proteins in cells" are also gathered attention among women scientists.

Policy Implications

During our investigation we observed the 'People/Staff' pages that includes information on individual scientists in the websites of the organizations are quite unstructured and maintained improperly. In most cases, this page does not bear the basic information of its scientific staff such as Name, Designation, DOB, DOJ, etc and latest curriculum-vitae of the scientist. Organizations must develop a dynamic website and encourage scientists to maintain their page in a structured manner as well as update the information frequently. In case a scientists leave the organization or promoted to higher post, the same must be reflected in the website. In this regard, the websites of NIO, may be considered as reference.

According to the World gender gap report (2020), India is one among two countries having a distinctively small gender gap in STEM higher education. However, in the same report, it is revealed that India is among four-country of the world where the women labour force is only 22%. This trend is almost same for women working in R&D laboratories of the Ministry of Science and Technology, GoI. Therefore, it is essential that government should emphasize more on policies that are necessary for attracting young women minds towards choosing career in R&D sectors for the overall improvement of science system in India.

While searching women names in International databases, we observed incomplete coverage of publications of a scientist. This is more because of use of variant form of scientist's forename or different way of rendering the scientist's forename and surname. Despite of the efforts like ResearcherID, Scopus ID etc. such anomalies are widely existed. Therefore, laboratories must work with their authors to identify all publications against an individual and linked with the correct unique identification number like ResearcherID or Scopus ID.

The study shows that, in all the three organisations the appointment policy for junior positions such as Scientist B and C were quite nominal and promotion policy for senior positions such Scientist E and F were non-uniform. To encourage the participation of women scientists towards qualitative research, organisations should implement standard appointment policy whereby giving preference to applicants with higher degree, the appointment/promotional policy may be reformed by adding supplementary support for women in the form of flexible publication and research tenure to ensure that women (and men) who interrupt their career during their child bearing years will not jeopardize their future career. Training, access to funds may be given more flexible for women.

The analysis of productivity difference between women scientists of various Scientific R&D laboratories shows no significant difference across laboratories. Therefore, a uniform policy may be helpful for the overall improvement of women's participation in science. However it is observed that organizations having more women scientists having more h-index, scientists having higher qualifications like post-doctoral fellow or Ph,D, have more publications, women scientists collaborate more with international authors and having publication in high impacted journals received more citations, laboratories with more technology oriented specialization having more patents. Studies shows that organizational factors, particularly scientist's reward systems, and compensation, influence the productivity of technology transfer activities of a scientist and thus motivate the scientists to disclose their inventions. Therefore, a national policy is needed to recruit more qualified women in R&D sectors because researchers who are active in their younger years gain more scientific capital, thereby accessing more resources, which in turn, help them stay productive. Furthermore, a study by the National Centre for Women in Information Technology of the United States found that a research team with a great diversity of humans with all sexes tended to cite more than a single-sex applicant. This suggest that collaboration in the development of patents are more useful and in the Indian context, it will also help women scientists to get more citation to their articles and patents.

Our results shows that 'the young female researchers are more productive than the older' and most of the publications came between age 31 and 40 and then decrease slowly with the increase of age. However, active scientists sustain their productivity at a high level throughout their careers. At a time when the government is re-evaluating the policy of retirement age, the fact that older scientists still play an effective role in the productivity of scientific literature cannot be neglected. Moreover, if the turning point at the age 31 to 40 are relatively stable in a truly longitudinal sense or similar cohort in other subjects and gender, then providing better funding opportunities to younger scientists would give them more lead time to strong productivity before settling into a plateau.

Interest among Indian in the fields like chemistry is well established in the Global Scientific Research of WoS. Women prefer more in the subject like biology is also well established. The results of the present study indicates that women are also working with so many other emerging fields of science and are contributing successfully in the Hot Topics as identified by Essential Science Indicator. This suggests that intellectual preference might not be influenced by gender. The growing attention of fields like nano-science, space science, environmental science, drug discovery by women is a positive sign of the Indian science system. According to the World gender gap report (2020), India demonstrates larger shares of women across the most segmented professions Engineering and Cloud Computing. The lowest participation of women in mathematical sciences may be an indication that females may have a lack of early exposure to mathematics. Should it not be essential to design a national policy keeping these all in mind so that science must be explore unilaterally?

Chapter – I: Women and Indian Science

1.1 Indian Scientific Background

No nation can call itself civilized and progressive if it does not honour its women. In the oldest ancient Indian tradition, to be more specific in the oldest scriptures - *Vedas* and *Upanishads*, women were accorded high respect in the Society and had complete access to education to attain high intellectual and spiritual achievements. It belongs to the glorified past. However, during the medieval period or early modern period, the status of Indian women deteriorated. In the initial decades just after independence, the position of women did not change much, however, in the 1970s and 1980s, women made remarkable progress as they had more access to positions of power and authority. The progress considerably slowed again in the 1990s and the later period. Women's presence in most of the fields including sciences has significantly shrunk. Swami Vivekananda once in an interview in 1893 declared that "country and that nation which do not respect women have never become great, nor ever will be in future." Our former president Pranab Mukherjee on Women's Day, 2015 stated "The best thermometer to the progress of a nation is its treatment of its women. All nations have attained greatness by paying proper respect to women".

According to the All India Survey of Higher Education, AISHE 2018-19, India had 993 Universities, 39931 Colleges, and 10725 Stand Alone Institutions during the survey period. The total enrolment in higher education, including diploma, graduate, post-graduate, and Ph.D. were estimated to be 37.4 million, out of which 19.2 million were male and 18.2 million were female. So the overall, female enrolment in higher education was almost 48.6%. However, of the total enrolment (male and female), most of the students, i.e. 79.8% enrolled at the graduate-level programme and only 20% were enrolled for post-graduate and Ph.D. programme. At the graduate level, the highest number (39.7%) of students were enrolled in Arts/ Humanities/Social Sciences courses followed by Science (16.5%), Commerce (14.1%), and Engineering and Technology (13.5%). Interestingly, in Bachelor of Science (B.Sc.) 46.80 lakh students were enrolled in total, out of which almost 52% were female and 48% were male. On the other hand, Bachelor of Technology (B. Tech.) of the total 21.25 lakh enrolled students, 72% were male and only 28% percentage were female and in Bachelor of Engineering (B.E.), of the total 16.45 lakh enrolment, majority, i.e. 71% students were from male category and only 19% were female category. At the Post Graduate level, although, the enrolment has grown almost 4.94% during the last five years, maximum students are enrolled in the Social Sciences stream followed by Management. In Master of Science (M.Sc.), like Bachelor of Science, of the total 6.79 lakh enrolment, majority, i.e. 62.72% were female and 37.28% were male. So it is clear that enrolment of female students in Science remained higher than male in graduate and post-graduate level. The percentage of students who opted for a Ph.D. after completing their PG programme were 23% in Engineering and Technology, 19.4% in Science and 15.5% in Medical Science. Although at the Ph.D. level, students' enrolment has increased from 117301 in 2014-15 to 169170 in 2018-19, it is needless to mention that this number accounted for less than 0.5% of the total enrolment. In 2018, in Ph.D., 40,813 students were awarded of which 23,765 were males and 17,048 were females. Among these female awardees, 8999 were from science, engineering, and technology, agriculture, and medical science disciplines and the remaining were from other disciplines.

1.2 Scientific Organization is India

India is a fast developing country and the same is reflected in the case of its scientific research and development wing. According to the "List of Indian Institutes with Research areas" prepared by DST (dst.gov.in) for their Research Training Fellowship for Developing Countries Scientists (RTF-DCS) programme, currently, there are 216 research institutes actively contributing to the development of science in India. All these 216 institutes have been categorically grouped on subjects including 66 research institutes in Agricultural Sciences, 60 in Biological and Medical Sciences, 23 in Engineering Sciences, 16 in Physical Sciences and Mathematics, 16 in Earth Sciences, 09 in Chemical Sciences, 09 in Materials, Minerals, and Metallurgy, and 17 in Multi-disciplinary and Other Areas. Apart from that, several other research institutes have not been included in the sourced list. These institutes are functioning under the corresponding ministry of the government. One such ministry is the Ministry of Science & Technology.

The Ministry of Science and Technology, the Government of India was established in 1971 with a motto to formulate science policy and to promote science and technological activities in India. The ministry currently has three major departments including the Council of Scientific and Industrial Research (CSIR), the Department of Biotechnology (DBT) and the Department of Science and Technology (DST).

In the Union Budget of 2019, the Government of India announced a provision for increasing the funds allocated for scientific research. With government support, the R&D sector is expected to exhibit robust growth. As in 2020, the Global Innovative index (GII) ranked India in the 48th position and with such government support, it is expected that India will likely rank 25th within the next 10 years.

1.3 Who are Scientists?

By Scientists, OECD 'refers to persons who, working in those capacities, use or create scientific knowledge and engineering and technological principles, i.e. persons with scientific or technological training who are engaged in professional work on science and technology (S&T) activities, high-level administrators and personnel who direct the execution of S&T activities' (OECD & Eurostat, 1995, p. 69). On the other hand, 'Researchers are professionals engaged in the conception or creation of new knowledge. They conduct research and improve or develop concepts, theories, models, techniques instrumentation, software or operational methods' (OECD, 2015a, p. 162).

To define scientific population, Xi (1989) applied three criteria: (1) contribution to scientific knowledge (contribution-based definition); (2) scientific education (supply-based definition); (3) scientific occupation (demand-based definition). As per the recommendations of the Sarkar Committee, CSIR in 1973 defined scientific posts as those where the incumbents are expected to contribute by doing research and/or development of new methods or knowledge and/or new techniques. Although the primary mission of a scientist is to create and disseminate knowledge, as their second mission, they are expected to interact with the surrounding society and develop a mechanism for its betterment. Quantity and quality publications, citations, etc. have been and are still considered the main mission of the scientific community, after the 1990s, however, under the third mission, the scientists are expected to participate in patenting activities along with other two missions (Göktepe-Hulten & Mahagaonkar, 2010). In the light of these, we have considered 'scientists' as those who meet the first criterion as mentioned by Xi and as per the recommendation of the Sarkar Committee of CSIR.

1.4 Indian Women and Science

While nationwide figures of women in higher education have grown steadily in the last decade, women are still the minority in the scientific discipline. As per Research and Development Statistics, 2019-20, DST, GoI, as on 1 April 2018, of the total 3,41,818 S&T personnel employed directly in R&D or creating new knowledge, 16.6% or 56747 women are directly engaged in R&D activities. This figure 13.9% up to July 2015 based on full-time equivalents (FTE) of the total persons that are employed in R&D (UNESCO Institute for Statistics, June 2019, UIS Fact Sheet No. 55 | June 2019. http://uis.unesco.org). A similar study also reveals that the women manpower engaged in R&D sectors of Indian science and technology is only 15% (Garg & Kumar, 2014). The number of women scientists who have received the various prestigious science awards in India ranges from zero to 25, representing almost 7%, taken collectively, of the total awards (Chaudhary & Dhanda, 2019). According to Global Gender Gap Index, 2020, India's rank is 112th of the total 153 countries. It was 108th in 2018. As per this report (Global Gender Gap Index: 0.668, STEMS attainment % of female: 26.93), it would take nearly a hundred years to close the gender gap in various fields in India compared to the time it would take time in other countries'. The NITI Aayog report reveals that the presence of women staff was 20.0% among scientific and administrative staff (including IITs, NIT's ISRO, and DRDO), only 13.9% of women work as a researcher in India.

Although the figures are self-explanatory, it does not mean that there aren't successful and renowned women in the field of science. Janaki Ammal specialized in cytogenetics and phytogeography, conducting chromosome studies on a wide range of garden plants, awarded the Padma Shri in 1957. Anandibai Joshi first Indian woman to have obtained a degree in western medicine. Asima Chatterjee is well known for her development of cancer medicine, anti-epileptic and anti-malarial drugs. She was the first woman to be named a Doctor of Science by an Indian university. Sunetra Gupta studies infectious diseases, like the flu and malaria, using mathematical models. She has been awarded the scientific medal by the zoological society of London and the Royal Society Rosalind Franklin Award for her scientific research. Dr. Indira Hinduja, a gynecologist, pioneered the gamete intra-fallopian transfer leading to the birth of India's first GIFT baby. Dr. Aditi Pant, an oceanographer was the first Indian woman to have visited the icy terrain of Antarctica in 1983. She worked in the National Institute of Oceanography and the National Chemical Laboratory. Dr. Suman Sahai, a recipient of the Padma Shri, studied the effects of genetically modified crops and address the problems faced by the farmers of India. Godbole and Ramaswamy (2015) in *'Lilavati's Daughters: The Women Scientists of India'* wrote brief biographical and autobiographical sketches of about one hundred women scientists from India, however, we believe a larger segment of Indian women scientists has remained underrepresented. Some eminent scientists of the contemporary decade have been discussed in the next chapter. However, such numbers are quite a few.

1.5 Why Women Scientists

As every nation is moving towards a knowledge society, multi-skilled, highly creative, and innovative inter-disciplinary teams are needed for globally competitive industrial research. While inequalities waste potential, excellence requires diversity. In the coming days, employers will need to become more competitive by investing in and developing staff for research and development, and using them wisely and more effectively. Therefore, irrespective of gender, the best employees are becoming vital for any organization in the context of skill shortage. Very importantly, recent social and economic changes have enhanced women's position in society. Women are increasingly important in determining various policy decisions and heading the organization. As soon as they become more significant in science disciplines, as an individual and as a policy makers there will be a better representation of the Indian science system.

1.6 Global Research Output by Women Scientists

According to UNESCO Institute for Statistics (UIS, June 2019), the average share of female researchers is 29.3% for the world with the highest percentage (i.e. 48.2%) for Central Asia and the least percentage (i.e. 18.5%) for South and West Asia. This data is based on head counts (the total number of persons employed in R&D) or full-time equivalent or total R&D personnel.

Country	Findings	Source
Italy	In technological scientific disciplines of the entire Italian academic system male do demonstrate higher average productivity with respect to the female in terms of Fractional Output, Contribution Intensity, Scientific Strength, Quality Index, etc. However, the gap between sexes seems to be less pronounced in terms of quality index and contribution intensity and the performance gap also seems to reduce with career advancement.	Abramo, G; D'angelo, Ca And Caprasecca, A (2008). Gender differences in research productivity: A bibliometric analysis of the Italian academic system, Scientometrics.
Iran	Women contributed 2275 papers out of 7138 records and have more cooperation in the science and applied science fields than technology-related fields.	Nourmohammadi, H., Hodaei, F. Perspective of Iranian women's scientific production in high priority fields of science and technology. *Scientometrics* **98,** 1455–1471 (2014). https://doi.org/10.1007/s11192-013-1098-1
USA	According to US National Centre for Education Statistics, 2010 women remain underrepresented in science, technology, engineering, mathematics, and computer	U.S. National Center for Education Statistics. (2010). Digest of education statistics, 2010. Retrieved from

	science. However, in biology, women's representation is almost 46% nearly matches with men.	http://nces.ed.gov/programs/digest/d10/tables_3.asp#Ch3aSub4
	Women represent only 29% in the science and engineering occupation. But this figure rose from 15% in 2013. The US technological industries have been progressively employing workforce from foreign countries like India and China to meet their industrial workforce needs.	Varma, Roli. (2018). U.S. Science and Engineering Workforce: Underrepresentation of Women and Minorities. American Behavioral Scientist, 62(5) 692–697.
China	Women's representation is 27% in science and 22% in engineering and a greater portion of women than men are single and have children in science, not engineering. A greater portion of women than men are lecturers but a lower percentage of women is a full professor. Furthermore, overall women published 8 articles and men published 10.7 articles in science, and 8.8 articles and mean published 10.8 articles in engineering.	Tao, Y., Hong, W., & Ma, Y. (2017). Gender Differences in Publication Productivity Among Academic Scientists and Engineers in the U.S. and China: Similarities and Differences. *Minerva*, *55*(4), 459–484. https://doi.org/10.1007/s11024-017-9320-6
Japan	According to the World Economic Forum's Global Gender Gap Report, 2011, in the field of science and technology, the percentage of female scientists in Japan is 13.8%. In another study, it was found that Japanese women account for only 10% of the researchers in Japan, but they account for 60% of Japanese researchers working abroad.	Homma, M. K., Motohashi, R., & Ohtsubo, H. (2013). Maximizing the Potential of Scientists in Japan: Promoting equal participation for women scientists through leadership development. *Genes to Cells*, *18*(7), 529–532. https://doi.org/10.1111/gtc.12065 https://www.sciencemag.org/careers/2014/10/whats-driving-women-scientists-out-japan
Russia	The study observed that Russian scientists have gender ending with 'a' denoting a female. They compared female's contributions during 1985, 1995 and 2005 with a corresponding analysis of major fields and found that women had a higher percentage in biological sciences and a very low percentage in engineering, mathematics, and physics.	Lewison, Grant & Markusova, Valentina (2011). Female researchers in Russia: have they become more visible? Scientometrics, 89:139–152
Poland	The study indicates that how the situation of Polish women in science has changed according to their age and scientific career level. It was observed that more than 50% of students studying in all fields of science, but for maths/physics/engineering their presence is only 10%. Of this total, only 25% pursued a Ph.D. degree in maths/physics/ engineering.	Suchanska, M., & Czerwosz, E. (2013). Women in technical universities in Poland. Paper presented at the AIP Conference Proceedings.

France	The study is aimed to understand the 'class celling effect' which reduce the proportion of women in the higher level of career. It concluded that organization bear an important responsibility to alleviate difficulties of staff in scientific research.	De Cheveigne, S. (2009). The career paths of women (and men) in French research. Social Studies of Science, 39(1), 113–136

1.7 Existing Researches on Contributions of Women Scientists/ Academics of the World & India

Locally and globally, contributions of women scientists have been measured in different dimensions including gender gap in scientific output (eg. Xie & Shauman, 1998; Lewison & Markusova 2011; Kretschmer & Kretschmer 2013; Geraci et al., 2015), the comparative contribution of women of different countries as well as different subject fields (eg. Leta & Lewison 2003; Muñoz-Muñoz 2005; Nourmohammadi & Hodaei 2014). Several studies on gender have shown that women scientists tend to publish fewer articles than their male colleagues of the same age (Zuckerman, 1991), publish papers in less reputed journals (Lerchenmüller et al., 2018), and received fewer citations (King et al., 2016). An explanation of low contribution by women has been pointed out by Ward and Grant (1996), where they mentioned that the women scientists devote more time to teaching and administrative work, while the male scientists focus more on the research and supervision of Ph.D. students. In a study by Husemann et al. (2017), it was observed that the female scientists suffer more, (their publicationism score = 2.577) on "publicationism"- an index of stress arising from the pressure to publish, than their male counterparts (score =2.364) and further found that publicationism decreased with the increase of age (a drop of 0.19 index points).

While overall women participation in higher education has been growing around the world in the past decades, studies have tried to explain the career choices of women in terms of people-related and thing-related by explaining women underrepresentation in mathematically intensive areas (Holman, 2018), and over-representation in life sciences (Su, 2009) but are unable to explain why their attendance is low in the subjects like medicine, surgery, and dentistry (Su, 2015). Subjects like computer sciences, engineering, and physics may have been avoided by women because of male dominance in these subjects, which makes them unattractive for women (Britton, 2017). In the context of women as authors in scientific literature, Bendels (2017) found the proportion of female authorship was 35.3% for *Life sciences*, 30.6 for *Multidisciplinary,* 24.0% for *Earth & Environmental Sciences,* and 23.2% for *Chemistry* out of a total of 293557 articles published in 54 journals indexed in Nature Index.

In the context of choosing a career that leads to jobs, Suter (2006) points out that women prefer a career that does not conflict with family responsibility and does not hinder childrearing such as education, psychology or medicine therefore, women do not consider STEM fields to be family-friendly (Suter, 2006). Ceci and Williams (2007) have noted that women prefer those fields that are more related to people than number. Those female scientists who choose engineering or other branches of science often have at least one member of their families with a profession in engineering or science. Therefore, they point to having a female role model for more female involvement in science. However, the research on biographical articles in scientific literature shows that biographical articles are mostly written about men, only twenty percent of the published articles were written about women (Iefremova et al., 2018).

To show how age and the scientific position are related to research productivity, Over (1988) observes that younger researchers are more productive than older ones. Even, the Dutch social scientists found that young female researchers outperformed young male researchers in terms of the number of publications (van Arensbergen et al., 2012) whereas Kyvik (1990) points out that the researchers with more recognition keep publishing more frequently even after their less-recognized colleagues reach their peak. Barjak (2006) observes that the average production of publications increases with the age and reaches the peak at some point during the career and then declines.

Scientific collaboration has become the rule and no longer an exception (Kartz &Martin, 1997); the predominant factors that encourage authors to collaborate are that works carried out in collaboration have more potential towards getting more visibility and impact (Uzzi &Spiro, 2005). However, the collaboration also has some problem, the position of each author's name needs to be determined. Up to now, there is no established norm available to determine the role of an author in any scientific article by looking at her position in the article. The better-known norms by the International Committee of Medical Journal Editors Group (2007) ask authors to mention the role of the author in the article rather than the order. The order decides by themselves. Nevertheless, the existing literature shows that the principal author appears either in the first or the last place, consequently, these positions are considered to have more value in the list of authors (Riesenberg & Lundberg, 1990). After a slightly deeper analysis, some suggest that the last position is usually occupied by a researcher with a good background or by the director/head of the research group (Tscharntke et al., 2007; Bhandari et al., 2014). However, in some disciplines, the alphabetical order is also an accepted norm.

1.8 Factors influencing the research performance by women

Research activities of any scientists are influenced by the input-output process, where the input consists of human and financial resources which enhance or hindered the research activities, the output is measured by tangible entities like publications, patents, books, etc., and intangible entities like knowledge, skill, competencies, etc. Although both input and output are important for quality research, the most commonly used indicators to measure the quality of researchers in science and technology are their outputs - the results of the research that appears in the forms of an article in high impacted journals. ZAINAB group (1999) identified few determinants of scientific performance mainly in two categories: personal and environmental.

1.8.1 Personal determinants include:

Age: Studies have shown the existence of a peak in productivity in years approaching age 40 and the years soon afterward but constant decline with the advancing age (Fox, 1983).

