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Scholarly Trends of Bhabha Atomic Research Centre in 21st century: A Scientometrics Study

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Abstract

This study has been formulated to map the scholarly output of BARCs during the first two decades of the 21st century. The data of BARC research from 2002 to 2021 was downloaded from the Scopus database using affiliation. The study examined scholarly trends in sub-domains, collaboration patterns, prolific authors, and journals. The co-occurrence of keywords indicates that X-ray difference, scanning electron microscope, nanoparticles, and controlled study are significant research terms. Co-authorship analysis shows that researchers of BARC have intra-national and international collaboration in atomic research. The USA and Austria are the most collaborative countries. As of 10 January 2022, all the 27700 publications received 440064 citations (citation per article, 15.16). A total of 8.39% of citations have been noted from 10 highly cited papers. The five articles from the top ten cited articles were published in "The Lancet" journal (IF 79.32). The citation trend indicates that 10% of citations are added by the top 46 (0.16%) articles. Further, 17% of articles received no citations, and 46% received less than ten. It is found that most cited papers are published in the highest IF journal.

Keywords: BARC, Bibliometric, VOSviewer, Co-citation analysis, Research Trend, Co-authorship.

1. Background

Bhabha Atomic Research Centre (BARC) was established in Trombay, Mumbai, Maharashtra (https://barc.gov.in). Covering the entire spectrum of nuclear science, BARC is also known to perform various advanced research and development in multi-disciplinary areas. Dr. Homi Jehangir Bhabha started (https://barc.gov.in) the Nuclear research program in India by establishing the Tata Institute of Fundamental Research (TIFR) in 1945 (Chakrabarty & Karhadkar, 2021). The Atomic Energy Establishment, Trombay (AEET) started to perform from January 1954, to support the future nuclear program of India, and in later years it was renamed as Bhabha Atomic Research center, BARC (Venkataraman, 1994). India's first 80 MW pressurised water reactor has been designed and built for the first Indian nuclear submarine, INS Arihant, and for later use to its sister units (http://hindu.com). Atomic Energy is crucial for reducing the carbon foot print for overall power production (Vasudev & Dadhaniya, 2017). Today's nuclear power plants generate 6780 MW (1.7%) of electricity and country committed to enhance the capacity to reduce carbon footprint to support for reducing global warming (Vishwakarma, 2009; Ferguson, 2007). India participating actively in the International Thermonuclear Experimental Reactor

project, and BARC has to play a crucial role in this project (Woddi, Charlton & Nelson, 2009).

This study has been structured to find the BARC research trend in terms of literature growth, subdomain of BARC research, a research collaboration of BARC with other organizations or countries, and the productivity status of the most preferred journals. Bibliometrics research is used (Granzel, 2003) to assess national and international research to find sources of research funds, performance evaluation, future research priorities, and collaboration at various levels (Zyoud, 2017). The research policymakers could get benefit from the findings of bibliometric research regarding their further steps to enhance the research (Sweileh et al., 2016). It is observed that few bibliometric studies have been done on various Indian research centres, so for this study has been formulated to know the scholarly performance of BARC during year 2002 to 2021. The Bibliometric study applies to all subjects and their branches. It may also be suitable to evaluate any research institutions (Leydesdorff and Milojevic, 2013). Knowing the growth of scientific activity can be used to investigate the development of science in the respective field (Kuhn, 1962; Tabah, 1999). After an intense literature search from various databases study collected important bibliometrics literature which are conducted on different research wings of BARC which are discussed in brief.

