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?