Marriage: Studies agreed on the positive effect of marriage on the scientific fertility of researchers and some studies show that men received the greater share of benefit due to the presence of a spouse (Prpic, 2002). Fox's (2005) study reveals that married women, and particularly those married for the second and third time, have a higher level of productivity.

Children: The results of the study conducted by Stack, 2004 have shown that women with pre-school children publish less than other women, probably due to the time and energy they devote to child-rearing reduce their research productivity, but men with children prove as more productive.

Levels of Specialization: studies have shown that an increase in specialization seems to have a positive influence on scientist's research productivity, but it is also mentioned that women tend to specialize less than men. Overall, if any study is conducted precisely by the scientific-disciplinary sector, level of specialization is always an important factor

1.8.2 Environmental Factors include:

Rank: Studies illustrate a correlation between higher rank and a scientist's productivity (Kyvik, 1990).

Prestige of Institution the scientist belongs: certain studies, not any clear cause-effect relationship, explains that productivity may be a function of the researcher's institute of affiliation (Fox, 1983).

1.9 Aim

Despite the increase in the proportions of women in science and engineering occupations over the past few years (Gupta & Sharma, 2002), how much research is being generated from the Research & Development (R&D) laboratories of India is yet to unfold. The government of India during the last few years has taken several initiatives to provide strong support to women scientists working in various academic as well as R&D organizations, by introducing various women scientist schemes/programmes[1]. It is important to understand how such policies affect the overall growth in science by the women working in research laboratories. We have, therefore, primarily taken up the research productivity issue focusing on the women scientists working in various research organizations and understanding what way they are performing their research in terms of quantity, authorship, collaboration, age, position, and subjects across different type of laboratories under the Ministry.

A considerable body of scientific studies has investigated the role of gender in the academic workplace, however, no such in-depth study has been conducted outside academia in India. The findings of the present study may use as a tool for evidence-based policy making for setting up, implementing, monitoring, and evaluating women's participation in science. As no indicator of the Indian context still exists, these methodological documents will support to take necessary steps for implementing policies for the overall growth of science. The specific questions that we have attempted to trace and track are:

- What trend can be seen from the pattern of publications in terms of publication, citations, patents, awards, etc. by the women scientists working in research organizations?

[1] (see https://dst.gov.in/scientific-programmes/scientific-engineering-research/ women- scientists-programs or https://indiabioscience.org/media/articles/Spoorthi_Grants_v1.pdf

- In what ways have women contributed more, and to what extent do they collaborate?
- Does publication of working women increase or decrease with the increase of age and position?
- In which subject they do research more and what are the hot topics of research among them?

1.10 Methods

The methodology followed in the present study can be explained in the following steps:

1.10.1 Identification of Research Laboratories – To identify laboratories of the Ministry, the official website (https://most.gov.in/our-departments.html) and identify the functional laboratories/autonomous institutions and sub-units of each department. At present, 39 research laboratories and 6 research units are functioning under CSIR, 19 under DST, and 15 under DBT. The areas of specialization of these organizations range in different branches of S&T. While organizations working under the purview of CSIR mainly specialize in the domains of physical, chemical & engineering sciences including building, road, mining, drug, leather, chemical technology researches, the organization working under DBT are specialized in biological science including cell biology, immunology, biotechnology, regenerative medicine, biomedical genomics, etc. The organizations of DST mainly specialize in earth sciences, astrophysics, geomagnetism, cultivation sciences, nano-sciences, medical sciences, etc. It is important to note that CSIR and DBT have used the term 'Research Laboratory' to designate the organization under their purview, whereas DST has used the term 'Autonomous Research Institution'. In the present study, therefore, the term, 'laboratories' is used when referring to such institutions, organizations, or bodies. Despite 2896 posts lying vacant in 2019[2], presently almost 4310 men & women scientists (Designated as Scientist-B to Scientist-G) are working under various research organizations of the Ministry.

1.10.2 Identification of women scientists- To identify the name of women scientists, the official websites of various research organizations under CSIR, DST and DBT have been visited. Each author's gender was confirmed by inspecting available photographs on the author's institutional website, or an internet search if necessary. In case it was unavailable, the given name of the scientist was considered. In general given name of an Indian woman mostly ends with the letter like 'a' [Amit Vs Amita, Anil Vs Anila], 'ee'[KiranmayVs Kiranmayee] or 'i'[Parmeshwar vs Parmeshwari]. Internet available name-matching software like "Baby name Guesser" (http://www.gpeters.com/name s/baby-names.php) and GenderAPI have also been explored. "Baby name Guesser" gives the likely gender and predicts gender ratio. A ratio of 3.0 or above was chosen as correct[11]. It is important to note that GenderAPI cannot identify gender where the author's first name is unavailable or in initial form. In several instances, we observed the name of authors has been rendered differently. Furthermore, the publication that came before 2009 does not bear the author's forename in full. As the name matching software was not perfectly accurate for our sample, we relied more on the manual identification process. After deciding the gender, necessary information like designation, date of birth, position served over time, patents filled and granted, awards and achievements

[2] https://www.newindianexpress.com/nation/2019/jul/13/2896-scientist-posts-lying-vacant-in-70-institutes-under-ministry-of-science-and-technology-govern-2003071.html

received, etc. have been noted from the official websites. In case the required information was incomplete, various official sources, like Annual Report, Fact-file, etc. as well as social network sites were consulted. By using these means, if the required information remained incomplete, an online questionnaire was sent, followed by personal visits. Finally, we assigned a few scientists as 'Unidentified' whose required information was unavailable despite using all these means. As of March 2020, 618 women scientists are working in a permanent position (junior scientists and upward) under 44 organizations of CSIR followed by 178 scientists in 19 organizations of DST and 106 scientists in 15 organizations of DBT under the Ministry of Science and Technology, the Government of India, excluding Ph.D. scholars, ad-hoc scientists, guest faculty-cum-scientists, project scientists have been considered for the present study. The Male-Female ratio of these organizations is 84:16 in CSIR, 77:23 in DST, and 70:30 in DBT. A sort sketch of few prominent scientists of CSIR, DST & DBT have been mentioned in chapter II and the profile of the publication of individual women scientists is mentioned in Annexure-1.

1.10.3 Data Source–To carry out work, all identified scientists' names along with their organization presently serving now were searched through the 'Author Search' tab in the Web of Science (WoS) and Scopus databases. Complete surname along with full first name was applied. In the case where the full first name was unavailable, the abbreviated first name or few letters of the first name along with wild characters were used. The detailed methodology of searching names and problems associated with searching Indic names have been explained in Chapter III. The searched results have been manually verified to confirm that the result is the correct representation of the population. In case of any doubt about scientists having the same surname with the same abbreviated first name (eg. Khare, P. for Puja Khare and Priyanka Khare) Author-ID of Scopus was used to gain higher precision. The publication data of individual scientists were downloaded from both the two databases, however, the highest publications against a scientist among the two databases were considered for final analysis. It was observed that not in all instances the number of results of WoS for individual author search was less than Scopus. Therefore, to maintain exhaustibility, the highest results against individual authors were considered irrespective of databases. Although publications of a scientist were searched along with the organization she is presently serving, publication belongs to her early career is also considered to know the complete contributions of any scientist. To permit the analysis of scientific production by currently working women, from the initial data set, eliminating all those who were assumed after December 31, 2019, or exited before January 1, 2020. Scientists consistently working in these organizations till December 2019 are considered for final analysis and eliminating those who changed jobs for whatever reason during the study period. Publication data were searched in the last two weeks of June 2020, however, publications up to the end of 2019 were considered for analysis. The coupling of the highest publication of each scientist from these two databases resulted in a unique dataset, containing about 902 women scientists with 24322 publications (full counting) appeared in various scholarly forms. However, in the present study publication appeared in form of 'articles', 'proceeding papers' books or book chapters, which represent almost 94% of the total searched results, are only considered for final analysis, leaving aside other forms like reviews, meetings, notes, erratum, etc.

1.10.4 Analysis of data- Overall, simple descriptive statistics have been used but the individual performance of a scientist was evaluated based on several indicators. The detailed method for each analysis has been mentioned in the corresponding section of Chapter IV, i.e. analysis & interpretation of data.

1.11 Limitations

The present investigation is based on an analysis of the contribution made in scientific journals, proceedings, and books. Other codified forms of output such as reports, reviews, and monographs are not considered. It is well established that, in science communication, journal publications are highly representative of real output from research activity.

Other limitations may be termed as our sample. We have analysed the publication pattern among working women of S&T laboratories of GoI. There are other laboratories, educational set-up exists where considerable women are also actively engaged in research. Due to paucity of time, we left them.

Chapter – II: Highly Decorated Women Scientists in Indian S&T Laboratories

In chapter I, we have mentioned that women's participation in science is increasing. In this chapter, attempts have been made to acknowledge few women scientists who have contributed significantly to the enrichment and enhancement of science and technology. There are a lot of scientists who have performed a great deal of research in their respective fields of study but due to lack of space, we cannot acknowledge them all. Here, we have enlisted a few women scientists who somehow have enriched Indian science, enhanced the prestige of the nation, and have acted as path finders for next-generation scientists. The scientists included in this chapter have a very highly decorated research career in terms of publication and patents or have received the most recognised and prestigious national as well as international awards and honours or may have served at the highest position of their organisations.

Prof Gagandeep Kang:

Gagandeep Kang (born November 3, 1962) is a clinical scientist, Professor in the Department of Gastrointestinal Sciences at the Christian Medical College, Vellore, India and has served as the Executive Director of Translational Health Science and Technology Institute, Faridabad, India. She is a leading researcher with a major research focus on viral infections in children and the testing of rotaviral vaccines. Her comprehensive research on rotavirus has demonstrated the high burden of rotavirus diseases across India, the genetic diversity of viruses, the lower protection from infection and vaccines, and the exploration of several approaches to improve the performance of oral vaccines. Her work has led to her being described as India's "**vaccine godmother**".

She has performed immense research throughout her career which has been presented several research papers, Researchgate has enlisted 707 of them and more than 350 of her articles are indexed in SCOPUS and WOS databases. She is also present in editorial boards of several journals, including PLoS Neglected Tropical Diseases, Current Opinion in Infectious Diseases and Tropical Medicine, and International Health. She chairs the WHO SEAR's Regional Immunisation Technical Advisory Group and has received honorary appointments as an associate faculty member at various foreign institutions. Kang played a significant role in the efforts that culminated in the development of **Rotavac**, a vaccine from Bharat Biotech International that targets **diarrhea**.

She is the first Indian woman scientist to be elected as a ***fellow of the Royal Society*** *in 359 years of history of this prestigious scientific academy. She is also the first Indian woman scientist to be elected as the* ***fellow of the American***

Academy of Microbiology *and the only physician-scientist to receive the* ***Infosys award in Life Sciences*** *till then. She is also a fellow of the Indian Academy of Sciences, National Academy of Sciences, and Indian National Science Academy. She has also won the Woman Bioscientist of the year award 2006 and Ranbaxy Research Award 2013 for medical research.*

Prof R. Sowdhamini:

Ramanathan Sowdhamini (born May 24, 1964) is an Indian computational biologist, bioinformatician, and a professor at the department of biochemistry, biophysics, and bioinformatics of the National Centre for Biological Sciences, a TIFR research facility. She also serves as a collaborator at the Centre for Cardiovascular Biology and Disease of the Institute of Stem Cell Biology and Regenerative Medicine (InStem). Sowdhamini's research focuses on computational studies of Protein Science and genome sequencing and she is reported to have done advanced research in code development for studying protein folding and unfolding. Her team was successful in preparing the draft genome of Ocimum tenuiflorum (Tulsi) for the first time which assisted in identifying the genes responsible for producing Ursolic acid, a Triterpenoid and Eugenol, a phenylpropene, compounds responsible for the medicinal properties of the plant. Her studies have been presented by many articles and Researchgate has listed 498 of them. She also sits on the editorial board of Bioinformation journal.

The DBT of GOI awarded Sowdhamini the ***National Bioscience Award*** *for Career Development for her contributions to Biosciences in 2007. She received the Human Frontier Science Program award in 2010 and was also elected as a fellow by the Indian Academy of Sciences and the Indian National Science Academy in the year 2010 and 2011 respectively. She is also a recipient of the Bharat Jyoti Award of the India International Friendship Society. She is also a J. C. Bose national fellow of DST since 2016.*

Prof Apurva Sarin:

Apurva Sarin (born March 1, 1962) is an Indian Cell Biologist and a professor at the National Centre for Biological Sciences. She also serves as the **Director** of the Institute of Stem Cell Biology and Regenerative Medicine. She is known for her studies on the *mechanism of apoptosis in metazoan cells.* Her studies have been presented by many articles, and the online article repository of the Indian Academy of Sciences has listed 44 of them.

For her contributions to Biosciences, Sarin was awarded the ***National Bioscience Award*** *for Career Development in 2005 from DBT of GOI. She is also an elected fellow of the Indian Academy of Sciences.*

Prof Maneesha S Inamdar:

Maneesha S Inamdar (born Feb 25, 1967) is a developmental biologist with a specialization in stem cell research. She is a professor and chair at Molecular Biology and Genetics Unit of Jawaharlal Nehru Centre for Advanced Scientific Research where she also served as the Dean of fellowships and extension programmes from 2015 to 2019. She has also served as an adjunct professor at the Institute of Stem Cell Biology and Regenerative Medicine.

Inamdar has carried out projects for the DBT, the DST, the CSIR, and several other international agencies. She is a well-known member of several Indian and International scientific societies. She represents India in the International Stem Cell Initiative (ISCI) and the International Stem Cell Banking Initiative (ISCBI). She is also a member of the Global Forum on Bioethics in Research (GFBR) planning committee and the WHO expert advisory committee to examine the ethical, scientific, social, and legal challenges associated with Human Genome editing.

The DBT of GOI awarded her ***National Bioscience Award*** *for Career Development for her contributions to Biosciences in 2011. The same year she was also awarded the National Woman Bioscientist Award. She was elected as the fellow of the Indian Academy of Science and Indian National Science Academy in the years 2017 and 2018 respectively. She was awarded the Dr. Kalpana Chawla Award for 2017 and the Prof. C.N.R. Rao Oration Award and the J C Bose National Fellowship in 2019.*

Prof Joyanti Chutia:

Joyanti Chutia (born August 1, 1948) is an Indian physicist with a research specialization in solid-state physics and plasma physics. In 2005 she became the **Director** of the *Institute of Advanced Study in Science and Technology*, the first major research institute in North-East India, hence enlisting herself among the first women who have headed scientific institutions in India. She was also among the first girls to take mathematics as a main subject in her school.

Chutia's main research focus was on biomedicine, material science, and biotechnology. Her research work has been presented by many articles, and Researchgate has listed 103 of them. Her research work has also led to the development of a highly durable and degradable wound suturing material from Muga Silk.

In 2005, she was elected as a fellow of the National Academy of Sciences, India. She is also an Emeritus Scientist at the DST in the Government of India.

Prof G C Anupama:

G C Anupama is an Indian Astronomer with a major research focus on Supernovae. She also serves as the **Dean** and Senior Professor at the Indian Institute of Astrophysics. Currently, she is also serving as the **President of the Astronomical Society of India**, becoming the first woman to head this prestigious association of professional astronomers in India.

Anupama's research work focuses on the initial physical conditions after a *Supernova*, besides she is also involved in the study of *transients* – objects that brighten up for a brief period before going dark in the space. She has published her works by way of many articles, Researchgate, an online article repository, has listed 268 of them.

Anupama was the project in charge of the design and establishment of the Himalayan Telescope at Hanle near Leh in Ladakh, which is also the world's ninth-highest site for optical, infrared, and gamma-ray telescopes in the world. She is also a prominent member of the Indian core team which is part of the International effort to establish the thirty-meter telescope "TMT" in Hawaii, USA.

Anupama has received the Sir C V Raman Young Scientist Award in the year 2001. She is an elected fellow of the National Academy of Sciences in India and the Indian Academy of Sciences. She has also served as the editor of the Bulletin Astronomical Society of India from 2004 to 2010.

Dr. Mitali Mukerji:

Mitali Mukerji (born November 13, 1967) is a Chief Scientist at CSIR Institute of Genomics and Integrative Biology with a major specialization in the field of human genomics and personalized medicine. Under the mentorship of Prof Samir K Brahmachari, she along with her colleague Dr. Bhavana Prasher initiated the field of *Ayurgenomics* – a blend of the principles of Ayurveda and genomics.

Mukerji took an active role in establishing the Indian Genome Variation Consortium, a comprehensive database that is producing "the first genetic landscape of Indian population". She is also a major contributor in the consortium and has done comprehensive research on hereditary ataxias, dyslexia, hypoxia, and many other projects related to tracking disease origins and mutational histories.

*Over the years, Mukerji has received several prestigious awards including the prestigious **Shanti Swarup Bhatnagar Award** in 2010 for her exceptional contributions in the field of medical sciences. She has also received CSIR Young Scientist Award in 2001 and National Young Woman Bioscientists Award in 2008. She is also an elected fellow of the Indian*

Academy of Sciences. Recently, in 2016, she received the VASVIK award for woman scientists and, in 2017, Pushpalata Ranade National Woman Award.

Dr. Veena K. Parnaik:

Veena Krishnaji Parnaik (born 1953) is an Indian cell biologist and the current chief scientist at CCMB, Hyderabad. She has also served as the **President of the Indian Society for Cell Biology from 2011 to 2013**. Her research is mainly focused on understanding the functional role of the nuclear lamina and the applications of her research may lead to insight into the causes and genetic origins of laminopathies – a group of rare genetic disorders that are caused by defects in nuclear lamina coding genes.

Over the years, Dr. Parnaik has received many prestigious awards including the Shakuntala Devi Amirchand Prize of ICMR in 1992, the Dr. PA Krup Lecture Award of Society of Biological Chemists for India in 1997, and the Prof SP Ray-Chaudhuri Lecture Award of Indian Society of Cell Biology in 2010. She was also an elected fellow of the Indian National Science Academy and the Indian Academy of Sciences. She also received the JC Bose Fellowship in 2011.

Prof Jyotsna Dhawan:

Jyotsna Dhawan is an Indian cell and developmental biologist, Emeritus scientist at CCMB, and visiting professor at InStem. She has also served as the Dean of InStem from 2009 to 2014. Currently, **she is also serving as the President of the Indian Society for Cell Biology (2019-2021) and the Indian Society for Developmental Biologists (2017-2020).**

Dhawan's research has focused on skeletal muscle regeneration and the effect of quiescence or dormancy on adult stem cell function. Her immense research work has garnered her a position on the editorial board of Physiological Genomics, BBRC, and Frontiers in Cell and Developmental Biology. On the back of her contributions to biomedical research, she was elected as a fellow to the Indian National Science Academy in 2019.

Dr. Nimisha Vedanti:

Nimisha Vedanti is an Indian Geophysicist and a Senior Principal Scientist at CSIR-NGRI with research in hydrocarbon exploration and reservoir geophysics that includes sei smic data analysis, reservoir monitoring, and geophysical inversion. Presently she is in charge of the Shallow Seismic Group at NGRI.

Vedanti has performed a great deal of research and her research work has been presented by way of many articles, ResearchGate has listed 78 of them. Two of her papers on 4D seismic were rated as one of the most popular articles in 2009 and 2010. One of her papers on signal processing fetched the 'best technical paper award' at the international convention of the Society of Petroleum Geophysicists in 2004.

Vedanti has received several prestigious awards including the ***National Geoscience Award*** *(2012), the K.R. Gupta Award of the Geological Society of India (2015), and the Krishnan Gold Medal of Indian Geophysical Union in 2017.*

Dr. Atya Kapley:

Atya Kapley is an Indian environmental geneticist who is Senior Principal Scientist and **Head** of the Director's research cell of the CSIR National Environmental Engineering Research Institute. She is also serving as the **Vice President for the Organisation for Women in Science for the Developing World.**

She has a wide range of research work. Her research varied from the study of estrogen receptors to studying the use of microorganisms to reduce the pollution in factory waste. She has also studied how individual genetics can affect response to treatment of Chronic Myeloid Leukemia and how anaerobic digestion of kitchen waste is affected by commonly used spices.

Kapley won the Young Scientist Award from the Association of Microbiologists of India in 2000 and in 2008 she was presented with the Women Scientist Award by the Biotech Research Society of India.

Dr. Vandana Prasad:

Vandana Prasad (born July 21, 1963) is an Indian paleo scientist who joined Birbal Sahani Institute of Paleosciences in 1994 as a Scientist A, and currently, she is serving as the **Director** of the institute. She is also a life member of the Paleobotanical Society of India and Palaeontological Society of India.

She has performed a great deal of research in her career on a wide range of subjects varying from evolutionary biology (history of grasses in particular) to high-resolution biostratigraphy, biotic turnover, paleoenvironment, and palaeoclimatic studies. Her research work has been reflected through a considerable amount of research articles, Researchgate has listed 58 of them. She has also published papers in some of the topmost journals such as Science and Nature Communications.

Dr. Sumana Chakravarty:

Dr. Sumana Chakravarty is an Indian woman scientist who joined the Indian Institute of Chemical Technology as a Ramalingaswami Re-entry Fellow and currently, she is serving as a Principal Scientist in the same institute. She became the first woman to receive the prestigious "Ramalingaswami Re-entry Fellowship" award from DBT in 2009.

She has performed a great deal of research to understand the sexual dimorphisms in cellular and molecular mechanisms behind various mood disorders and neurological disorders affecting the brain and behaviour by using mouse and zebrafish models. Her vast research has been reflected through a considerable number of research papers, Researchgate has enlisted 90 of them.

After working for 10 long years in the USA, first as a post-doctoral fellow in different fields of biology and then as a faculty in the Department of Psychiatry, University of Texas she returned to India and joined the Indian Institute of Chemical Technology, Hyderabad. She has completed successfully many granted projects in the past few years and has been actively involved in various national and international collaborative projects.

Dr. N. Kalaiselvi:

Dr. Nallathamby Kalaiselvi (54 years old) is an Indian Chemical scientist in CSIR CECRI and has been serving as the Director of the institute since February 22, 2019. She became the first female **Director** of the institute in more than 65 years of the institution's existence.

Dr. Kalaiselvi has performed a great deal of research during her research career of more than 25 years. Her research has been primarily focused on developing electrochemical power materials, in particular electrode materials. She has a keen interest in lithium and beyond lithium batteries, supercapacitors, and waste-to-wealth driven electrodes and electrolytes for storing energy and electrocatalytic applications. She has more than 125 research articles and 6 patents to her credit which highlights the immense work she has performed in her career.

For all her significant contributions in the development of Science and Technology, she has been awarded many prestigious awards including the MRSI medal, CSIR Raman Research Fellowship, Brain pool fellowship of Korea, and the Most Inspiring Woman Scientist award.

Dr. Asha Kishore:

Dr. Asha Kishore (born February 9, 1960) is an acclaimed Indian neurologist and movement disorder specialist. Presently she is serving as a senior grade professor at Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum. She also became the first woman **Director** of the institute and served the institute for a term of 5 years from 2015 to 2020. She is also a member of the Neurological Society of India.

Prof Kishore is apt to research the Genetics of Parkinson's Disease and has an interest in the research of neurological diseases such as movement disorders, motor learning, synaptic plasticity, and neurodegenerative diseases. She has an extensive academic and scientific career in which she has published her works in a lot of research papers in peer-reviewed journals. Researchgate database has enlisted 94 of her works.

Dr. Ranjana Aggarwal:

Dr. Ranjana Aggarwal is an accomplished academician and is currently serving as the Director of the National Institute of Science, Technology and Development Studies, New Delhi. She joined the institute as its **Director** in June 2019 and she has been assigned the additional charge of the post of Director, CSIR- National Institute of Science, Communication and Information Resources, New Delhi. Previously, she has served as Professor of Chemistry and Director of Women's Studies Research Centre at Kurukshetra University, Kurukshetra.

Dr. Aggarwal has an impeccable research career, and she has worked with many renowned European Labs such as Cambridge University, UK as a Commonwealth Fellow, Trinity College Dublin, Ireland, and the University of Trieste, Italy. She has an active collaboration network with the scientists of the USA, Spain, and Ireland. Her research is focused on the design and synthesis of azaheterocycles, involving green reagents of therapeutic interest as anticancer, anti-inflammatory, antimicrobial, and photodynamic agents, computational studies, and 2D NMR spectroscopy. Recently she has developed a strong liking towards gender studies. She has 83 articles on her credit all peer-reviewed in national and international journals of high repute.

For her significant contributions to science and technology, she has been awarded Dr. Basudev Banerji Memorial Award (2014) by the Indian Chemical Society and the Prof. S. S. Katiyar award (2015) by the Indian Science Congress. She has also been awarded the Commonwealth fellowship at Cambridge University (2003-04).

Dr. Manjula Reddy:

Dr. Manjula Reddy (born 1965) is an Indian bacterial geneticist and presently serves as the chief scientist at the Centre for Cellular and Molecular Biology, Hyderabad. In 2019, she was awarded the prestigious **Infosys Prize** in Life Sciences for her groundbreaking work on bacterial cell wall structure and synthesis. She is also a fellow of the Indian Academy of Sciences.

Dr. Reddy and her research group at CCMB have been actively researching cytokinesis and its regulation using a gram-negative model bacterium, Escherichia coli K12, and Mycobacterium smegmatis, a surrogate model organism that is used to understand the biology of Mycobacterium tuberculosis. She has done a lot of research and her findings have been published in some of the finest journals including Nature Communications, Molecular Microbiology, etc. She has 2 patents and 29 publications on her credit. She is also an editorial board member of the Journal of Bacteriology.

Dr. Suman Lata Jain:

Dr. Suman Lata Jain (born Oct 26, 1975) is serving as senior principal scientist and area head of Synthetic Chemistry and Petrochemicals Department of Indian Institute of Petroleum, Dehradun.

Dr. Jain has a wide area of research interest in chemical and material sciences. Her research interest includes CO2 utilization, waste utilization to produce chemicals and materials, fuel and lubricant multifunctional additives, photocatalysis and green chemistry, etc. The findings of her research have been published in the form of articles in various SCI-International Journals. Over 200 of her articles have been indexed in WOS and SCOPUS databases. She also has developed several technologies and processes and has 21 patents (including 5 foreign patents) to her credit.

She has a highly decorated academic as well as scientific career in which she has received several medals, awards, and honours. She was a University topper and gold medallist in M.Sc. *She has also received the CRSI Bronze medal (2017) and MRSI medal (2020). She was awarded the NASI-Young Scientist award (2007) and SERB Women Excellence Award by DST in 2013.*

Dr. Tanusri Saha Dasgupta:

Dr. Tanusri Saha Dasgupta (born 1966) is an Indian Physicist, a Senior Professor, and S. N. Bose Chair at the Indian Association for the Cultivation of Sciences. She is also serving as the **Dean** as well as Senior Professor at S. N. Bose National Centre for Basic Sciences.

She has extensive research experience in Condensed Matter Physics, Computational Materials Science, and Electronic Structure Calculations. Her research work has been presented through a lot of research papers in several renowned journals, Researchgate has indexed 297 of them and about 180 of her articles are indexed in WOS and SCOPUS databases.

She has received several awards and honours during her career. She was a University topper in M.Sc. She is a recipient of the Swarnajayanti Fellowship in 2006. She is a fellow of the Indian Academy of Sciences and National Academy of Sciences (2010), American Physical Society (2015), and The World Academy of Science (2019). She has also received Dr. P. Sheel Memorial Lecture Award in 2012, MRSI-ICSC Superconductivity & Materials Science Annual Prize for the year 2016, and APJ Kalam HPC Award in 2018.

Dr. Chitra Mandal:

Dr. Chitra Mandal (born 1951) is a chemical biologist, currently serving as SERB Distinguished Fellow at Cancer Biology & Inflammatory Disorder department of Indian Institute of Chemical Biology, Kolkata. She Joined the institute as Scientist B in 1981 and went on to become Scientist-H, the highest position of the institute in 2015. She also went on to head CSIR-Innovation Complex at Kolkata and also served as the **Director** of IICB during 2014-15. She was also the project director at NIPER, Kolkata.

Dr. Mandal has extensive research experience particularly in the field of glycosylation of biomolecules and its potential application in disease management, cancer, and tumor immunology. She along with her research group is currently aiming to deliver low-cost affordable healthcare to all using medicinal plants and has already identified a non-toxic herbal drug showing great potential in the advancement of cancer treatment. Her contributions to science and technology come in the form of research papers, reviews, book chapters, technology transfers, and patents. She has more than 150 research papers on her credit (almost 90% of them published in international journals). She also had 3 technology transfers and 15 patents on her credit till Oct 2015.

Dr. Mandal has been awarded several awards and honours for her outstanding contributions in the field of biological and medical sciences. For her extraordinary scientific career, she has garnered a place for her autobiography in the book "Leelavati's Daughters: The Women Scientists of India" by the Indian Academy of Sciences. *Some of her many honours are Smt Chandaben Mohanbhai Patel Industrial Research award (2000), Kanishka Oration award (2002), BioTech Product and Process Development and Commercialization award (2005), Sir J C Bose Fellowship award (2010), and National Woman Bioscientist Award (2013). She is also elected fellow of The World Academy of Sciences, Indian National Science Academy, Indian Academy of Sciences, National Academy of Sciences, National Academy of Medical Sciences, and many more.*

Dr. Annapurni Subramaniam:

Dr. Annapurni Subramaniam (born 1968) is an Indian Astronomer with a major focus on research areas like star clusters, stellar evolution, and population in galaxies. Currently, she also serves as the **Director** of the Indian Institute of Astrophysics, Bangalore. She is also an active member of the International Astronomical Union.

Dr. Subramaniam has specialization in a wide area of research including Star Clusters, Stellar Population, Stellar Evolution, Galactic Dynamics, Astrosat Mission & UV Studies. She has also worked on the developmental activities of the Thirty

Meter Telescope. Her research work is presented with many research papers, 178 of them being listed on ResearchGate.

Dr. Nahid Ali:

Dr. Nahid Ali (born 1956) is a chemical biologist currently serving as a Raja Ramanna Fellow at the Infectious Diseases and Immunology Division of CSIR- Institute of Chemical Biology. After completing her Ph.D. from Kolkata University, she joined IICB as a research scientist and went on to become the Chief Scientist of the institution.

She devoted her entire research career to Kala-azar (Visceral Leishmaniasis), an endemic in India and across the world. Her research is focused on unraveling the enigma of immune suppression in kala-azar patients and she is determined to develop new strategies for diagnosis, vaccinations, and anti-leishmanial chemotherapy. Her research works have been displayed by way number of papers, ResearchGate has listed 200 of them. She also has 8 patents to her credit as per CSIR patent database Patestate.

In recognition of her contributions to the development of science and technology, she has been provided with several awards and honours including the *prestigious Sir J. C. Bose fellowship and National Women Bioscientist award. In addition, she has also been elected as the fellow of several national and international scientific academies such as the National Academy of Science, the Indian Academy of Science, the Indian National Science Academy, and The World Academy of Science.*

Dr. Suman Kumari Mishra:

Dr. Suman Kumari Mishra (born 1964) is a materials scientist currently serving as the **Director** of CSIR-CGCRI. After completing her Ph.D. from IIT, Kharagpur, she started her scientific career as a scientist in CSIR-NML, Jamshedpur, and rose to the level of Chief Scientist. During her tenure, she has headed some of the divisions of CSIR-NML and has also served as Professor and Dean of Engineering Sciences at AcSIR for several years.

Dr. Mishra is specialized in advanced material processing, material properties, and applications. Her research work has been presented in form of way number of articles. She has more than 100 papers and 13 patents to her credit. She has also been a member of the International Editorial Board of the IIM-Universities Press.

In recognition of her scientific contributions, she has been awarded several awards and honours including the *Best Metallurgist of the year award in 2012, Vasvik award in women category in 2004, MRSI medal in 2004, CSIR* *young scientist award in 1999*. She was also elected as the Fellow of the National Academy of Sciences of India in 2018.

Dr. Sridevi Annapurna Singh:

Dr. Sridevi Annapurna Singh (born 1965) is an accomplished food technologist currently serving as the **Director** of the research institution CSIR-CFTRI, Mysore. She joined the institution as a scientist in 1991 and grew up to the position of Chief scientist and headed the department of Protein Chemistry and Technology before taking over the charge of the Director of the institution. She is also an active member of several national and international societies.

She has expertise in the research area of structural and functional analysis of enzymes. Her major research interest is protein chemistry. In a career spanning over three decades, she has worked extensively on both basic and applied aspects of food science. She has contributed significantly toward unfolding protein structure-function activity relationship, protein, and enzymes as food ingredients and developing technologies for combating malnutrition. Some of the technologies transferred by her to industries are amylase-rich energy foods, soy protein hydrolysates, and supplementary food for severely malnourished children, and so on. *She has published her works in over 50 research papers in peer-reviewed journals and she holds a total of 11 patents to her credit including 5 US patents.*

Dr. Anjali Shiras:

Late Dr. Anjali Shiras was an Indian biologist who passed away on 2nd October 2020 due to coronavirus disease. She was 58 years old and had served as the Director of the National Centre for Cell Science, Pune. She was a brilliant scientist and pioneer in the field of non-coding RNA. She joined the institute in 1989 soon after its inception and grew up to the position of Chief scientist.

Her main area of work pertained to cancer research especially glioma, stem cells, and understanding mechanisms of stem cell proliferation and growth concerning the role of microRNAs and cellular signaling pathways in driving cellular transformation. She and her team had identified a non-coding RNA 'Ginir' which acts as a cancer-causing oncogene. Her works have been published in more than 50 peer-reviewed journals. In recognition of her contributions to science, she was selected as a member of the Prime Minister's delegate that participated in the Indo-Japan S&T Joint Committee meeting held in Tokyo in 2014. She was also elected to the Executive Committee of the Indian Association of Cancer Research and the Indian Society of Neuro-Oncology.

Dr. Subhra Chakraborty:

Dr. Subhra Chakraborty (born September 25, 1964) is a Bioscientist currently serving as the Director of the National Plant Genome Research Institute, New Delhi. She started her scientific career as a research scientist in JNU, New Delhi, and went on to achieve the highest position of Staff scientist VII at NIPGR, New Delhi. She is also serving as the president of the Proteomics Society of India.

Dr. Chakraborty has conducted a great deal of research in the field of plant biology throughout her career. Her main research interests are Nutritional Genomics, Plant Immunity, Plant Proteomics, Molecular Biology, Genetic Engineering, and Biotechnology. She has presented her works in more than 150 research papers in peer-reviewed journals and she holds a total of 29 patents to her credit including 9 US and PCT patents each.

In recognition of her outstanding contributions in the field of science & technology, she has been awarded several awards and honours including *Sir J C Bose National Fellowship (2020), TATA Innovation Award from DBT, GoI (2014), Inspiring Women Scientist Award (2014), NASI-Reliance Industries Platinum Jubilee Award (2010), National Young Women Bioscientist Award (2002), Prof Hiralal Chakraborty Award from ISC (2002), Technology Development Award from DBT, GoI (2000), Young Scientist Award, IUBMB (1994)*. She is also a fellow of the Indian Academy of Sciences, National Academy of Sciences India, and Indian Academy of Agricultural Sciences.

Dr. Jyotirmayee Dash:

Dr. Jyotirmayee Dash (born July 9, 1976) is a chemical scientist currently serving as a professor at the School of Chemical Sciences in the Indian Association for the Cultivation of Science, Jadavpur. After completing her Ph.D. from IIT Kanpur, she worked as a post-doctoral fellow in Germany, France, and the UK and then returned to India in 2009 to work as Assistant Professor in IISER, Kolkata. She joined IACS in 2012 as Assistant Professor and rose to the current position of Professor in 2018.

Dr. Dash's area of specialization is Organic and Bio-organic Chemistry. She has elegantly applied principles of chemical biology to modulate the structure and function of nucleic acid targets in biological systems leading to new therapeutic tools for anticancer research. She has more than 100 research papers to her credit and sits as a member of the International and Editorial Advisory Board of various journals. To recognize her contribution to the development of science and technology, she has been showered with some of the prestigious awards and honours including the most coveted **Shanti Swarup Bhatnagar Prize**, 2020. She is also a **Fellow of the Royal Society of Chemistry**.

Chapter – III: Inconsistency in Searching Indic Women Names: Experience from Web of Science Database

In general, names are a valuable source of information from an indexing point of view. However, a person's name can exhibit many variations in published documents, and users searching for a name may enter a variant form not found in documents and text, or not matching the form indexed in the system. For example, a user using an author name "*Maria Goeppert Mayer*" (see https://en.wikipedia.org/wiki/Maria_Goeppert_Mayer) search as "Geoppert Mayer, Maria" or "Mayer, Maria Geoppert" is likely to miss a record indexed as "Geoppert-Mayer, Maria" - the second women recipient of Nobel Prize. Another challenging issue with a name search is that in a name, a single token misspelled affects the search results a lot. Every word in name and its order is important, e.g. in a name like Swapoora Rani, the term Rani is equally important for the accurate representation of an author's name, as it is the author's last/surname name. If the term Rani is attached with the first part of her name like 'Swarooparani' – which is quite common in Indic women names, then it may represent a different author. However in the name 'P Shobha Kruparani' if the term 'rani' becomes detached as 'P Shobha Krupa Rani', it won't give correct results, as 'Kruparani' is her correct surname.

The given names of Indian women reveal their gender, marital status, birthplace, nationality, religion, etc. but their last name varies significantly after their marriage; some of them retain their ancestral name even after marriage but some of them use their husband's family's ancestral name or both. No standardized format exists to date which can guide as to how to identify the last name element from the first name element for any name. The vast variation in the pattern of Indian names differs from place to place or community to community.

3.1 The Issue

There is no standardized pattern of rendering Indian women names. Sometimes it appears that one would be lucky to be able to locate the literature that they are looking for by the name of the researcher. Of course, in the case of authors with only first names and surnames, there should be little problem in finding information. But for authors resides in south India who do not generally use surname/family name, inaccuracies occurred for them. Rendering of their name depends upon the region they belong and no database of the world has provision to index names according to the region. Furthermore, a database like Web of Science (WoS) wherein before 2006, the author's given name was frequently stored only in initial, the same author was indexed twice - one with her full forename and surname and another with surname and initial forename. The possible reason may be some journals earlier insisted on listing given names in initial only whereas others allowed authors to present their full given name according to the tradition in their country. But this creates huge ambiguity and inconsistency in the database with the popular Indian family name like Singh, Dwivedi, Rao, etc. with the same initial given name for two different authors working on the same or different fields/organizations. For eg., while searching publications by Debashri Ghosh, CGCRI by initial of author's first name (Ghosh, D.), then along with publications of Debashri Ghosh, publications by Debarati Ghosh and Dinabandhu Ghosh of the same organization appeared. As no database permit search through subjects or fields of specialization, these problems create low precession in search results. The problem is sufficiently widespread that some authors have taken advantage of the ambiguity.

WoS in their website claimed that they have worked extensively to overcome such issues, introduced fully integrated ResearcherID, Author search, Author Record, and curation mechanism to provide the global research community with an invaluable index to author information[3]. It is therefore pertinent to track how far such efforts work for authors of the Indian subcontinent in reality. In this section, attempts have been made to get answer the questions like:

- Among the 'Author Search' field and 'Basic Search' by author field which search strategy provides exhaustive and accurate results for Indian women names; and
- Have there any duplicity or anomalies occurred in search results, and if so, what are the best possible way to overcome the variations

3.2 Strategy followed to check inconsistency

To understand how international databases handle Indian women's names or how far the search results are exhaustive in the database like Web of Science (WoS), each name as it is available on the official website was used to search publications in the Web of Science database. Complete last name along with full first name was applied. In case full the first name was unavailable, the initials as they are available on the official website were used. In most of the cases, official websites of the authors enlist only 'recent publications', maybe of last few years, therefore to know the publication of a scientist exhaustively, searching international databases is essential. For the present study, we searched publications of a scientist in both 'Author Search' and 'Basic Search' fields of Web of Science. Chicago Manual indexed Indian names under family then given names separate by a comma. Author last name, the full-first name was used as search string under author tag. Needless to mention that search results of any author search display author's name and current affiliation of the author. However, it also shows the name of other organizations that the author had served in her lifetime. By inspecting publications from official websites, both results were included. In the basic search tag, on the other hand, we used the 'Author' field as well as the 'Organization-enhanced' field both to identify exact publications. The searching was made in November 2020 and searched results were compared with the enlisted publications on the profile page of official websites.

3.3 Differences in search results of 'Author Search' field and 'Basic Search' by author field

Table 1 explains the variation in search results while searching names (20 randomly selected authors from all regions) in the 'Author Search' field as well as the 'Basic Search' field in Web of Science. The search string, mentioned in the bracket, has been chosen based on the name available on the official website of the author/ her institution.

Table 3.1: Variation of Search Results in Basic and Author Search

Name as in Website (Search String), Organization belongs	A	B	Remark
Tanusri Saha-Dasgupta (Saha-Dasgupta, Tanusri), SNBNCBS	225	90	Results from Alternative names: Saha-Dasgupta, Tanusri; Saha-Dasgupta, T; Sahadasgupta, T; Dasgupta, T.; Saha Dasgupta, Tanusri Saha are included. While clicking for download, out of 225 only 214 articles are downloaded.
Swati Gupta Bhattacharya (Bhattacharya, Swati Gupta), BI	44	24	The author is also searched by Gupta Bhattacharya, Swati with the same 44 publications. If only initial first name and affiliation are used, then 121 records appeared. As per ResearchGate, the author has more than 44 publications in those journals that are indexed in WoS.
Sarika Maitra Bhattacharyya (Bhattacharyya, Sarika Maitra), NCL	39	20	Although the name is correctly written, records under Author search and Basic search have significant differences.
Sumana Das (Das, Sumana) CGCRI	38	1	So many authors record with the same name. In the Basic search if the name is rendered in the same way as it is written in Author Search only 1 record appeared.
Manikyamba C (Manikyamba, C), NGRI	85	88	Although Manikyamba is her given name, this given name is to be placed under the last name field in the author search. Alternative name: Manikyamba, Chakravadhanula. Two authors record of the same affiliations with a different number of records appeared. No. of records in each result differs considerably.
Priya S (Priya, S), NIIST	5	16	149 variants of the same name appeared in the author search but none belonged to the same affiliation of the desired author. In the Author search, her affiliation is to be mentioned CSIR.
Asha SK (Asha, SK) NCL	60	60	Although 'Asha' is the given name, the publication of this author is only shown when her given name is placed in the last name tag. Two authors' records of different affiliations appeared.
Manju S (Manju, S) SCTIMST	0	11	Through Author Search no record available, but through Basic search with affiliation 11 records available
Shikha, CMERI	2	1	The author has many publications indexed in WoS, but no record of the same name & affiliation available through an Author search.
Vandana (Vandana), NPL	1	24	77 authors record of the same name with different affiliations appeared. Although Vandana is a given name, for searching this

			name is to be placed in the Last name field. The search results in the Author search are not exhaustive, the Author has more publications than it searched in Author Search.
Inderpreet Kaur (Kaur, Inderpreet), CSIO	79	96	Eight Authors' records of the same name appeared. Alternative name: Kaur, I
S. *Saravanadevi* (*Saravanadevi*, S), NEERI	7	6	Devi here to be attached with the name. Alternative name: Saravanadevi, Sivanesan
R. Nandini Devi (Devi, R. Nandini), NCL	50	40	Nandini and Devi if joined, no results appeared. Although Devi is not a known Last name but here to be used as the Last name. Alternative names: Devi, RN; Devi, R. N.
B L A Prabhavathi Devi (Devi, B. L. A. Prabhavathi), IICT	50	33	Alternative names: Devi, Bethala L. A. Prabhavathi; Devi, BLAP; Devi, B. L. A.; Prabavathi Devi, Bethala Lakshmi Anu Prabhavathi. Here the author can be searched by Devi, BLAP, or Prabhabatidevi, BLAP.
Archanamoni Das (Das, Archana Moni) NEIST	11	7	1 result appeared under Das, Archanamoni, but 11 results search through the search string Das, Archana Moni. Alternative names: Das, Archana M.; Das, Archana Das, AM
Asha Lalwani (Lalwani, Asha), NEERI	0	0	No record was found in this last name. She is known in her publications as Asha Chelani. 2 author records appeared in the same author, one having WoS ID: WoSRID: Y-4417-2019, another one without any ID.
Manohar Cathrine Sumathi (Sumathi, Manohar Cathrine), NIO	0	0	At least 8 publications are searched by string Manohar, CS under basic search and author search, but no record available under the Sumathi, Manohar Cathrine.
Maria-Judith, BDG, NIO	27	6	No search results are available under the name available on the official website. Her publication is accessible only under Gonsalves, Maria-Judith BD.
Lidia DS Khandeparker, NIO	47	37	She is only searched by Khandeparker, Lidia. If DS is added no results are found. However, another author Khandeparker, Rakhee D S is searched with DS and two author records on the same name and affiliation have appeared.
Joao, Maria Hilda Das Marcus, NIO	0	9	Although she has publications in this string nothing is searchable. She is searched only by the name Joao, H M.

A= Max. Results in 'Author Search', B= Results in 'Basic Search' by Author

From the 'Remark' column of Table 3.1, it is clear that for searching the author's publications, the name as exactly is available in official websites (eg. Goanese names) cannot be a recommendable way to search. Furthermore, search results differ considerably for 'Author Search' and 'Basic Search'. For some names, author search displayed exhaustive results while in few cases basic search displayed more comprehensive results. Therefore, to get better results it is recommended to execute search both in Author search and Basic search. Furthermore, married women with three parts names (last name, middle name, first name) need not necessarily be searched by fixed order of search string. Sometimes their publications are searched with their parental family name as the last name, sometimes with their husband's family name. Similarly, if any women's name ended with 'Devi', the term 'devi' doesn't need to always represent their surname or middle name. It differs significantly from women to women and is mostly based on how they render themselves in publications. Therefore searching for those names needed much attention by looking at the rendering of their name in an existing publication.

3.4 Duplication of records by the same author

As we have seen in most of the cases that 'Author search' provides more exhaustive results than 'Basic search' is, in the next, therefore, attempts have been made to check how far the search results of the author are precise & complete. For this purpose, another set of fifteen authors have been chosen. The results of the analysis are shown in table 2, on which the column 'Remark' is self-explanatory. While searching the name through the Author search tab it was observed that a considerable number of authors have been indexed more than one time, despite both the author belong to the same name and organization. Table 2, shows such inconsistencies.

Table 3.2: Duplication of same author records

Name as in Website	in Author Search	in Basic Search		Remark
	A	B	C	
Manju Y Krishnan, CDRI	19	14	14	Two author records on the same name and affiliation with a different set of 11 publications for this author.
Rishemjit Kaur, CSIO	12	11	15	The same authored name working in Commonwealth Scientific & Industrial Research Organisation (CSIRO) with a different set of publications has searched.
Prabha D. Nair, SCTIMST	55	47	50	Three separate entries of the same author name and affiliation with different author IDs and publications are available.
Vandana Prasad, BSIP	41	09	28	Two different entries of the same author and affiliation appeared. The significant publication appeared in *Science* are not included in search result. That work is available in different entry with Prasad, V. However, no linking between two entries are available.

S. Swarnalatha, CLRI	29	24	26	Three author entries of the same name and same affiliation were found. Some appeared as **Swarnalatha, S.** and some **Somasundaram, S.** Another author entry of Somasundaram, Swarnalatha with same author ID but a different set of publications has also appeared.
Tanusri Saha-Dasgupta, SNBNCBS	223	86	88	Two entries of the same author name are searched. In basic search, almost 24 articles appear under affiliation Indian Association for Cultivation Sciences.
Sumana Chakravarty, IICT	161	39	40	Same affiliation and author name but a different set of results for basic and author search appeared.
Suman Kumari Mishra, NML	57	4	45	Two author records of the same name and affiliation with the different number of publications came. If the initial is used as first-name in the basic search option, then only results appeared.
Arpita Ghosh, NML	8	2	2	Twenty author records of the same name appeared. Her publications are searched by the different affiliation, and almost three author records appeared in that affiliation
Nisha P, NIIST	54	24	44	Two author entries of the same name and affiliation with a different number of publications appeared.
Sandhya SV, NIO	0	1	1	3 authors record of the same name with different affiliations (Central Marine Fisheries Research Institute & NIIST) appeared. None was of desired results. Although the author has publications indexed in WoS, no results appeared under the author search.
Debashree Ghosh, IACS	51	15	15	Two author entries of the same affiliation but with a different number of records. One with WoS ID, another one without any ID. Basic searches provide incomplete results.
Dipali Devi, IASST	76	19	26	Two entries of the same author and affiliation appeared. Another one consists of 5 publications. Alternative names: Gochhait, Debasis Gochhait, D. Basic search results are completely different than author search results.
Elizabeth Jacob, NIIST	27	3	5	Four authors record the same name, two with the same affiliations but separate entries and the remaining two are from different affiliations. No. of records with the same affiliations differs considerably in different results. Alternative names: Jacob, Sajini Elizabeth; Jacob, E; Jacob, Elizabeth R.; Jacob, Elizabeth A.; Jacob, Elizabeth C.

Sanghamitra Bandyopadhya, IITR	22	22	22	Six author records of the same name, two with the same affiliation, and four with another affiliation (Ind. Stat. Inst.) appeared.

A= Complete Last name and First name, B= A + Address of Affiliation (institute name used in WoS abbreviated form), C= A + Organization Enhanced

It may be explained the possible reasons for these inconsistencies are because of the switch-over of scientists from one organization to another as a result of which two entries appeared in the searched results. But in some cases, it is observed that more than one entry of the same author with the same affiliation also appeared in the search results.

3.5 Inconsistencies in search results

The next attempt has been made to test how far the search records are accurate and complete for an individual author while searching their publication by the Author search tab. The author search function of WoS only allows to search authors by 'Last name and 'First name' and middle initial(s). The anomalies as mentioned by taking only a few cases, in table 3 are quite surprising. Despite the fact, WoS is one of the leading databases, several cases included the publication of other similar authors with the publication of another author. If the number of publications by an author is more than a hundred then it becomes very difficult to identify such anomalies.

Table 3.3: Inaccuracies in total publications by an Author

(based on Author's Lastname and Firstname in Author Search)

Name	Records	Anomalies
Divya Singh, CDRI	80	35 authors record of the same name with different affiliations appeared – Alternative names: Singh, Divya Pratap; Singh, Divya Jyoti, Singh, D. At least 5 authors record belongs to our source author.
Pooja Devi, CSIO	70	One entry with 70 publications (ID: K-4199-2015) another with 8 publications. Some of the publications that are searched through WoS are not seen on the official website of the author. Eg. In 2020 author mentioned 14 publications in her credit on the official website but in WoS has indexed 18 publications.
Nandini Das, CGCRI	51	Almost 20% of her total articles have been indexed in WoS that has been written by the different author of the same name belonging to different affiliation.
Charu Sharma, IMTECH	95	Her name with exact affiliation is not searched through the Author search Tab but she is searchable in Basic search through author and affiliation. In this tab her 8 publications show, however, on clicking the Author name in her 8 publications, a further 95 publications appeared under her credit.

Neelam Kumar, CSIO	100	Her name can be searched in the Author search tab but the search results show publication under her credit which she probably not written. On cross-checking of the journal, it observed that some title belongs to optics, other are physics and some are of economics.
Sumana Chakraborty, IICB	164	In our first phase of searching only 64 records were showing under her credit, which later increased to 164 records. On minute inspection of publications under this name with 164 publications, it was observed that publication that originates from a similar name with a different affiliation is also included here.
R Pratibha, RRI	57	One entry of the same author was linked with 57 publications (ID: E-5101-2012) and another entry was linked with 9 publications.
Aruna Dhathathreyan, CLRI	30	One entry of the same author linked with 79 publications (ID: AAK-2473-2020). But in the Basic search, actual 30 publications appeared.

3.6 Lesson learned

From the above set of data, it is clear that in international databases like WoS, getting a complete publication of a woman author is quite difficult. 'Author search' in most cases provides more exhaustive results but not complete. It may be argued that the significant difference in search results between 'author search' and 'basic search' is because of that in author search all publications of an author that belong to her current as well as earlier affiliation are included however, in basic search we restrict the results by adding current organization name, where the author currently working, under 'organization enhanced tab. Therefore, the results were only those records that fulfil both the two conditions. However, in some cases, it is observed that the results from the basic search showed a larger number of publications by an author than author search, reasons of which are unexplored. Furthermore, in some cases, author searches do not show any results even though the author has a publication of the same affiliation. The reasons were not clear to us. Therefore, the accuracy and authenticity of the retrieved data cannot be solely left to click the button. The researchers need to eliminate the noise and spurious records that get crept into the downloaded records because of various factors including the different styles and orders of writing the names and affiliations. Women with similar names might be working in different areas in different institutions. Thus, it would be naïve to rely on simple downloads without going into cleaning the data and this problem arises because of homonyms.

During our exploration, we observed that for getting better search results of an author it is essential first to identify at least a few titles written by that author. Of these identified titles, any title may be placed in the basic search tab to get complete bibliographic detail of that title. In WoS, while displaying the search result of any title, it shows the name of all contributing authors in hyperlinked, as it is appeared in the title, the author's full first name in the bracket, author's current and earlier affiliations, and alternative names of that author. By clicking the hyperlink of the desired author name, the total publications of that author in his/her lifetime are possible to track. However, the greatest challenge by this method is to identify any correct publication by an author as in several cases it was observed that the official website of the author does not contain any information about his/her publications. In that case use of social network sites like ResearchGate, Google Scholar may be explored to know the publications of that author.

The Classified Catalogue Code in its rules JA & HD has discussed the rules for handling Name-of-Person. In CCC, the family name has been considered as the Primary element and the given name has been considered as a Secondary Element. Other parts of any personal name have been considered as an auxiliary element. Accordingly, journal publishers while asking authors to submit their articles may also ask them to indicate the primary element, secondary element, and auxiliary element of their name instead of forename or surname.

Another possible solution to this problem is that the author may be asked to write her name as they are willing to render in their publication. Furthermore, authors should always be asked to render their given names in full instead of in abbreviation. It will further minimize the overflow or super-flow of one author's publication with another similar given name. An author may also be asked to fill in the name of other organizations she served earlier to establish the connection between old and new publications.

3.7 Way Forward

Although the current study deals with a small sample of Indian women authors, we believe our results may seem true with a large volume of data too. It is a fact that throughout the world, including China, Europe, Africa, South America, no consistent rules are existing for names, therefore a single prototype system cannot be applied uniformly. The name confusion among Indians is prevalent more with south Indian authors, as their names consist of the father's given name, place of origin, and caste name instead of the surname. Therefore, journal editors & publishers, indexers should understand the cultural variation of the name in various regions and accordingly ask authors to render their names in an unambiguous format. At the same time, the official website of the author must render their author's name in a specific order so that understanding the last name does not become an issue.

Our results show that in WoS the search results for Indian women's names are not always accurate. Even though WoS is working to overcome anomalies, a huge number of inaccurate records exists. We observed that irrespective of regions, the Author search leads to more compressive results than the basic search by name. But not necessarily author search always shows the correct number of records by that authors. In several cases, we observed that more than one author entries for the same author with the same affiliation, and each entry consisting of a different number of records. More research studies with different samples need to be conducted to conclude. It would help to increase the consistency and effectiveness of search results. In the meantime, laboratories (librarian/information scientists of that organizations) must work with their authors to identify all publications against an individual and linked with the correct unique identification number like ResearcherID or Scopus ID.

Chapter IV: Analysis & Interpretation of Data

Before interpreting the results, it must be borne in mind that the intention of this research is not to test whether gender inequality in Indian science exists or not. The persistent gender gap in the fields of science, technology, and engineering over the last 70 years has widely been discussed and has posited myriad reasons for that. The intention, rather, of this research, therefore, is to illuminate the patterns of the contribution of women presently working in various research organizations under the Ministry of Science & Technology, GoI. Women who did not hold any scientific post throughout the entire observation period (i.e. 2018 to 2019) in these organizations were not included in our dataset, eliminating all those who had superannuated before 2018 but we included those who retired during 2019. The women scientists that changed the research sector for whatever reasons during the period of observation were also excluded from the data.

4.1 Research Performance in terms of Publications, Patents Awards & Citations

As of December 2020, 618 women scientists are working in a permanent position (junior scientists and upward) under 44 organizations of CSIR followed by 178 scientists in 19 organizations of DST and 106 scientists in 15 organizations of DBT, excluding Ph.D. scholars, ad-hoc scientists, guest faculty-cum-scientists, project scientists. The Male-Female ratio of these organizations is 81:19 in CSIR, 76:24 in DST, and 71:29 in DBT.

Table 4.1: Women Scientists in Research Laboratories

	CSIR	DBT	DST
# of Laboratories	44	15	19
# of Scientists	3215	365	730
# & (%) of Women Scientists	618 (19.22)	106 (29.04)	178 (24.38)

It has been observed that overall CSIR has a large number of women scientists per organization (14 women scientists/organization) as compared to DST (9 women scientist/organization) & DBT (7 women scientist/organization). However, the percentage of women scientists as compared to the male scientists is higher in the organizations of DBT (29%) followed by DST (24%). At the individual organizational level, overall it was observed that the percentage of women scientists as compared to the male scientists in CSIR organizations is only 19%. Almost 33% of institutions under DBT (5 out of 15) have 30 to 40 % working women scientists and 20% (i.e. 3 out of 15) of the institutions under DBT have more than 40% working women scientists. However, in DST, 5 out of 19 institutions (26.31%) have 30% women scientists. CSIR despite having the highest number of women scientists, has only 5 of such institutions (out of 44) which have more than 30% working women scientists, and 3 of these 5 institutions have more than 40% working women scientists.

We were unable to unfold the reason but it is fact that laboratories of DBT are specialized in the domains of life sciences, biotechnological sciences, cell sciences, immunological sciences and the laboratories of DST mostly specialize in diversified fields of sciences including nano-sciences, biotechnology, observational sciences, astronomy & earth sciences, cultivation sciences, etc. On the other hand, the laboratories of CSIR are mostly specialized in the fields of physical, chemical, and earth sciences. Several studies have discussed that life sciences and its related disciplines are preferred choices of subject among women (eg. Adamo, 2013) may be because of that the women scientists population in DBT is satisfactory than CSIR.

The recruitment process has an important influence on the representation of women in research laboratories. Studies have shown a reluctance among women in academia of European countries to apply for promotion and there is a relationship between gender, organizational culture, and career in higher education. But how the scenario is for research organizations of India is yet to explore. The below table is explaining the promotion achieved by the women in various positions during our study period, i.e. when we have started the study and when we have ended our study. The data have been gathered by looking at the designation of each scientist and change of designation, if any, in both these two periods.

As indicated in table 4.2, the pattern of promotion across laboratories is not uniform. In DST and DBT during the last two years, the promotion was mostly made among the Senior Scientists (Scientist-D) level whereas, in CSIR it was made mostly among Chief Scientists (Scientists G) and Senior Principal Scientists (Scientists-F) level. Important to note that maximum of 3% of new appointments at the Scientists (Scientists-C) level were made in both three organizations. Based on our observations, therefore, it may be fair to suggest that government must take necessary steps towards the adoption of a national, standardized policy for career and promotion of women scientists in research laboratories so that women representation in science can be visualized in terms of their presence in R&D laboratories.

Table 4.2: Women Scientists under various scientific positions and their promotion made during 2019-2020

Positions	No. of Scientists								
	CSIR			DBT			DST		
	Before 2019	During 2019-20	% Change	Before 2019	During 2019-20	% Change	Before 2019	During 2019-20	% Change
Chief-Scientists (G)	32	48	50.00	8	10	25.00	20	24	20.00
Senior Principal Scientists (F)	75	104	38.67	25	16	-36.00	25	22	-12.00
Principal Scientists (E)	115	166	44.35	20	20	0.00	45	46	2.22
Senior Scientists (D)	167	161	-3.59	19	33	73.68	31	49	58.06
Scientists (C)	222	138	-37.84	32	24	-25.00	47	33	-29.79
Junior Scientists (B)	7	1	-85.71	2	3	50.00	10	4	-60.00

As far as publications of these women scientists are concerned, we found 21203 publications in the WoS database and 23012 publications in the Scopus database (Table 4.3) by all 902 women scientists up to December 2019. Of the total publications, almost 86% of publications appeared as journal articles, followed by 6% as conference proceedings, 2% as book articles or chapters in books. The remaining 6% of publications appeared as reviews, short surveys, retracted articles, notes, letters, editorials, and data papers.

For the present study, only the publications that appeared as Articles, Conference proceedings, and Book & Chapters in Books were considered for further analysis. So our sample consists of 19970 publications in WoS and 21612 publications in Scopus. The term, publications, or articles are used throughout this paper when referring to these four types of documents. It may be argued that we exclude review publications for final analysis as it is known that reviews tend to get more citations than research papers (Sigogneau , 2000).

Table 4.3: Distribution of publications by women scientists in various databases

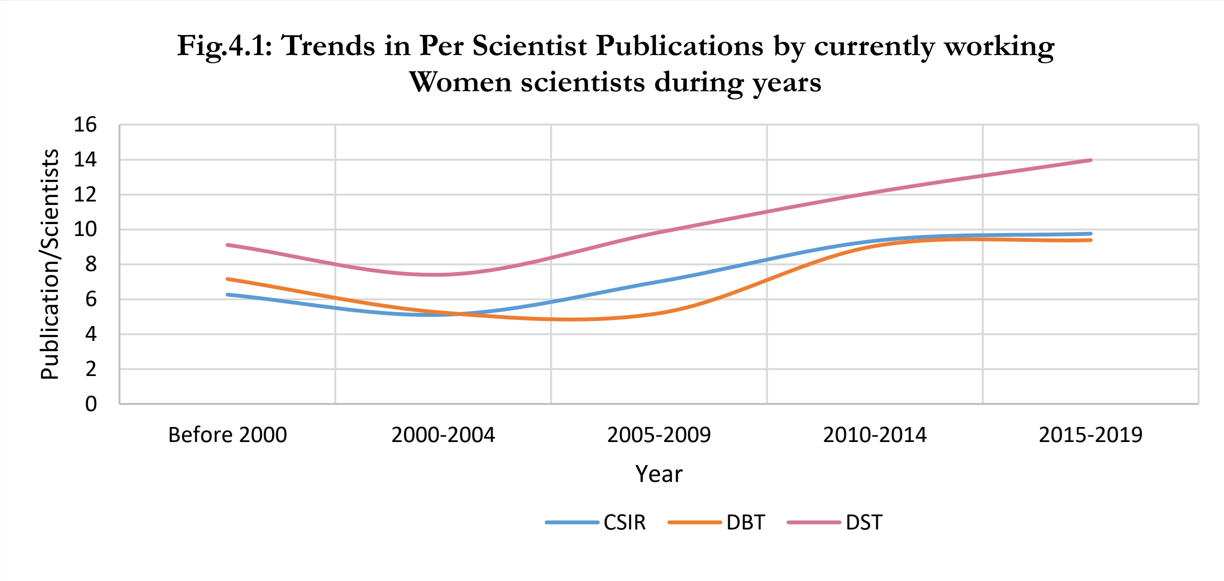
Web of Science	CSIR	DBT	DST
Publications by Identified women	12158	2613	5199
Fractional Publication	3127.00	593.14	1456.96
Average number of authors in which women as an author	5.23	9.25	6.27
Citations Received	219093	75921	100167
The average number of citation per article	18.02	29.05	19.26
Fractional Citations	54870.50	12737.11	25663.86
Scopus			
Publications by Identified women	13707	2639	5266
Fractional Publication	3641.00	611.97	1513.80
Average number of authors in which women as an author	5.01	8.25	5.87
Citations Received	250331	81954	104742
Average number of citation per article	18.26	31.05	19.89
Fractional Citations	66899.98	15288.56	26764.79

From the above table, it is clear that in all three laboratories the gross number of publications identified in the Scopus database is higher than the WoS database. It is well known that the coverage of the Scopus database is larger than WoS, as this database index a larger number of journals than WoS. However, interestingly it was observed in some cases that the searched records against an individual scientist's name in WoS are higher than Scopus. Therefore, it was decided to consider only the highest publications of an individual scientist irrespective of databases for final analysis. Considering only the unique and highest publications of a scientist from both the two databases, a total of 22617 publications are considered for final analysis that appeared as Articles, Conference Proceedings, Books, and Chapters in Books. The publications by year are represented in table 4.4 and figure 4.1.

Table 4.4: Contributions of currently working Women Scientists

Year	CSIR (n=14065)		DBT (n=2516)		DST (n-6036)	
	TP	NS	TP	NS	TP	NS
Before 2000	833	133	179	25	419	46
2000-2004	1104	216	251	48	548	74
2005-2009	2453	350	369	71	1052	107
2010-2014	4280	458	769	85	1698	140
2015-2019	5395	553	948	101	2319	166

TP= Total Publications, NS=No. of Scientists involved, Non-publication scientists have been excluded here. n =number



From figure 4.1 it is clear that there an increasing trend among scientists to publish more articles during the last twenty years or so. Among the three laboratories, the scientists of DST witnessed the highest increase of almost 6% in its publication share from the year 2000 to the year 2020. A marginal increase, almost 2% in the publication share (ranging from 7.2% earlier to 9.4% now) was registered by CSIR and DBT.

Publication pattern by Women Scientists

To describe publication patterns various indicators have been used. Following are some of them:

i) **Total Output (TO)** – the sum of publications realized by the scientist that are searched in the databases under consideration.

ii) **Fractional Output (FO)** – the sum of scientist's contributions to the publication realized, the contribution of each publication being considered as the inverse of the number of co-authors. Simply, fractional publication output has been measured as article equivalent per person per year. In this calculation, co-authored publications are fractionalized among the authors. The sum of the weight of all co-authors of a publication is equal to 1. The difference between full and fractional counting is, full counting gives each contributing author one credit, i.e. five authors equal to five credits. Fractional counting assign a fraction of one credit to each author (Osoria, 2018)

iii) **Normalized output (NO)** – the average of normalized count by all women scientists of that department. Normalization has been made by adjusting publications of different scientists to a common framework among all scientists of that department. The following formula has been used for normalization:

$$\mathbf{X_{new} = (X - X_{minl}) / (X_{maxl} - X_{minl})}$$

[where X is the set of the observed value of an individual scientist; X_{minl} is the minimum value of $X_{scientists}$ of that department (DST/DBT/CSIR) and X_{maxl} is the maximum value of $X_{scientists}$ of that department]

iv). **Scientific Strength** – equals the weighted sum of publications realized by the scientist. The weight is the FO multiplied by the impact factor of the publishing journal.

v). **Quality Index (QI)** - the ratio of scientific strength to output, indicating the average quality of publications authored by the scientist.

Table 4.5: Pattern of Publications by Women Scientists

(based on highest publications of a Scientists irrespective of databases)

	CSIR	DBT	DST
# of Women Scientists	618	106	178
# of Publications Considered	14065	2516	6036
Large producers [>=50]	67 (10.84%)	8 (7.54%)	43 (24.15%)
Moderate producers [>= 20, <50]	188 (30.42%)	35 (33.01%)	64 (35.95%)
Applicant [>=10, <20]	124 (20.06%)	31 (29.24%)	30 (16.85%)
Passers-by [<10]	174 (28.15%)	27 (25.47%)	29 (16.29%)
Without any publication	65 (10.51%)	5 (4.71%)	12 (6.74%)
Normalized publication count (X_{new})	0.09	0.06	0.15
Average Age of Article	7.54	7.95	9.53
Average article per women scientist	22.75	23.73	33.91
Publications in Fractional authorship	6.67	5.45	10.37
h-index	152	113	127

Note: Average age of articles is based on 2019 as the base year.

As indicated in table 4.5 on average DST women authors produced more articles per scientist (34 articles) than DBT (24 articles) and CSIR authors (23 articles). It is evident that research is now more collaborative, but how does that look for each researcher? Are individually writing more or more authors writing collaboratively? To judge we count fractional publications of each scientist. The publications under fractional authorship as compared to the average article per scientist indicate that DST authors collaborate with a fewer number of authors than women authors of CSIR and DBT collaborate most. The fractional value of 10.37 for DST scientists means scientists of DST have at least 10 publications exclusively in their credit. Whereas, this value is quite lower for CSIR (6.67) or DBT (5.45). Having a higher value of average author per article and a lower value of fractional publications for DBT authors indicates that there is a larger number of mega-author groups among DBT authors than CSIR.

While looking at publications patterns through the normalized count, it is seen that at least 15% of women authors of DST have quite a good publication record. The normalized value 1 indicates the highest publication of that group, near to 1 means at least that percentage of data have a nearer value to the highest. However, the *h-index* of CSIR authors is highest (152) followed by DST (127) and DBT (113), even though the percentage of authors without any publication is highest in CSIR (11%) followed by DST (7%) and DBT (5%). A major portion of authors of all these three organizations is moderate producers having publications between 20 and 49 of their credit, which is quite promising.

On the other hand, the citation figure of these three organizations as indicated in table 4.6 is just reversed, it was seen that articles written by DBT authors received more citations per article (31 citations) than DST authors (20 citations) or CSIR authors (19 citations). As a result of which fractional citation and normalized citation value are a little higher for DBT authors than CSIR or DST authors. While maximum articles of CSIR and DST scientists have IF between 1 and 2.999, maximum articles of DBT authors have IF 3 to 4.999.

Table 4.6: Citation Patten by Women Scientists

	CSIR	DBT	DST
# of Citations received	260145	78659	122619
Average Citation per Article	18.49	31.26	20.31
Citations received in Fractional authorship	3.15	5.14	3.75
Normalized Citation impact/scientist	0.08	0.09	0.08
%article without received any citation	10.16	12.23	14.29
# of Usage Count (Since 2013)	215035	27951	85502
Average Usage Count per Article	18.48	13.33	15.85
# of journals where publication appeared	3631	1208	1795
%Article having IF Range:			
Without IF	29.40	18.81	25.45
0.01 to >1	7.17	2.35	8.15
1 to 2.999	34.07	30.51	29.64
3 to 4.999	20.55	30.83	19.55
5 to 10.999	7.51	12.49	14.45
Above 10	1.31	5.01	2.77
Average Impact Factor	3.2296	4.4827	3.8183
Scientific Strength per scientist	13.507	16.645	28.825
Quality Index	0.53	0.66	0.79

However, the qualitative dimension, which is here measured by the scientific strength and quality index among scientists of all three laboratories indicates that scientists of DST have higher scientific strength and quality index than DBT. A considerable number of articles by DST scientists have appeared in high-impact journals (not necessarily a percentage of articles in high-impact journals) like *Nature, Science*, *Journal of Clinical Oncology,* etc. As a result of which the scientific strength is highest in DST (28.825) than DBT (16.645), even though the average citation per article for DBT authors is highest (31.26) followed by DST (20.31). The quality index of 0.79 for DST scientists means at least 79% of the total articles of DST is qualitative whereas this value is 66% for DBT and 53% for CSIR.

Patents and Awards

To find the number of patents filled/awarded by the scientists, we first looked at the official web pages of the institutions that they belonged. Individually uploaded CV excavated and the 'Patent Tab' in the official website of the concerned scientists was thoroughly explored. Thereafter, the 'Patestate' (CSIR India Patent Database) and Scopus database were explored. A simple, as well as binary search, was implied in Patestate and Scopus. We used two fields for searching the patents: the first one is the inventor field (scientist) and the second is the applicant (institution) field. In the search results, if any woman's name of our sample came as an inventor, we considered it as patent of her credit. Each search result was verified manually to confirm the correct representation of the sample.

For the awards, we heavily relied on the data available on the official web pages of the scientists. To verify the claim looked at the official web pages of the awarded institution related to several fields of science and technology and then looked for the names of our women scientists in the recipient list of the respective awards.

Table 4.7: Patents (filled and awarded) & Awards received

# of Patents & (# of Scientists)	CSIR	DBT	DST
Before 2000	16 (8)	5 (3)	9 (3)
2001 to 2005	45 (24)	9 (6)	17 (6)
2006 to 2010	109 (39)	15 (10)	34 (11)
2011 to 2015	122 (50)	31 (12)	62 (20)
2016 onwards	262 (106)	28 (13)	58 (14)
# of Awards Received			
Before 2000	19	9	8
2001 to 2005	32	12	11
2006 to 2010	17	13	14
2011 to 2015	34	16	13
2016 onwards	51	16	12

According to a study (https://www.bbc.com/news/technology-49843990) women, inventors accounted for under 13% of patent applications globally. As indicated in Table 4.7, a similar trend is also observed for women of CSIR, DBT, and DST. Although the female inventor has increased from 4% in 2005 to 17% in 2020 in CSIR, the increase is quite slow for DST (3% in 2005 to 8% in 2020). On the other hand, the per-scientist award was higher among scientists of DBT (0.55 awards) than DST (0.37 awards) and CSIR (0.24 awards) There are six scientists of DBT who are the recipient of the prestigious National Bio-Science Award, two received NASI-Reliance Award, and three scientists bagged Infosys award in Life Sciences for their seminal contribution to biological sciences. One scientist from CSIR is the recipient of Santi Swarup Bhatnagar in biology and five scientists are the recipient of the National Geoscience Award of the Government of India. In India, these prestigious awards are conferred upon those who have made an outstanding contribution, scientific breakthroughs, and developed a deeper understanding of science.

4.2 Research Performance in terms of Scientist's Rank, Degree & Tenure of Service

A research doctorate comprises a process of independent research that produces an original contribution to knowledge. Studies reveal that the research environment has a decisive influence on the productivity of quality research but not necessarily the student's previous academic outcome and research training. However, it is generally assumed that those with previous experience in research should be more productive, but have a more complex career orientation (Schomburg, 2007) and conception of career success than others.

Table 4.8: Academic Qualifications and Publications pattern/trends

Highest Educational Qualifications	CSIR			DBT			DST		
	NS.	Pub	PP	NS.	Pub	PP	NS.	Pub	PP
Post-Doc, RA, DM	105	2971	28.30	62	1576	25.42	77	3402	44.18
	17.0%	21.1%		58.5%	62.6%		43.3%	56.4%	
Ph.D., MD, D.Sc.	352	9334	26.52	40	933	23.33	81	2428	29.98
	57.0%	66.3%		37.7%	37.1%		45.5%	40.2%	
Master's Degree (ME, M. Tech, MSc., MBA)	105	893	8.50	0	0		6	33	5.50
	17.0%	6.3%		0	0		3.4%	0.5%	
Others (including MBBS, BE, BTech)	7	59	8.43	0	0		5	10	2.00
	1.1%	0.4%		0	0		2.8%	0.2%	
Unidentified	49	808	16.49	4	7	1.75	9	163	18.11
	7.9%	5.7%		3.8%	0.3%		5.1%	2.7%	

NS=Number of Women Scientists, Pub. Publications, PP=per scientist publication

Table 4.8 shows the pattern of publication concerning their highest degree of qualification. It is evident in the table larger portion of women scientists of DBT has a Post-doctoral degree (59%) followed by a doctoral degree (38%). However, a larger portion of CSIR scientists has a doctoral degree (57%) followed by a post-doctoral and master's degree (17% each), and an almost equal portion of women scientists of DST has a post-doctoral degree (43%) and doctoral degree (46%). Overall, scientists with a doctorate (Ph.D.) or post-doctoral fellows publish more (almost 90%) with marginal variations, but scientists having post-doctoral degrees produced more per-scientist-publication, 44 for DST, 28 for CSIR, and 25 for DBT. Studies have shown that postdoctoral appointments are the platform from which the next generation of researchers embarks on independent research careers (Mitchell et al. 2013) and they also have the potential to become key players, bridging knowledge between national and international scientific and scholarly network (Horta, 2009).

In the next attempts have been made to correlate publications with the tenure of service. Here 'date of joining' has been considered as a benchmark to count the tenure of service and the year of publication has been adjusted with the tenure of the service period. As indicated in table 4.9, the trend is quite similar for women scientists of CSIR and DST but differs for DBT. The maximum percentage (26%) of CSIR scientists belong to those who have served 10 to 15 years of service, but the maximum percentage of publications (28%) came from the scientists who have served more than 20 years of service. Similarly, in DST maximum (32%) of scientists belong to 10 years of service tenure, in spite, maximum publications (32%) came from the scientists who have served more than 20 years of service. However, in DBT scientists who are comparatively young and served a maximum of 10 years of service contribute more significantly than others.

Table 4.9: Publications according to Year of Joining

Tenure of Service/Year of joining	CSIR		DBT		DST	
	NS	Pub	NS	Pub	NS	Pub
More than 20 years/Before 2000	116 18.7%	3886 27.6%	8 7.5%	239 9.5%	37 20.8%	1936 32.1%
15 to 20 years/ 2000 to 2004	84 13.5%	2613 18.6%	15 14.1%	410 16.2%	18 12.4%	737 16.0%
10 to 15 years 2005 to 2009	162 26.2%	3768 26.8%	15 14.1%	447 17.7%	34 21.3%	1108 19.9%
5 to 10 year/2010 to 2014	129 20.9%	2271 16.1%	35 33.0%	743 29.5%	52 32.0%	1582 25.9%
5 Years or Less/2015 onwards	116 18.8%	1204 8.6%	33 31.1%	677 26.9%	34 11.8%	595 4.8%
Unidentified	11 1.8%	323 2.3%	0 0.0	0 0.0	3 1.7%	78 1.3%

NS=Number of Women Scientists, Pub. Publications

In theory, the scientist's rank should reflect his/her demonstrated level of performance and future prospects. When the performance of low-ranking scientists equal or exceeds the average of scientists at a higher level then advancement should be possible. Table 4.10 explain the pattern of publications by women in various scientific position. Needless to mention that scientists of different laboratories of equal rank have different designations. Therefore a generic position has been created by considering various designation of equal rank and pay scale.

Table 4.10: Scientific Positions and Publications pattern

Current Position	CSIR		DBT		DST	
	No.	Pub	No.	Pub	No.	Pub
Chief-Scientists (Scientists G)	32 5.2	1419 10.0	8 7.5	609 24.2	20 11.2	1370 22.7
Senior Principal Scientists (Scientists F)	75 12.1	2823 20.0	25 23.6	932 37.0	25 14.0	1068 17.7
Principal Scientists (Scientists E)	115 18.6	3076 21.9	20 18.9	336 13.4	45 25.3	1687 27.9
Senior Scientists (Scientists D)	167 27.0	4215 29.9	19 17.9	245 9.7	31 17.4	908 15.0
Scientists (Scientists C)	222 35.9	2470 17.6	32 30.2	361 14.3	47 26.4	953 15.8
Junior Scientists (Scientists B)	7 1.1	62 0.4	2 1.9	33 1.3	10 5.6	50 0.8

- Chief Sct and above includes Chief Scientist, Emeritus Scientist, Scientist-G, Scientist-H, Staff Scientist VII, SERB Distinguished fellows, Senior Professor, Outstanding Professor, and National Chairs

- Sr. Pr. Sct includes Senior Principal Scientists, Scientist-F, Staff Scientist VI, Professor equivalent to Scientist F, Engineer F and other posts equivalent to Scientist F
- Pr. Sct includes Principal Scientists, Associate professor-II or full Associate professor equivalent to Principal scientist, Full Scientist E or Scientist E-II, Staff Scientist V, Professor E, and other posts equivalent to Principal Scientist
- Sr. Sct includes Senior scientists, Scientist D, Scientist E-I equivalent to Scientist D, Associate Professor-I, Reader, Staff Scientist IV, and other posts equivalent to Senior Scientist
- Sct includes Scientists, Scientist C, Assistant Professor, Staff Scientist III, Inspire Faculties, DBT-Biocare Scientist, Welcome Trust Intermediate fellows, and other posts equivalent to Scientist C
- Jr. Sct includes Junior Scientists, Scientist B, Staff Scientist II, and other equivalent posts.

It shows in table 4.10 that although a majority of the scientists in both the three organizations are quite young and they are holding the position of Scientists-C, however, Senior Scientists (Scientists-D) of CSIR, Senior Principal Scientist (Scientists F) of DBT, and Principal Scientists (Scientist-E) of DST have highest publications. Comparing the figure with table 4.8, it may be concluded that the relatively higher proportion of women at post-doc or Ph.D. level have not translated into more equitable proportions at the top level.

Publications during the different span of service and age

In tables 4.8 to 4.10, attempts have been made to explore how much research has been produced by scientists in different ranks, educational qualifications, and years of service of women scientists. Here all variables are static. In the next, attempts are made to correlate scientist's age with scientific productivity, which means with the change of physical and service age whether a women scientist become more creative. Some empirical studies like Simonton's (1984) model of creativity suggest that individuals have an initial 'creative potential' that decreases over time. Kuhn (1962) also suggested that young researchers have a fresh look at scientific problems and are more likely to cause a scientific revolution. The below mention table explains how Indian women scientists performed in different span of their service or how the age of a women scientist become a factor in publishing. To know how many publications a scientist produced at a different age, the data about the year of publication of an article was adjusted with the year of birth and the year of joining of a scientist in the organization. Therefore, here, we have used publication output per scientist per year as a measure (not the average for a long time). Although the current study is not intended to investigate the cause of such differences encountered, the author will indicate further investigations that findings could suggest. Here several 'Active Scientists' of each three laboratories were also identified who had at least one publication each year since joining.

Table 4.11 presents the distribution of the number of scientists by (A) service age as well as (B) physical age and percentage of share to the total publications. Although the percentage of publication for A (counted using the date of joining) is based on the total publication after joining of a women scientist, the percentage of publication for B (counted using the date of birth) is based on the total publications of a scientist in her lifetime. The results show that while women scientists of CSIR contributed the maximum percentage of their publications during the first 6 to 10 years of joining but women scientists of DBT and DST contributed most of their publications during the first 5 years of their joining. This may be because most of the scientists of these two laboratories have more post-doctoral fellows and they remained productive even after joining.

Table 4.11: Physical Age, Service age and Publication Pattern

	CSIR			DBT			DST		
Joining	N	(%T)	PS	N	(%T)	PS	N	(%)T	PS
Publications before joining currently serving organization	323	16.8	7.3	83	28.1	8.5	124	21.5	10.5
Publications after joining	521	80.9	21.8	95	71.9	19.0	164	77.2	28.4
Unidentified	11	2.3	-	0	0.0	-	03	1.3	-
# Active Scientists	319	86.3	30.8	71	92.0	23.5	127	93.6	34.4
A. Service age									
Publications within 5 years of joining	436	27.4	7.2	88	43.2	8.9	145	31.2	10.0
Publications during 6-10 years of joining	371	28.5	8.7	60	27.7	8.4	118	29.8	11.8
Publications during 11-15 years of joining	262	19.0	8.2	33	18.1	9.9	69	15.0	10.1
Publications after 15 years of joining	162	25.2	17.7	19	11.0	10.5	49	24.0	22.8
B. Physical age									
Publications up to 30 years of age	327	15.3	6.6	63	10.2	4.1	98	13.6	8.4
Publications between 31-40 years of age	467	37.7	11.4	89	39.0	11.0	136	36.9	16.4
Publications between 41-50 years of age	323	32.6	14.2	64	32.1	12.6	95	30.5	19.4
Publications more than 50 years of age	123	13.1	15.0	20	17.8	22.5	60	17.7	17.9
Unidentified	09	1.3	-	03	0.8	-	2	1.0	-

Note: N= Number of women Scientists, %T=Percentage of the total publications, PS=Publication/Scientist. Service age is calculated based on the date of joining in current position, Physical age is calculated based on the Date of Birth of the Scientist.

On the other hand, it is observed that at the age between 30 and 40, the scientists of all three organizations contributed the highest percentage of publications. To confirm whether publication rate increases or declines with time, it was observed that there are almost 20% scientists of CSIR & DST and 33% scientists of DBT whose publication rate does not decline on attaining age 50 years or more. They have contributed almost 18-19 publications each year. This means we cannot interpret decline with age as a general finding of our study. Our study, therefore, supports 'a scientist in a senior position is more likely to have a better ability to do research and write articles and the juniors are less experienced as researchers because knowledge is cumulative' (Tien & Blackburn, 1996).

4.3 Research Performance in terms of Authorship & Collaborations pattern

It is evident that the number of publications is growing in each field of science, but how has the growth been achieved? – Is it purely the investment in research or is it individual's efforts, or increase the number of researchers in the field or there may be some other cause like changing trend of authorship? To get an answer to these questions we have analysed the collaboration pattern of published articles. Perhaps the most straightforward measure to understand the growth is to verify whether the number of authors per article is increasing or decreasing over the year? The rise in the number of authorship per publication over the years suggesting that authors are writing more collaboratively.

Fig. 4.2: Trends in Colloborative Research

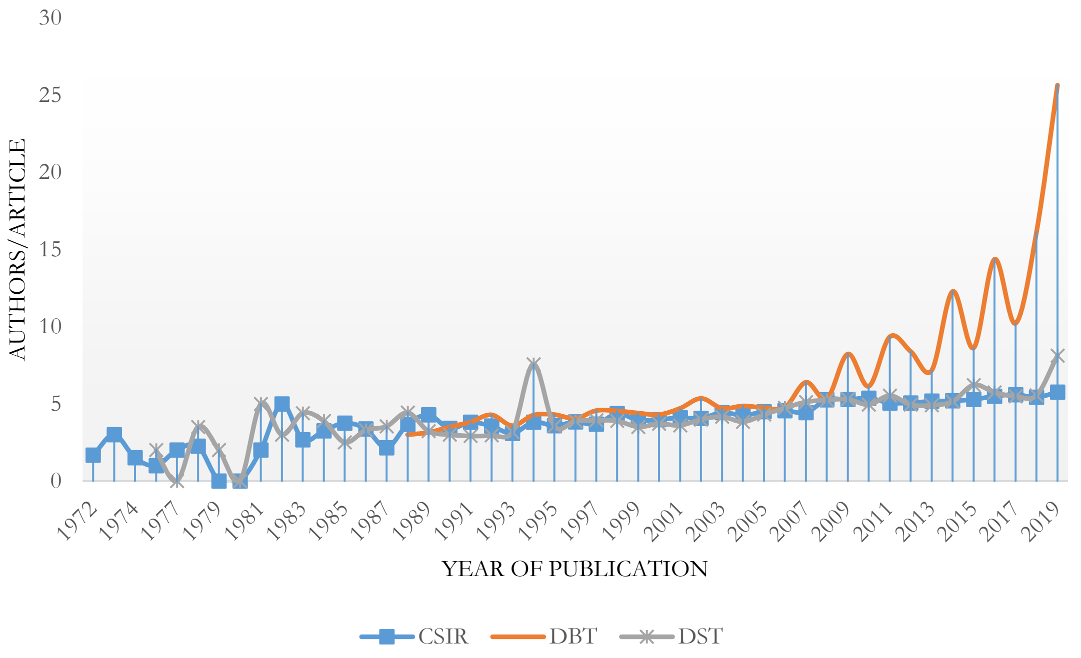


Figure 4.2 reveals how the pattern of collaboration has changed over time. The figure clearly shows that women authors of CSIR and DST collaborate with authors of small groups and this trend remains the same in the last five decades. In CSIR, the average number of co-authors per article was almost 2 in 1972 which reached 5.55 in 2019, and in DST, the average number of co-authors per article was 2 in 1975 which reached 8.5 in 2019. However, the size of collaboration of women scientists of DBT is increasing, it was almost 3 in 1988 but since 2007 it is increasing from almost 8 authors-group to 25 authors-group in 2019.

However, while looking number of articles in different authors- group (here we classified it as micro-, mini-, and mega-), as displayed in table 4.12, that it is observed on an average maximum number of articles (above 75%) in both the three organizations have appeared under a mini group, means authors-group consisting of 3 to 9 authors. But in the case of DBT, almost 15% of publications appeared with mega-group having more than 9 authors per article.

Next, we analyze the position of women authors in the article. As the position of the author in the article helps to understand whether they are a genuine contributor and not as a 'gift author' or 'ghost author'. Believing these, in this part attempts have been made to understand how women scientists contributed in the article, - whether as first author, last author, or middle author? Although it does not honour the scientific merit of the author's intellectuality, it, however, shows the hierarchical structure of the research community (Tscharntke, 2007). In common practice "the first author indicates the person whose work underlies the paper as a whole" and the last authorship "indicate a person whose work or role made the study possible without necessarily doing the actual work" (Murphy, 2004).

The scientific productivity and collaboration at the national or institutional level is an important issue for policymakers in science and higher education to decide the sanction of grants. It also holds an important key to achieve future success in the science system. In the next, therefore attempts were made to understand the pattern of collaboration. To gauge the extent of collaboration a scientist made during her lifetime, the method of residue (method of eliminating alternative potentials causes based on previously known facts) approach was followed. As we searched the publications of a scientist by her name, it was confirmed that in each searched article there was at least one scientist who belonged to our sample (source author). Therefore, in the 'Authors with Affiliation' field of a multi-authored article, we checked the country of the institution for other authors (target author) than our source authors. If the affiliation of any target author of a multi-authored article was located in an institution outside India we considered it as 'Global collaboration'. We separated these publications and among the remaining publications, if the affiliation of any target author was from a university, college, or academia, we marked it as 'Academy-Industry collaboration'. With the remaining articles, we moved forward to know the other types of collaboration.

As every downloaded article of Scopus contains EID (Unique Academic Work Identifier) tag and every downloaded article of Web of Science contains UT (Accession number), we searched common UT/EID between all articles of scientists of the same organization. If duplicate UT/EID were found for the same articles under two different women scientists' names (source author), it implies the articles were written jointly by those two authors of our sample organizations (between women of the same organization). Articles having unique UT/EID were further used to understand whether the collaboration is between the authors of the same organizations or different organizations.

The 'affiliation' tag of Scopus and 'C1-Author Address' tag of Web of Science mention the organization name only once when all authors of the article belong to the same organization. If the affiliation tag contains names of more than one institution, it means that the article has been written by authors of other organizations instead of authors of the same organization.

As indicated in table 4.12, a larger number (almost 98%) of articles were collaborative, however, their position in multi-authored articles is mostly as a member of the team than that of a leader. The percentage of the last authorship is a little higher, with roughly 27% for CSIR and DBT and 29% for DST. Somewhat lower than this figure is the percentage of women under the first authorship where roughly 20% for CSIR and DST, even lower, only 14% for DBT. Our present analysis conclusively shows that women tend to be more collaborative but they have fewer distinct co-authors over their career. Highly productive or cited authors have week collaboration networks as results have nominal link strength. This is because authors with high link strength have many co-authorship links with other authors and authors with a higher number of citations have worked together with different sets of co-authors in most of her publications as a result these do not appear in the co-authorship network. This finding in association with the earlier findings where it was suggested that women are more collaborative and less competitive than men in decision making, making them potentially better collaborators (Bart & McQueen, 2013). The fewer distinct collaborator may be explained that women do not participate in the research team to the deep extend that is expected.

Table 4.12: Nature of Collaboration among women authors

Collaboration Pattern	CSIR	DBT	DST
% of publication appeared in collaboration	99.27	99.41	98.31
Micro-group (2 authors)	10.51	8.67	16.75
Mini-group (3 to 9 authors)	82.77	76.74	75.44
Mega-group (>10 authors)	6.71	14.59	7.81
Average # Authors in Multi-authored article	5.26	7.72	6.98
% publication women served as First Author	20.83	13.95	20.80
% publication women served as Last Author	26.26	27.14	29.24
Laboratory-Laboratory Collaboration	62.42	43.36	52.49
Intra-Collaboration (between same Laboratory)	4.54	2.03	3.09
University-Laboratory Collaboration	17.21	20.93	15.15
Global Collaboration	15.83	33.67	29.26

Note: The rationale for the threshold of micro-, mini-, and mega- is based on a study conducted by Crane (1972).

Women collaborate more with authors of various other similar research industries, a maximum of 62%, but collaborate quite less, a maximum of 4%, with authors of the same organization. Authors of DBT tend to collaborate more (34%) with global authors than DST (29%) or CSIR (16%) and they (DBT women authors) have also collaborated more with authors from academia. The collaboration pattern of CSIR and DST scientists are mostly intra-institutional or with 'academic-industry and their collaboration with the peers of their organizations are negligible. The finding can also be seen through the theoretical prism of the Triple Helix model. The triple helix of university-industry-government states that the university can play an enhanced role in innovation in a knowledge-based society. India still seems to be at the stage of triple helix II where separate institutional spheres (state, academia, industry) with strong borders dividing them and highly circumscribed relation among spheres. For complete development of science, however, it is essential to develop a model of triple helix III where industry-academic-government should develop a knowledge infrastructure in terms of overlapping institutional spheres with each taking role of the other and with hybrid organizations emerging at the interface (Etzkowitz & Leydesdorff, 2000)

Collaboration at the domestic and international levels is flourishing. The number of foreign partners with the women author of these laboratories is on an ascending track in the country. At the same time, more collaboration between all sectors of collaborative agency, i.e. industry, academia, and the government is necessary for accumulating the scientific wealth of the nation. It is well established that co-authorship with international partners can help raise production size and impact as it provides women scientists more opportunity to demonstrate their potential for research excellence. Furthermore, along with the global collaboration with the authors of the USA, Germany, China, or Japan, collaboration with other productive zones too is essential, for the betterment of science.

As it was evident that collaboration is prominent among scientists of these organizations, furthermore, we measured the extent of collaboration using various scientometric tools. In scientometrics, numerical vertices value like the *degree centrality* count number of co-authors with whom any author has collaborated. This number represents Links. The *closeness* centrality measures how close a node is to other nodes in the network. Therefore high closeness score reveals a short distance between nodes. The *betweenness* centrality measures how many shortest paths connecting any two authors in the dataset run through any single node. In this study, the calculation of numerical vertices values are made through Pajek (ver. 5.09) and the visualization of the collaboration network was made using VOSViewer (ver. 1.6.15). It is well described that co-authorship of a paper server as an indicator of the direct intellectual and social relationship between two authors. The co-authorship network thus made, consists of nodes representing authors, and two authors are connected through a line (link) if they have co-authored two or more papers. The total link strength (TSL) attribute of the co-authorship network indicates the total strength of the co-authorship links of a scientist with other scientists[3]. While the number of nodes and links represent the network size, the thickness of the link represents the intensity of collaboration between two nodes. The size of nodes represents the number of publications that the author has, and if the distance between two nodes is shorter it suggests more collaboration between the two authors. Every node is represented through some colours, similar colours indicate similar groups or clusters which are related to each other.

Table 4.13: Collaboration pattern of leading authors

Name	TP	TC	LN	TLS	CC	BC
CSIR: 59 Clusters, 5427 Links, 24248 Total Link Strength, Max. authors in a cluster - 84, min. authors in a cluster – 3						
Suman L Jain, IIP	224	4326	41	442	0.441150	0.004411
R I Kureshy, CSMCRI	184	3953	48	807	0.419260	0.002593
Chitra Mandal, CEERI	154	2245	72	326	0.472288	0.006997
Sadhana Rayalu, NEERI	145	3764	30	229	0.417155	0.001128
A Gnanamani, CLRI	130	1995	31	206	0.396106	0.008015
Divya Singh, CDRI	124	2073	21	189	0.495773	0.011547
K Annapurna, CGCRI	124	1771	37	307	0.431415	0.003194
Ritu Srivastava, NPL	123	1928	50	124	0.434233	0.001052
Aruna Dhathathreyan, CLRI	122	1347	15	90	0.334901	0.001086
Sunkara V Manorama, IICT	105	4908	5	37	0.381700	0.000797
DBT: 46 Clusters, 1625 Links, 7041 Total Link Strength, Max. authors in a cluster - 21, min. authors in a cluster - 2						
Gagandeep Kang, THIRST	326	9220	275	3755	0.571848	0.285780
R Sowdhamini, ISSRM (inStem)	179	3139	31	219	0.381854	0.060792
Malini Laloraya, RGCB	84	1304	21	163	0.348422	0.012308
Subhra Chakraborty, NIPGR	76	1682	36	297	0.353474	0.009950
Soma Chattopadhyay, ILS	59	1409	14	80	0.326968	0.002117
Ruby John Anto, RGCB	52	2531	20	95	0.336014	0.014181
Sabhyata Bhatia, NIPGR	52	2046	32	175	0.356490	0.008300

[3] https://www.vosviewer.com/documentation/Manual_VOSviewer_1.6.6.pdf

Ellora Sen, NBRC	51	1380	14	100	0.319338	0.017489
Sailza Singh, NCCS	48	227	23	56	0.444191	0.024041
Maneesha Inamdar, InStem	45	892	12	27	0.335821	0.000184
DST: 92 Clusters, 6492 Links, 25154 Total Link Strength, Max. authors in a cluster - 33, min. authors in a cluster – 2						
Tanusri Saha Dasgupta, IACS	218	4626	79	445	0.407960	0.073081
Anupama G C, IIA	139	3389	99	635	0.406489	0.053720
Durga Basak, IACS	121	4269	21	163	0.349612	0.001741
N Rajalakshmi, IARCPMNM	107	3591	18	203	0.294579	0.007252
Priya Mahadevan, SNBNCBS	104	2745	31	191	0.363710	0.010577
Tanusree Kar, IACS	103	2623	30	183	0.344801	0.012809
Jyotirmayee Dash, IACS	100	2374	39	216	0.361958	0.016233
Sylaja P N, SCTIMST	100	1848	37	203	0.255090	0.000011
Namita Surolia, JNCASR	99	2698	26	203	0.351520	0.007429
Geetha G Nair, CNSMS	97	1881	20	204	0.313958	0.003660

TP= Total Publications; TC=Total Citations; LN=Links, TLS=Total Link Strength; CC= % Closeness Centrality, BC=% Betweenness Centrality

In table 4.13 and Figures 4.3 to 4.5, show collaboration patterns among a few highly productive scientists of various research laboratories. The well-known tools VOSviewer and Pajek were used for such analysis. Overall, the value in table 4.13 reveals that the number of clusters among authors of all three organizations is many. The Watts-Strogatz Clustering Coefficient among CSIR authors is 0.78255679, DBT authors are 0.76473534 and DST authors are 0.74840779, which means there are many numbers of different authors clusters that exist among scientists, and each cluster are loosely connected as they have less relatedness in publications. Important to note that most of the highly cited or highly productive authors do not have high link strength.

The closeness value which measures the average shortest distance between a node and the rest is highest for Gagandeep Kang, (Former THIRST scientist, DBT) followed by Divya Singh, of CDRI, CSIR. In DST, Tanusri Saha Dasgupta, IACS shows the shortest closeness value among other top scientists. The highest centrality indicates that these nodes as more central than the other nodes of the graph. On the other hand, the degree of betweenness indicates the captures of a person's role in allowing information to pass from one part to another. The higher value of betweenness indicates the important role in the flow of information through this network. Technically, it measures the percentage of shortest paths that must go through the specific node. Here the betweenness value has been observed highest for Gagandeep Kang followed by Tanusri Saha Dasgupta, IACS and R Sowdhamini, ISSRM, while the rest have almost similar betweenness value. This may be interpreted that Dr. Kang has greater influence over the flow of information as she has enough publications. The common highest closeness and betweenness among DST and DBT authors indicate that they are the main author with a direct linkage to other authors. It was important to detect structural holes in the network under the important node. The structural hole identifies that link or author which if removed would discontinue clusters of authors. It is observed in Figures 4.3 to 4.5 that in all three laboratories the structural hole belong to nodes that are predominantly occupied by a male author.

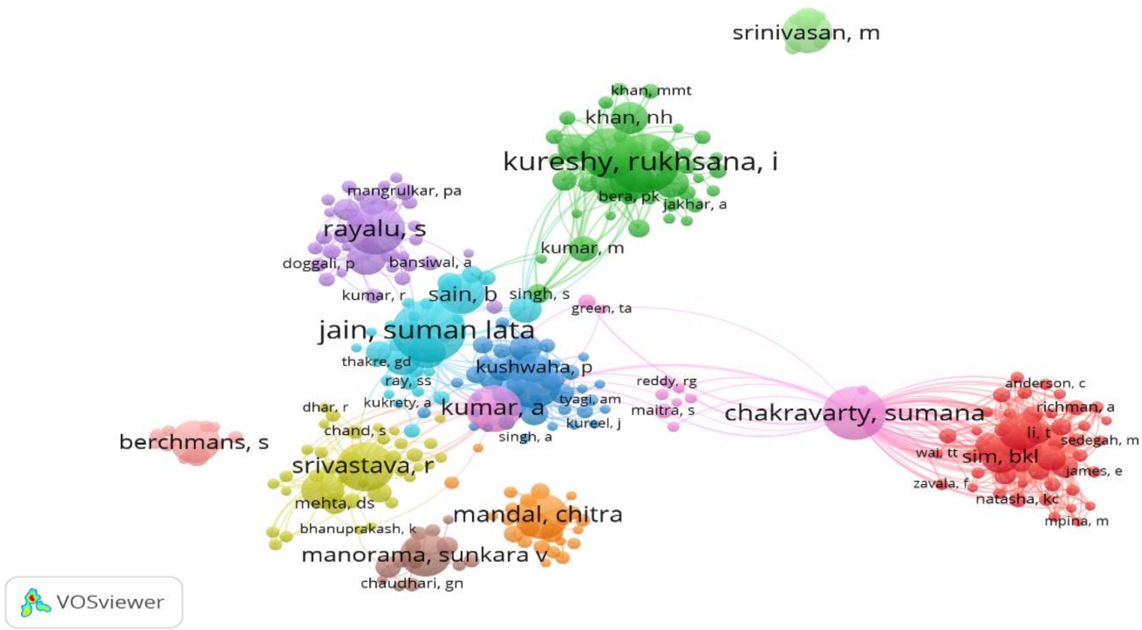


Fig. 4.3: Collaboration pattern of leading CSIR authors

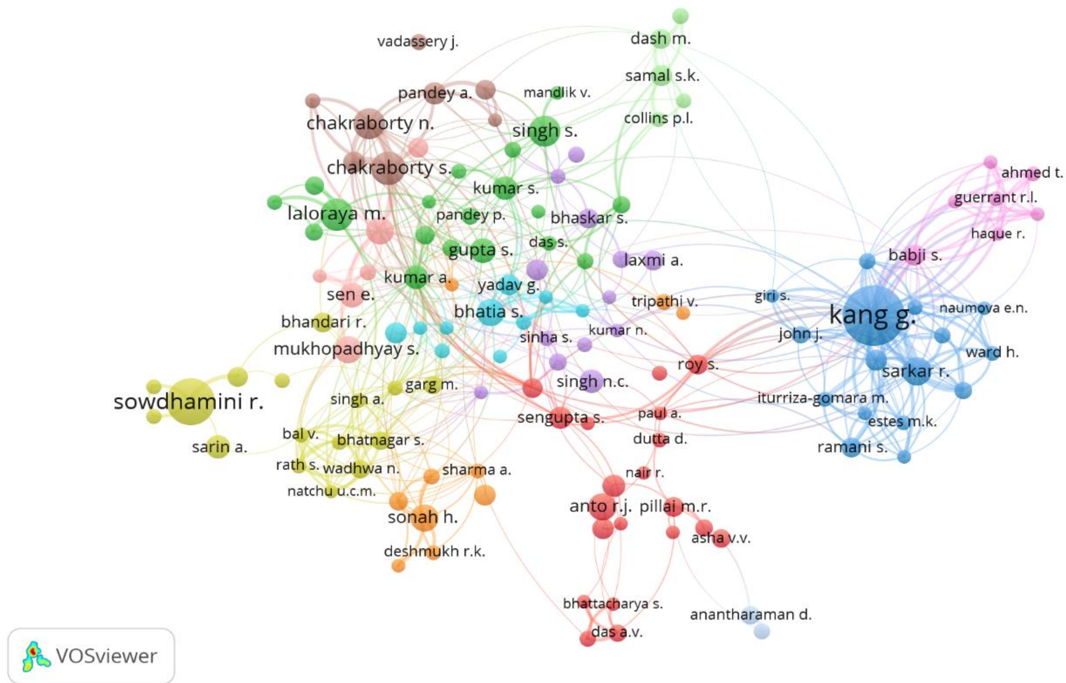


Fig. 4.4: Collaboration pattern of leading DBT authors

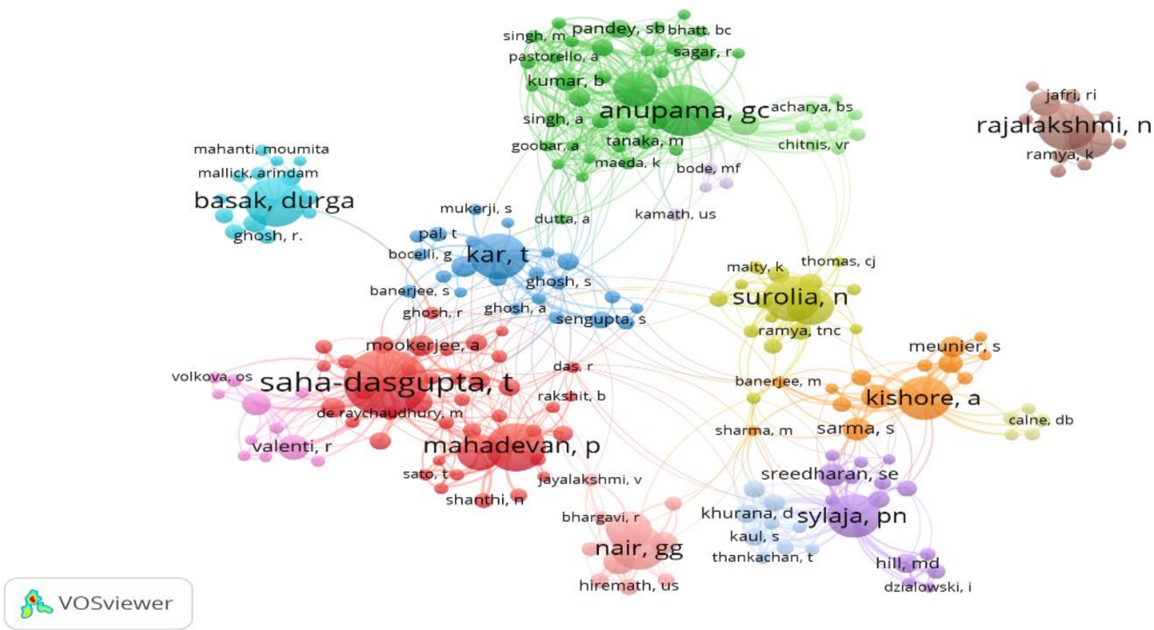


Fig. 4.5: Collaboration pattern of leading DST authors

4.4 Research performance in terms of Subjects of Interest

One of the most critical considerations of this study was the identification of the major domain of research among Indian women scientists and which emerging research fronts were most active or developing rapidly. For that, this research followed three steps: in the first, all the sub-fields under which the downloaded publications appeared were identified; in the second, all these sub-fields were categorized into a framework of major domains of research; and in the third, discovering the emerging research fronts by analysing the number of articles published and citations received during a period under major research domains. It is well known that although *Scopus* results show publication under various subjects, the downloaded results do not contain any tag like the broad 'Subject' of publication. Whereas, downloaded results of the WoS database contain tags like 'WC' and 'SC', among which the tag 'SC' displays the 'Research Fields'. To group publications under various sub-fields, therefore, we considered the 'SC' fields of WoS and arranged all publications under the major sub-fields. The number of sub-fields under which all the publications came was almost 1328. Therefore, it was essential to develop a framework for grouping all these sub-fields into a cluster of broad fields to a considerable limit.

To develop a framework, we consult the Essential Science Indicator (ESI) maintained by Clarivate Analytics and the *Revised Fields of Science & Technology* (FOS) classification in the Frascati Manual of OECD (2007) to understand how the subjects of science can be grouped in a best possible manner. Both the classification schema organizes related subjects under a broad subject category. On consulting both the schemas we have developed a new schema consisting of 20 broad fields. The reason behind developing a new schema was the existing two frameworks do not fully compatible to show the emerging and important research areas of Indian science and technology. For grouping subjects, two principles have been kept in mind, viz. 1). Specific research fields are preceded by General research fields and if any publication has 'practice' as well as 'theory' emphasis, the publication has been kept in practice sub-fields. Table 4.15 explains the subjects that are derived by the above-mentioned techniques and the frequency of occurrence of the terms.

Table 4.14: Subject of interest among scientists of various organizations

Code	Subject of Interest	CSIR	DBT	DST
MM	Mathematics (Statistics, Probability, Applied & Pure Mathematics)	14	01	10
SP	Astronomy, Astrophysics, Space Science	13	00	778
CS	Computer Science (Information Science & bioinformatics)	88	04	07
PY	Physical Sciences (Nuclear, Condensed matter, plasma, optics, acoustics, particle physics, Spectroscopy)	944	15	568
EG	Engineering (Civil, Electrical, Mechanical, Metal & Metallurgy, Chemical Engineering)	1460	27	187
MT	Materials Science (nono-science, polymer science, Crystallography)	1639	49	595
CH	Chemical Sciences (Physical, Organic, Inorganic, Nuclear, Electrochemistry, Analytical etc.)	2201	101	653
BM	Biochemistry & Molecular Biology, Bio-physics, Cell Biology	1250	680	406
BC	Biological Sciences (Fresh Water Biology, Marine Biology, Bio-diversity Conservation, Limnology, Plant Science, Animal Science)	605	249	125
EV	Environmental Science & Ecology, Environmental Engineering, Environmental Law	584	05	62
GS	Earth & Related Sciences (Geophysics, Geochemistry, Paleo science, Oceanography, Meteorology, Geography)	712	2	402
BT	Biotechnology (Medical Biotechnology, Industrial Biotechnology, Environmental Bio-technology, Agricultural Bio-technology, Microbiology, Applied, Food Science & Technology, Virology)	1391	257	236
AG	Agricultural Sciences (Forestry, Fishery, Animal Husbandry, Veterinary Science, Agronomy, Horticulture, Viticulture)	130	45	106
MH	Medical & Health Sciences (Clinical Medicine, Neuro Science & Neurology, Immunology, Physiology, Toxicology, Parasitology, Infectious Diseases, Nursing, Nutrition)	1091	537	695
PM	Pharmacology & Pharmacy (Pathology, Medicinal chemistry, Drugs)	920	182	189
MD	Multidisciplinary	990	345	1013
EC	Economics Business	8		2
PC	Philosophy, Psychology, Psychiatry	11	7	
SS	Social Sciences (Sociology, History, Political Science, Demography, General Law, Public Administration)	14	10	2

NL= No. of Laboratories, NS= No. of Scientists, NA= No. of Articles

Note: Biological Sciences including marine and freshwater biology, biochemistry, mycology etc.; Biotechnology including food, agricultural and industrial biotechnology etc.; Medical Sciences includes pharmacology, disease, vaccine etc.; Chemical Sciences including polymer science etc.; Physical Sciences including, astronomy and astrophysics; Earth Sciences including geochemistry and geophysics, seismology etc.; Materials Science and Nanotechnology including reinforced fibers and fabrics etc.

From table 4.14 it is evident that chemical sciences (2201 publications), material sciences (1639 publications) and engineering (1460 publications) are the three predominant fields of research among the women scientist of CSIR, however, in DBT, biochemistry & molecular biology (680 publications), medical sciences (537 publications) and biotechnology (257 publications) are the three major fields of interest. In DST, astronomy, atrophysics & space science (778 publications), medical science (695 publications) and chemical science (653 publications) are three major choices of research among scientists.

Key Research Terms

Based on the occurrence of similar terms in the 'Author Keyword' field, core research terms have been identified. In other words, key terms are highly occurred terms in the published articles by women scientists. There is almost 26884 keyword in CSIR, 5235 in DBT, 10267 in DST have been found in all 22617 articles. Table 4.16 displays only the top 25 key terms in total based on decreasing occurrence.

Table 4.15 Top Key Research Terms

Terms	CSIR	DBT	DST
apoptosis	139	57	34
oxidative stress	97	13	17
cytotoxicity	56	10	17
reactive oxygen species	55	11	12
genetic diversity	25	13	10
microstructure	90		18
x-ray diffraction	81		23
nanoparticles	59		33
plasmodium falciparum	19		48
mechanical properties	45		21
polarization	14		50
photoluminescence	36		27
antioxidant	44		16
Chitosan	37		20
parkinson's disease	19		38
self-assembly	26		30
fluorescence	36		16
gene expression	37	14	
optical properties	31		20
malaria	31		18
curcumin	35		12
sol-gel	33		14
tuberculosis	37	10	

As indicated in table 4.15, the most frequently occurred key terms of all these three laboratories are apoptosis (is a form of programmed cell death that occurs in multicellular organisms), oxidative stress (is an imbalance of free radicals and antioxidants in the body, which can lead to cell and tissue damage), cytotoxicity (is the quality of being toxic to cells), reactive oxygen species (are highly reactive chemical molecules formed due to the electron receptivity of O_2), genetic diversity (is the total number of genetic characteristics in the genetic makeup of a species).

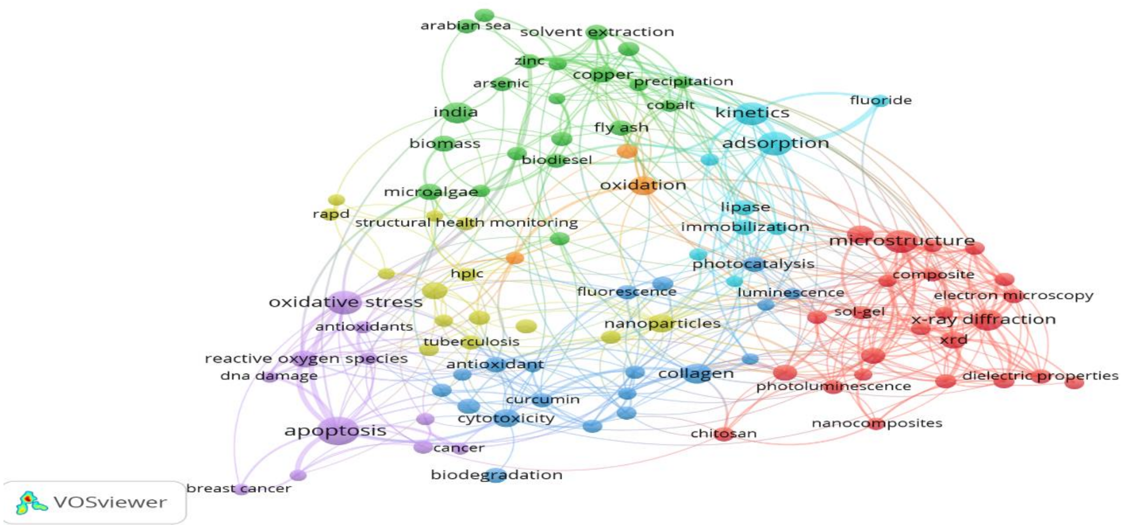


Fig 4.6: Key Terms of CSIR

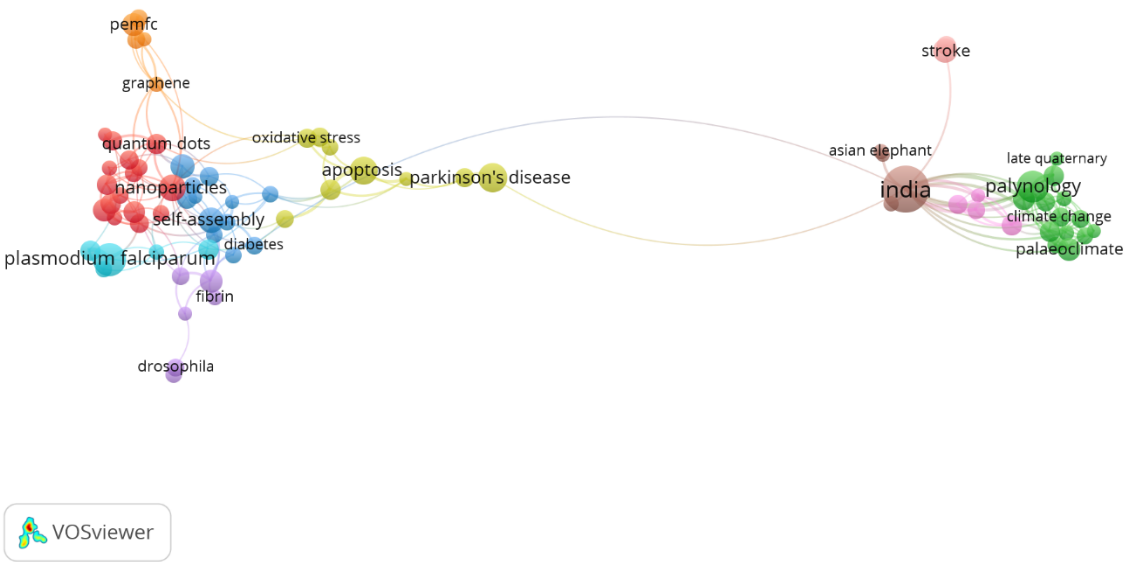


Fig 4.7: Key Terms of DBT

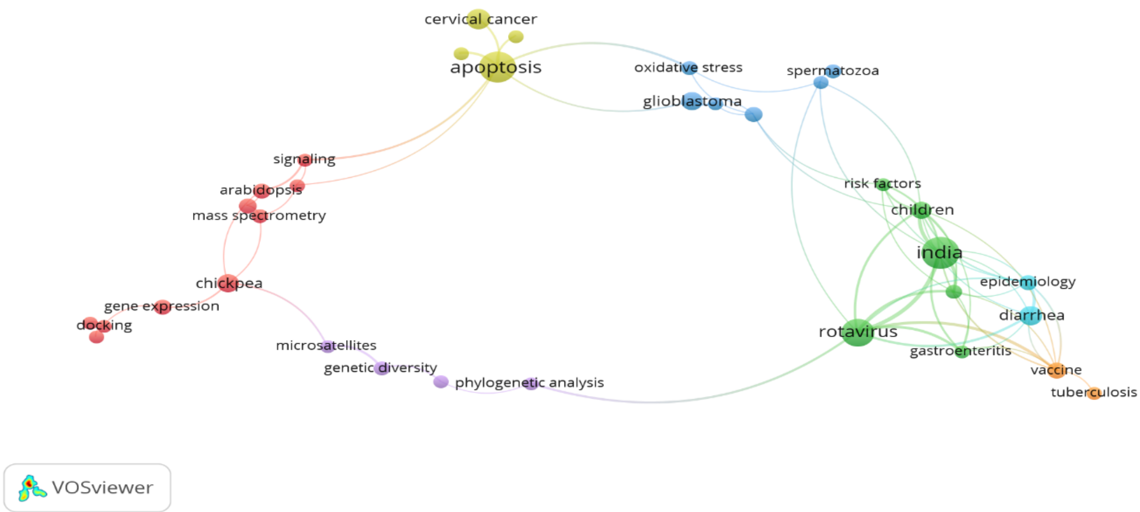


Fig 4.8: Key Terms of DST

Key Research Fronts

By tracking the most significant research output that gathered attention among scholars within a short period and grouping those correlated papers as clusters of papers help to identify the 'Research Fronts'. Research fronts data reveals links among researchers working on related threads of scientific inquiry, even if the researchers' backgrounds might not suggest that they belong to the same subjects. To unfold the emerging research fronts, we further analysed the 'Author keyword' tag of Scopus and the 'DE' tag of WoS. By tracking the frequently appearing keywords of the downloaded articles and the pattern of citations of the articles where those keywords appeared during a period, research fronts were identified. After identifying key fronts, we have calculated their CPT value. In the CPT, C represents the citations that the article received where the term appeared; P is the number of papers where those terms appeared; and T indicates the age of term, which is the number of publishing years from the earliest year of a published paper to the latest one. For example, if the most recent published paper came in 2019 and the earliest one came in 2014, the age of the article (T) will equal 6. The formula adopted for counting the CPT value is:

$$CPT = (C/P)/T$$

Table 4.16: Key research fronts of publications by women scientists

Research Front	CPT Value			
	Overall	CSIR	DBT	DST
Apoptosis for the cure of cancer for various age groups and organs of humans.	1.5048	1.4424	1.8712	2.7555
Identification of factors causing **oxidative stress** and DNA damage in various organs.	1.43771	1.318972	2.092308	7.99
Cytotoxicity of various foreign elements in human cells.	1.963801	1.641026	5.761905	2.706612
Cause and effect of **reactive oxygen species** damaging the DNA, RNA, and proteins in cells.	1.842141	2.612732	2.092593	1.858586
Genetic diversity and phylogeny analysis of various species.	0.585897	0.687831	0.767677	0.672222
Determination of structure, characteristics, properties, behaviour and defects of materials using **x-ray diffraction** technology.	0.790139	0.829012		0.791667
Identification of anti-malarial drugs and therapies to boost immune system and prevent susceptibility against **plasmodium falciparum.**	0.920455	1.56427		0.854783
Investigation of the **microstructure and mechanical properties** of hybrid nanocomposites.	1.089524	1.519871		0.578846
Photophysical, thermal, optical and chemical properties of luminescence from transition metal ions doped nanoparticles.	1.084259	0.935215		1.397701 1
Various aspects of **polarized lined formation** with respect to frequency redistribution in arbitrary magnetic fields.	0.540274	1.685897		0.389778
Determination of **antioxidant activities** of various biochemical extracts of various plants and animal species.	1.007862	1.28677	1.7725	0.548148
Development, optimization and biological evaluation of hybrid nanoparticles based on **chitosan** and their applications in various medical aspects.	2.741602	2.361111	17.44318	1.548611
Implications of motor vulnerability associated with **Parkinson's disease** and nueroprotective and neurorescue effect of various dopamine-lesioned rat models of **parkinson's disease**.	1.201079	1.537946		1.27566
Study on the structural, chemical, medicinal properties as well as formation of self-assembled supramolecular polymers and nanostructures.	1.065686	0.923214		2.478260
Removal of fluoride and other contaminants from aquods solution as well as environment by **adsorption**.	1.701507	1.713649		4.24
Influence of various nanoparticles on properties of **collagen** based biocomposites for possible biomedical applications.	0.806996	0.808279		3.028571
Photometric and spectroscopic observation of various types of supernova.	1.709447			1.709447
Theoretical and Experimental studies for the development of self-healing coatings for **corrosion** protection of various alloys.	0.822763	0.851543		0.915625
Gene expression profiling for identification and cure of sex organs cancer.	0.882352	0.772515	1.482683	
Augmentation of therapeutic potential of **curcumin**.	2.35868	2.321429		3.841346

Discussions on Top ten Research Fronts:

(1) Development, optimization and biological evaluation of hybrid nanoparticles based on chitosan and their applications in various medical aspects.

The research on chitosan-based nanoparticles has been quite popular for the last two decades. As chitosan is one of the most functional natural biopolymers which has two much-needed qualities in biocompatibility and biodegradability which has led to its wide application in the pharmaceutical field. Our women scientists have also shown keen interest in this research field. The overall CPT value for this research topic is 2.7416 and the highest CPT value is for DBT (17.4431) followed by CSIR (2.3611) and DST (1.5486). Although DBT has contributed only 11 articles, it has a whooping CPT value of 17.4431 as it has all the articles published within a period of only 8 years and has garnered 1535 citations comparatively way more than the other organizations. It was also noticed that 9 out of these 11 articles has been co-authored by Momani Das and 1 article has alone received 1406 citation which has resulted in such a huge CPT value for DBT. The research has also paced with time as more than 38% (33 out of 86) articles have been published in the last five years of research i.e., since 2015. Sadhana Rayulu has contributed a maximum of 15 articles and Prabha D Nair, Rekha MR, and Ira Bhatnagar are some of the major contributors. It is also interesting to point out that more than 50% of publications of CSIR (25 out of 48), almost 50% publications of DST (13 out of 27) and 45.45% publications of DBT (5 out of 11) has been co-authored by our women scientists as either first or last author. DBT-Institute of Life Sciences, DST-SCTIMST, Agharkar Research Institute, CSIR-CECRI, NEERI, CLRI, CFTRI and CCMB are the top contributing institutions of this topic.

(2) Augmentation of the therapeutic potential of curcumin.

Scientists have developed various chemical combinations to treat diseases but to effectively use, apply or deliver these chemical combinations into the human body is another challenge. Our women scientists have often tried to resolve this problem and in the process, they came to determine the therapeutic potential of curcumin which exhibits a wide range of medical applications for various diseases. The overall CPT value for this research topic is 2.3586 and the CPT value for DST and CSIR are 3.8413 and 2.3214 respectively. DST has contributed 13 articles within a period of 16 years and has received 799 citations whereas CSIR has contributed 28 articles within a period of 13 years but received 845 citations, comparatively lower than DST. It is worth noticing that this research topic has evenly caught the attention of a lot of women scientists in the field. There are no women scientists who have contributed a lot more than others, they have an even contribution of 1 to 3 articles each. This research has gained quite a lot of popularity in the last 5 years which is indicated by the fact that 43.9% of the total publications (18 out of 41) have been published from 2015 to 2019. Sridevi Annapurna Singh, Tanya Das, Manju S, Purnima Tiku Kaul and L Suguna are a few notable names of the field. It is also interesting to point out that 53.57% publications of CSIR (15 out of 28) and 38.46% publications of DST (5 of 13) have been co-authored by our scientists either as first or last author. DST-SCTIMST, Bose Institute, INST, CSIR-CFTRI, CDRI, CLRI, etc are the institutions contributing to this topic.

(3) Cytotoxicity of various foreign elements in human cells.

Cytotoxicity is the quality of foreign elements which results in cell damage or cell death. Scientists from all over the world have tried to find such elements which be used to cause cell damage and death so that they can apply them in killing cancer cells and other medical uses. In the same process, our women scientists have also shown interest in this research area for the past decade. The overall CPT value for this research topic is 1.9638 and the CPT value for DBT, DST, and CSIR are 5.7619, 2.7066, and 1.641 respectively. The higher CPT value for DBT is the result of the fact that although its scientists have contributed only 9 articles within a period of 7 years but have amassed 363 citations which are way better than their counterparts DST and CSIR who have received only 655 and 1152 citations for 22 and 54 articles within a time span of 11 and 13 years respectively. It was also found that CSIR scientists have shown more interest in this research area in the past few years and have contributed more than 50% of articles in the period 2015 to 2019 whereas there has been an incredible downfall in the interest of DBT and DST scientists who have altogether published only 5 articles after 2015. It is also interesting to point out that no scientist has published more than 3 articles in this field. A S Shiras, Prabha D Nair, Jyutika M Rajwade, Manju S, and

Priya S are some notable scientists with significant contributions. It was also found that 27.78% of publications of CSIR (15 out of 55), 50% of publications of DST (11 out of 22), and 22.22% publications of DBT (2 of 9) have been co-authored by our scientists as either first or last author. RGCB, NCCS, SCTIMST, ARI, INST, IICT, CDRI, IIIM, etc are the institutions contributing to this topic.

(4) Cause and effect of reactive oxygen species damaging the DNA, RNA and proteins in cells.

Reactive oxygen species are free radicals. They are natural biproducts of cellular oxidative metabolism and play important roles in cell survival, signaling, differentiation, and even death. Scientists have shown keen interest in finding out the cause and effect of reactive oxygen species in human cells and their biomedical applications. The overall CPT value of this research topic is 1.8421 and the CPT value for DBT, DST and CSIR are 2.0925, 1.8586, and 2.6127 respectively. CSIR has received maximum of 1970 citations for 58 articles within a period of 13 years whereas DBT and DST have received 565 and 184 citations for 15 and 9 articles within a period of 18, and 11 years respectively. The first literature of this field from our scientists came for a DBT scientist in 2001 but regular articles have been published by our scientists only after 2006. There has been seen quite a significant increase in the publications from 2015 as 37.8% of the total publications came in the period 2015 to 2019. Chitra Mandal, Poonam Kakkar, and Sneha Sikta Swarnakar are some of the notable scientists who have contributed significantly to the field. It is worth mentioning that 66.67% of publications of DBT (10 out of 15), 77.77% of publications of DST (7 out of 9), and 62% publications of CSIR (36 out of 58) have been co-authored by our scientists as either first or last author. NBRC, NCCS, RGCB, BI, CDRI, etc are the institutions contributing to this topic.

(5) Photometric and spectroscopic observation of various types of supernova.

Supernova is a powerful and luminous stellar explosion. Astrophysicists across the world have shown keen interest in finding the cause and effect of a supernova. Our women scientists have also researched in this area for more than a decade. The overall CPT value is 1.7094. Since this research topic is a subject of interest only for astrophysicists, all the work studied on this topic under this project has been contributed only by two DST institutes namely the Indian Institute of Astrophysics (IIA) and Aryabhatta Research Institute of Observational Sciences (ARIOS). There have been 51 articles within a period of 11 years that have received 959 citations. All these works have been primarily contributed by two scientists Anupama G C of IIA and Kuntal Mishra (ARIOS). There has been an increase in the frequency of research with time as 56.86% of total publications came in the last 5 years of the study period. It is also worth mentioning that nearly 10% of the total work has been co-authored by our scientists as either the first or last author.

(6) Removal of fluoride and other contaminants from aqueous solution as well as the environment by adsorption.

Fluoride and other contaminants when available in an aqueous solution or environment raise several health-related issues. Scientists have tried to resolve this problem in the process they have shown keen interest in the adsorption technique for removal of these contaminants. Our women scientists have been researching this topic for almost 3 decades. The overall CPT value for this research topic is 1.7015 and the CPT value for DST and CSIR are 4.24, and 1.7136 respectively. Although CSIR has contributed almost 11 times more publications than DST, DST has a way better CPT value since it has garnered comparatively more citations in a much less period. DST has received 424 citations for 10 articles in just 10 years whereas CSIR has taken 27 years' time to receive 4997 citations for 108 articles. 31.35% of the total publications came in the last 5 years of the study which reflects that this research topic has gained more popularity among scientists. Sadhna Rayulu has co-authored the maximum number of works (21). Aruna Dhathathreyan, S Mayadevi, M G Sujana, Mamata Mohapatra, and Sushree Swaroopa Tripathy are some of the significant contributors. Interestingly 66% of the total publication (78 out of 118) has been co-authored by our scientists as either first or last authors. IMMT is the highest productive institute on this topic. CLRI, NEERI, CECRI, RRI, etc are some other institutions contributing to this topic.

(7) Apoptosis for Cure of cancer for various age groups and organs of humans.

Cancer has been one of the most dangerous diseases in the world which has targeted every age group and organ of the human body. There is no guaranteed cure for this disease and hence it is very necessary to assess this problem and develop a cure. For this purpose, our women scientists also participated in this area of research to determine the cause and remedy of this disease. In this process, apoptosis is a very much needed step that has been researched by our scientists and the results have been published through a significant number of research papers. The overall CPT value for this research topic is 1.5048 and the highest CPT value is for DST (2.7555) followed by DBT (1.8712) and CSIR (1.4424). Although CSIR scientists have contributed for a maximum of 132 articles within 20 years but could only receive 3808 citations which resulted in their lowest CPT value, whereas DST scientists contributed a minimum of 34 articles within 16 years, but they received better citations (1499) which resulted in the highest CPT value. It is also worth noticing that this research has paced with time, as more than 35% of all the articles (77 0f total 218) have been published in the last 5 years i.e., since 2015. Neeru Saini, Chitra Mandal, Tanya Das, Apurva Sarin, Poonam Kakkar, and Sarika Singh are the major contributors who have contributed more than 10 articles each. It was also observed that 63.46% of publications of DBT (33 out of 52), 47% publications of DST (16 out of 34), and 66.67% publications of CSIR (88 out of 132) have been co-authored by our scientists as either first or last author. InSTEM, RGCB, NCCS, BI, CDRI, IITR, IICB, etc are the institutions contributing to this topic.

(8) Identification of factors causing oxidative stress and DNA damage in various organs.

Our women scientists have been researching this topic for nearly three decades. The overall CPT value for this research topic is 1.4377 and the CPT value for DBT, DST, and CSIR are 2.0923, 7.99, and 1.3189 respectively. Although CSIR has contributed the highest number of articles (98), DST has the highest CPT value as it has obtained comparatively more citations within a much less period. CSIR has received 3490 citations for 98 articles within a period of 27 years whereas DST has received 799 citations for only 10 articles in 10 years. On the other hand, DBT has received 408 citations for 13 articles in 15 years. This research topic has gained significantly high popularity in the last decade as nearly 50% of the total publications (60 out of 121) have been published in the last five years of the study. Chetana Singh, Poonam Kakkar, S L Sitasawad, Smrati Bhadauriya, and Sneha Sikta Swarnakar are some of the predominantly contributing scientists of the field. It is also interesting to point out that 53.72% of the total publications (65 out of 121) have been co-authored by our scientists either as first or last author. CDRI, IITR, and IGIB are the main contributing institutions of this topic.

(9) Implications of motor vulnerability associated with Parkinson's disease and neuroprotective and neurorescue effect of various dopamine-lesioned rat models of Parkinson's disease.

Parkinson's disease is a disorder of central nervous system that affects movement often including tremors. Scientists have been trying to cure this disease and lower its post-disease effects. Our women scientists have been researching this topic for more than 2 decades now. The overall CPT value for this research topic is 1.201 and the CPT value for DST and CSIR are 1.2756 and 1.5379 respectively. DST has published 31 articles in a period of 22 years and has received 870 citations while CSIR has received 689 citations for 28 articles in a period of 16 years. This research topic has also gained popularity with time as 45.76% of the total articles (27 out of 59) have been published in the last five years of the study. Asha Kishore has been the highest contributor who has contributed 44% of the total work whereas Chetna Singh and Shubha Shukla are other significant contributors. Interestingly more than 60% of the total publications (30 Out of 59) have been co-authored by our scientists as either the first or last author. Shree Chitra Tirunal Institute of Medical Science and Technology (SCTIMST) is the highest productive institute of this field followed by the Indian Institute of Toxicology (IITR) and Central Drug Research Institute (CDRI).

(10) Investigation of the microstructure and mechanical properties of hybrid nanocomposites.

In Today's world nanocomposites is one of the most important materials widely used in almost every sector of science and technology. Scientists have been studying different strategies to develop and enhance superior nanomaterials with enhanced microstructure and mechanical properties. Our women scientists have been working on this research topic for more than two decades. The overall CPT value for this research topic is 1.0859 and the CPT value for DST and CSIR are 0.5788 and 1.5198 respectively. CSIR has been a much better productive organization for this research topic. DST has produced 26 articles in 20 years which has received only 301 citations whereas CSIR has produced 49 articles in 19 years and has received 1415 citations. This research has also gained popularity with time as 36% of the total productions has come in the last five years of the study period however it is worth mentioning that this increase in popularity is only for CSIR scientists as reflected by their contributions (21 out of 49) whereas DST has significantly poor contribution (6 out of 26) during this period. Suman Kuman Mishra, Sushree Swaroopa Tripathy, R Subasri, and Tanusree Kar are significant contributors to the topic. It is also worth mentioning that 68% of the total publications (51 out of 75) has been co-authored by our authors as either first or last author. Many institutions are contributing to this topic namely CGCRI, IMMT, AMPRI, NAL, SERC, IICT, CLRI, NML, NPL, ARCI, INST, IACS, etc. CSIR-CGCRI is the most productive institute of this research topic.

Chapter V: Conclusions & Recommendation

The findings, interpretations, and conclusions expressed in this work do not necessarily reflect the research productivity trend among women of the whole of India. Our sample was currently working women of R&D laboratories of Ministry & Science & Technology only. The analysis is based on the data that were compiled and/or collected by the project staff "as is, as available" in the databases like Scopus and Web of Science. One should also keep in mind the limitations in searching and/or database. In this report, no attempt has been taken to trace the reasons or track the trends in gender inequality in Indian science, as we believe that even if at the present rate the disparities become lessen, it will take nearly a century to achieve parity, a timeline we simply cannot accept in today's globalized world.

During our investigation we observed the 'People/Staff' pages that includes information on individual scientists in the websites of the organizations are quite unstructured and maintained improperly. In most cases, this page does not bear the basic information of its scientific staff such as Name, Designation, DOB, DOJ, etc and latest curriculum-vitae of the scientist. Organizations must develop a dynamic website and encourage scientists to maintain their page in a structured manner as well as update the information frequently. In case a scientists leave the organization or promoted to higher post, the same must be reflected in the website. In this regard, the websites of NIO, may be considered as reference.

According to the World gender gap report (2020), India is one among two countries having a distinctively small gender gap in STEM higher education. However, in the same report, it is revealed that India is among four-country of the world where the women labour force is only 22%. This trend is almost same for women working in R&D laboratories of the Ministry of Science and Technology, GoI. Therefore, it is essential that government should emphasize more on policies that are necessary for attracting young women minds towards choosing career in R&D sectors for the overall improvement of science system in India.

While searching women names in International databases, we observed incomplete coverage of publications of a scientist. This is more because of use of variant form of scientist's forename or different way of rendering the scientist's forename and surname. Despite of the efforts like ResearcherID, Scopus ID etc. such anomalies are widely existed. Therefore, laboratories must work with their authors to identify all publications against an individual and linked with the correct unique identification number like ResearcherID or Scopus ID.

The study shows that, in all the three organisations the appointment policy for junior positions such as Scientist B and C were quite nominal and promotion policy for senior positions such Scientist E and F were non-uniform. To encourage the participation of women scientists towards qualitative research, organisations should implement standard appointment policy whereby giving preference to applicants with higher degree, the appointment/promotional policy may be reformed by adding supplementary support for women in the form of flexible publication and research tenure to ensure that women (and men) who interrupt their career during their child bearing years will not jeopardize their future career. Training, access to funds may be given more flexible for women.

The analysis of productivity difference between women scientists of various Scientific R&D laboratories shows no significant difference across laboratories. CSIR have large women scientist but DST women authors produced more articles per scientists. On the other hand, DBT women received more citations per article than DST or CSIR authors, but scientific strength is highest among DST scientists than DBT. Interestingly, the h-index of CSIR authors is highest followed by DST and DBT. A major portion of authors of all these three organizations having publications between 20 and 49 of their credit, which is quite promising. The fractional count and normalization count also reveals the almost equal publication profile, with slight variations, among scientists. Therefore, a uniform policy may be helpful for the overall improvement of women's participation in science. However it is observed that organizations having more women scientists having more h-index, scientists having higher qualifications like post-doctoral fellow or Ph,D, have more publications, women scientists collaborate more with international authors and having publication in high impacted journals received more citations, laboratories with more technology oriented specialization having more patents. Studies shows that organizational factors, particularly scientist's reward systems, and compensation, influence the productivity of technology transfer activities of a scientist and thus motivate the scientists to disclose their inventions. Therefore, a national policy is needed to recruit more qualified women in R&D sectors because researchers who are active in their younger years gain more scientific capital, thereby accessing more resources, which in turn, help them stay productive. Furthermore, a study by the National Centre for Women in Information Technology of the United States found that a research team with a great diversity of humans with all sexes tended to cite more than a single-sex applicant. This suggest that collaboration in the development of patents are more useful and in the Indian context, it will also help women scientists to get more citation to their articles and patents.

A considerable number of patents, although it is as low as 0.9 patents per scientist, are granted under the credit of CSIR women scientists in recent time. It was also observed that several women scientists of DBT are the recipient of the various prestigious awards of the Government of India. These awards are conferred upon those who have made an outstanding contribution to science. All these may be promising indicators related to the increased participation of women in different laboratories. Earlier a few seminal studies have shown a positive relationship between a scientific publication and patenting activities (Agrawal &Henderson, 2002), one should keep in mind that publication and patenting are complementary and not competing activities of researchers (Jensen &Murry, 2005). Siegel et al. (2003) in this regard, showed that organizational factors, particularly scientist's reward systems, and compensation, influence the productivity of technology transfer activities of a scientist and thus motivate the scientists to disclose their inventions.

The results also show that majority of the highly productive scientists have post-doctoral or doctorate degrees who at present make up the staff of the research laboratories. This suggests that researchers who are active in their younger years gain more scientific capital (Bourdieu, 1975), thereby accessing more resources, which in turn, help them stay productive. This also supports because we observed that during the first 10 years of the service age, women scientists produced more afterward decrease sharply but again start raising after 15 years of service. In terms of physical age, it is showing that most of the publications came between age 31 and 40 and then decrease slowly with the increase of age. This may be because they strive for getting the promotion to a senior position, one needs a long publication list to justify the promotion. Our results corroborate the view that 'the young female researchers are more productive than the older' (Stroebe, 2010). However, per scientists publication reveals that there is a continuous increase of publication with the increase of service and physical age. This may be because active scientists sustain their productivity at a high level throughout their careers. Longitudinal analysis following the career of cohort scientists during many decades could show conclusively that whether those older scientists who remain highly productive are the same as those who were productive at their younger age. Our data nonetheless shows that per scientists publication reaches its maximum during their fifties or after serving 15 years of service. The decline is due to the fact that after attending at a certain age few scientists are less active in research and stop publishing. Therefore, it may be fair to say that science is a collective endeavor and as our data shows, scientists of all ages play an effective role in dynamics.

Our results have also science policy implications. At a time when the government is re-evaluating the policy of retirement age, the fact that older scientists still play an effective role in the productivity of scientific literature cannot be neglected. Moreover, if the turning point at the age 31 to 40 are relatively stable in a truly longitudinal sense or similar cohort in other subjects and gender, then providing better funding opportunities to younger scientists would give them more lead time to strong productivity before settling into a plateau.

We examined the collaboration pattern and found an increasing trend of collaboration among DBT scientists than DST or CSIR. The growth substantially increased from 2009 onwards. The diminishing fractional count of paper also suggests the size of collaboration increasing. Most importantly scientists of DBT collaborate more with the international scientific community. A study by the National Centre for Women in Information Technology of the United States found that a research team with a great diversity of humans with all sexes tended to cite more than a single-sex applicant. This suggest that collaboration in the development of patents are more useful and in the Indian context, it will also help women scientists to get more citation to their articles and patents. It is also important for more participation of women scientists in various innovations as the study suggested that full female participation and integration into the labour force could boost global gross domestic products (GDP) by as much as 26 percent (McKinsey Global

Institute. 2015. *The Power of Parity: How Advancing Women's Equality Can Add $12 Trillion to Global Growth*. McKinsey & Co.). The policy implication of the present findings suggests that like the Chinese government, the Indian government should pay attention to a significant increase of investment to incentivize research and development as well as collaboration within and outside the national border. While providing such support, one should call attention to regional disparities that have been seen for such laboratories. Scientifically it is well established that to increase knowledge production and catch up with the more advanced region, local authorities should be aware that domestic collaboration, in particular with more advanced laboratories is more efficient than international collaboration.

Although here we have investigated the collaborative research pattern of women's contribution rather than the cause, the results suggest few remedies for the sustainable science system. From a collaboration perspective Shrum, Genuth and Chompalov (2007) identified 4 factors of better collaboration – inter-personal collaboration (relation among scientists), the funding context, the sectoral context (academic, government), and the context of participating organization (university, research laboratories, etc.). While the first context is person-related, the last context is policy-related. With the assumption that women would like to collaborate more, better organizational behaviour, positive attitude from grant allocating institutions, and an enthusiastic attitude from the organization may lead to a better tomorrow.

The results paint a picture that some branches of science such as chemical science, biosciences, medical sciences, engineering etc. receive more attention among women scientists. For quite a long time India has been at the forefront of research in these fields. This suggests that intellectual preference might not be influenced by gender. At the same time, the growing attention of fields like nano-science, space science, environmental science, drug discovery is a positive sign of the Indian science system. According to the World gender gap report (2020), India demonstrates larger shares of women across the most segmented professions Engineering and Cloud Computing. The lowest participation of women in mathematical sciences may be an indication that females may have a lack of early exposure to mathematics.

The people/thing theory hypothesis suggests that females are more slant towards people-oriented subjects, while males are thing-related subjects. However, exceptions also exist as subjects like patients or surgery although are people-related themes but predominantly researched by the male. In the results of the present study, we observed that females are more in fields like bioscience, medical science than mathematics, computers, or physical sciences.

References

Abramo, G., D'Angelo, C. A., & Caprasecca, A. (2009). Allocative efficiency in public research funding: Can bibliometrics help?. *Research policy*, *38*(1), 206-215.

Adamo, S. A. (2013). Attrition of women in the biological sciences: Workload, motherhood, and other explanations revisited. *BioScience*, *63*(1), 43-48.

Agrawal, A., & Henderson, R. (2002). Putting patents in context: Exploring knowledge transfer from MIT. *Management science*, *48*(1), 44-60.

Barjak, F. (2006). Research productivity in the internet era. *Scientometrics*, *68*(3), 343-360.

Bart, C., & McQueen, G. (2013). Why women make better directors. *International Journal of Business Governance and Ethics*, *8*(1), 93-99.

Bhandari, M., Guyatt, G. H., Kulkarni, A. V., Devereaux, P. J., Leece, P., Bajammal, S., ... & Busse, J. W. (2014). Perceptions of authors' contributions are influenced by both byline order and designation of corresponding author. *Journal of Clinical Epidemiology*, *67*(9), 1049-1054.

Bourdieu, P., The specificity of the scientific field and the social conditions of the progress of reason. *Social Science Information,* 1975, 14: 19–47.

Britton, D. M. (2017). Beyond the chilly climate: The salience of gender in women's academic careers. *Gender & Society, 31(1),* 5-27.

Ceci, S. J., & Williams, W. M. (2007). Why aren't more women in science. *Top researchers debate the evidence. Washington, DC: American Psychological Association*.

Chaudhary, K. & Dhanda, S. K. (2019). India's top science awards heavily gender skewed. Nature India. Available at: https://www.natureasia.com/en/nindia/article/10.1038/nindia.2019.14

De Cheveigné, S. (2009). The career paths of women (and men) in French research. *Social studies of science*, 39(1), 113-136.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. *Research policy*, *29*(2), 109-123.

Fox M.F., (2005). Gender, family characteristics, and publication productivity among scientists. Social Studies of Science, 35, 1, 131–150.

Fox, M. F. (1983). Publication productivity among scientists: A critical review. *Social studies of science*, *13*(2), 285-305.

Garg, K. C., & Kumar, S. (2014). Scientometric profile of Indian scientific output in life sciences with a focus on the contributions of women scientists. *Scientometrics*, *98*(3), 1771–1783. https://doi.org/10.1007/s11192-013-1107-4

Geraci, L., Balsis, S., & Busch, A. J. B. (2015). Gender and the h index in psychology. *Scientometrics, 105,* 2023–2034.

Godbole, R. M., & Ramaswamy, R. (2015). Women Scientists in India. In report on Women in Science and Technology in Asia.

Göktepe-Hulten, D., & Mahagaonkar, P. (2010). Inventing and patenting activities of scientists: in the expectation of money or reputation?. *The Journal of Technology Transfer*, *35*(4), 401-423.

Gupta, N., & Sharma, A. K. (2002). Women academic scientists in India. *Social studies of science*, *32*(5-6), 901-915.

Holman, L., Stuart-Fox, D., & Hauser, C. E. (2018). The gender gap in science: How long until women are equally represented?. *PLoS biology*, *16*(4), e2004956.

Homma, M. K., Motohashi, R., & Ohtsubo, H. (2013). Japan's lagging gender equality. *Science*, *340*(6131), 428-430.

Homma, M. K., Motohashi, R., & Ohtsubo, H. (2013). Maximizing the Potential of Scientists in Japan: promoting equal participation for women scientists through leadership development. *Genes to Cells*, *18*(7), 529-532.

Horta, H. (2009). Holding a post-doctoral position before becoming a faculty member: does it bring benefits for the scholarly enterprise?. *Higher Education*, *58*(5), 689-721.

Husemann, M., Rogers, R., Meyer, S., & Habel, J. C. (2017). "Publicationism" and scientists' satisfaction depend on gender, career stage and the wider academic system. *Palgrave Communications*, *3*(May). https://doi.org/10.1057/palcomms.2017.32

Iefremova, O., Wais, K., & Kozak, M. (2018). Biographical articles in scientific literature: analysis of articles indexed in Web of Science. *Scientometrics*, *117*(3), 1695–1719. https://doi.org/10.1007/s11192-018-2923-3

Jensen, K., & Murray, F. (2005). Intellectual property landscape of the human genome. *Science*, *310*(5746), 239-240.

Katz, J. S., & Martin, B. R. (1997). What is research collaboration?. *Research policy*, *26*(1), 1-18.

King, M. M.; Bergstrom, Carl T.; Correll, Shelley J.; Jacquet, Jennifer West, Jevin D. (2016). Men set their own cites high: gender and self-citation across fields and over time. Accessed 11.07.2020 from arXiv:1607.00376

Kretschmer, H., & Kretschmer, T. (2013). Gender bias and explanation models for the phenomenon of women's discriminations in research careers. *Scientometrics*, *97*(1), 25–36. https://doi.org/10.1007/s11192-013-1023-7

Kuhn, T. S. (1962). Historical structure of scientific discovery. *Science*, *136*(3518), 760-764.

Kyvik, S. (1990). Age and scientific productivity. Differences between fields of learning. *Higher Education*, *19*(1), 37-55.

Lerchenmüller, C., Lerchenmueller, M. J., & Sorenson, O. (2018). Long-term analysis of sex differences in prestigious authorships in cardiovascular research supported by the National Institutes of Health. *Circulation*, 137(8), 880-882.

Leta, J., & Lewison, G. (2003). The contribution of women in Brazilian science: A case study in astronomy, immunology and oceanography. *Scientometrics*, *57*(3), 339–353. https://doi.org/10.1023/A:1025000600840

Lewison, G., & Markusova, V. (2011). Female researchers in Russia: Have they become more visible? *Scientometrics*, *89*(1), 139–152. https://doi.org/10.1007/s11192-011-0435-5

Mitchell, S. M., Lange, S., & Brus, H. (2013). Gendered citation patterns in international relations journals. *International Studies Perspectives*, *14*(4), 485-492.

Muñoz-Muñoz, A. M. (2005). The scholarly transition of female academics at the University of Granada (1975-1990). *Scientometrics*, Vol. 64, pp. 325–350. https://doi.org/10.1007/s11192-005-0254-7

Murphy TF. (2004). *Authorship and Publication*. In: McGee G, editor. Case Studies in Biomedical Research Ethics. 1st ed., The MIT Press, pp. 273–305.

Nourmohammadi, H., & Hodaei, F. (2014). Perspective of Iranian women's scientific production in high priority fields of science and technology. *Scientometrics*, *98*(2), 1455–1471. https://doi.org/10.1007/s11192-013-1098-1

OECD (2007). Revised field of science and technology (FOS) classification in the Frascati manual.

OECD. (2015a). Are education and skills being distributed more inclusively? Education indicators in focus. Paris: OECD.

OECD/Eurostat (1995). The measurement of scientific and technological activities; manual on the measurement of human resources devoted to S&T; Canberra Manual", OECD, Paris, p. 69

Osório, A. (2018). On the impossibility of a perfect counting method to allocate the credits of multi-authored publications. Scientometrics, 116(3), 2161–2173.

Over, R. (1988). Does scholarly impact decline with age?. *Scientometrics*, *13*(5-6), 215-223.

Pripić K., (2002).Gender and productivity differentials in science. Scientometrics, 55, 1, 27-58.

Riesenberg, D., & Lundberg, G. D. (1990). The order of authorship: who's on first?. *Jama*, *264*(14), 1857-1857.

Schomburg, H. (2007). The professional success of higher education graduates. *European Journal of Education*, 42(1), 35-57.

Shrum, W., Genuth, J., Carlson, W. B., & Chompalov, I. (2007). *Structures of scientific collaboration*. MIT Press.

Siegel, D. S., Waldman, D., & Link, A. (2003). Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study. *Research policy*, *32*(1), 27-48.

Sigogneau, A. (2000). An analysis of document types published in journals related to physics: Proceeding papers recorded in the Science Citation Index database. *Scientometrics,* 47(3): 589–604.

Simonton, D. K. (1984). Creative productivity and age: A mathematical model based on a two-step cognitive process. *Developmental Review*, 4(1), 77-111.

Stack S., (2004). Gender, Children and research Productivity. Research in Higher Education, 45, 8, 891-920.

Stroebe, W. (2010). The graying of academia: Will it reduce scientific productivity?. *American Psychologist*, 65(7), 660.

Su, R., & Rounds, J. (2015). All STEM fields are not created equal: People and things interests explain gender disparities across STEM fields. *Frontiers in psychology*, 6, 189.

Su, R., Rounds, J., & Armstrong, P. I. (2009). Men and things, women and people: a meta-analysis of sex differences in interests. *Psychological bulletin*, 135(6), 859.

Suchanska, M., & Czerwosz, E. (2013, March). Women in technical universities in Poland. In AIP Conference Proceedings (Vol. 1517, No. 1, pp. 138-139). *American Institute of Physics*.

Suter, C. (2006). Trends in gender segregation by field of work in higher education. *Women in Scientific Careers: Unleashing the Potential*, 95-104.

Tao, Y., Hong, W., & Ma, Y. (2017). Gender differences in publication productivity among academic scientists and engineers in the US and China: Similarities and differences. *Minerva*, 55(4), 459-484.

Tien, F. F., & Blackburn, R. T. (1996). Faculty rank system, research motivation, and faculty research productivity: Measure refinement and theory testing. *The Journal of Higher Education,* 67(1), 2-22.

Tscharntke, T., Hochberg, M. E., Rand, T. A., Resh, V. H., & Krauss, J. (2007). Author sequence and credit for contributions in multiauthored publications. *PLoS Biol*, 5(1), e18.

Uzzi, B., & Spiro, J. (2005). Collaboration and creativity: The small world problem. *American journal of sociology*, 111(2), 447-504.

Van Arensbergen, P., Van der Weijden, I., & Van den Besselaar, P. (2012). Gender differences in scientific productivity: a persisting phenomenon?. *Scientometrics*, 93(3), 857-868.

Varma, R. (2018). US science and engineering workforce: Underrepresentation of women and minorities. *American Behavioral Scientist*, 62(5), 692-697.

Ward, K. B., & Grant, L. (1996). Gender and academic publishing. In J. C. Smart (Ed.), Higher education, handbook of theory and research (Vol. XI). New York: Agathon Press.

Xie, Y., & Shauman, K. A. (1998). Sex differences in research productivity: New evidence about an old puzzle. *American sociological review*, 847-870.

Zainab, A. N. (1999). Personal, academic and departmental correlates of research productivity: a review of literature. *Malaysian Journal of Library & Information Science*, 4(2), 73-110.

Zuckerman, H. E., Cole, J. R., & Bruer, J. T. (1991). The outer circle: Women in the scientific community. In *This volume is based on papers from four symposia held at Stanford University, CA, from 1983 to 1986.*. WW Norton & Co.