2. Literature Review

B. S. Kademani et.al (2007). analyses the research pattern of the Radiochemistry Division at Bhabha Atomic Research Centre (BARC) and found that 94% of articles are multiauthor, Radiochimica Acta is the preferred journal, and the Netherlands, England, and USA are most collaborative country. The study on research of the Analytical Chemistry Division (BARC) conducted by B. S. Kademani et.al (2006). shows that Electrochemistry is the most preferred research domain, M. Sudersanan is a prolific author, and the Indian Journal of Chemistry (54) has been used for the highest number of research publications. Priya Girap, et.al. (2009) evaluated the research performance of Technical Physics and Prototype Engineering Division (BARC) studied and results showed that crystals (192), thin films (173), glasses and ceramics are frequent research areas. The most preferred journal is Physica C, and multiauthor pattern used for the research. This study was conducted to know the research contribution of BARC women scientists, who are 16% of the total researchers. Rekha P. Upadhye et.al. (2014). conducted study on gender participation and found that women scientists publish 27.50 % of publications and 36% of technical journal publications. B.S. Kademani, et.al. (2005). formulated study on Bio-Organic Division (BARC) during 1972-2002 shows that the most prolific author A. Banerji (125), and the Indian Journal of Chemistry-B, is the most preferred journal for publication. The literature review indicates that there a need to map the BARC research performance, especially in the 21st century Yu Yuetian et al. (2020). Therefore, this is the most comprehensive study designed to fill this gap. The finding of this study can be use by researcher to aware about research trends, publication patterns, author and institute collaboration, citation pattern etc.

3. Objectives

The study has been formulated to explore the BARC research efforts in terms of (i) growth of literature in twenty years, (ii) research in various sub-domains, (iii) BARC research collaboration with organizations or countries, and (iv) research productivity of the most preferred journals and most productive authors.

4. Methodology

Bibliometric techniques have been used for the data analysis. To avoid any possible differences through updates in the database, data were downloaded on January 10, 2022. There is a large number of high-impacted journals are indexed in Scopus. Works of literature affiliated with BARC were searched within a time limit of 2002–2021 from databases. The Search Strategy for BARC literature follows an affiliation search window for data download. Affiliation-specific search in the database was used because of its precision and assumed to be a much higher result of data availability than topic-related search. After using all predefined parameters for data access, 27801 publications have been downloaded in CSV and RIS format separately. The downloaded data was again refined to remove the duplicates using Microsoft Excel; after that, 27704 unique BARC publications were selected for final analysis. VOSviewer software was identified and found suitable for data visualization and representation. It is used for constructing and visualizing bibliometric networks of any research area. The journals, researchers, and individual publications are part of this network. The network can be based on citation, bibliographic coupling, co-citation, co-authorship relations, etc. (Van Eck, Nees Jan, & Waltman, 2010). The text-mining functionality of VOSviewer can be used to create and visualize co-occurrence networks of various terms extracted from a body of scientific literature (Yi Bu, Tian-yi, and Win-bin, 2016). The analysis of author's co-citations (Henry, 2001). has been used to locate the intellectual structure of science studies and to identify authors from the same or similar research fields. The author's co-citation analysis was mapped to highlight major subject specializations in BARC research and identify authors and their relationships within the field of specialties (Harzing & Alakangas, 2016). Visualization techniques were used to know the authors' and institutes' collaboration patterns of the BARC. VOSviewer (ver. 1.6.15) is an open-access software developed by Leiden University f or constructing and visualizing bibliometric networks to visualize the collaboration network.

5. Analysis and discussion

After the analysis of downloaded bibliographic data, it was observed that most of the literature are journal articles (22592, 81.54%) followed by proceeding (3642, 13.14%), Review (565, 2.2%), Book chapter (382) and in other format (523). It is observed that 27700 of literature were published in English language, indicating that BARC researchers are closely attached to the world community for broader collaboration and dissemination of their research.

5.1 Growth of Literature

The research output of BARC for the last 20 years has been depicted in Figure 1. Out of 27700 publications, more than 1700 article were published every tear during last decade. The lowest amount of publications was noted in 2003 (691 or 2.57%), where the highest in 2014 (1919, 6.92%) followed by (1891, 6.82%) publications in2017. About half of publications were published in the first 12 years, i.e., 2002 to 2012, followed by the remaining half took only 8 years, i.e. 2013 to 2021.

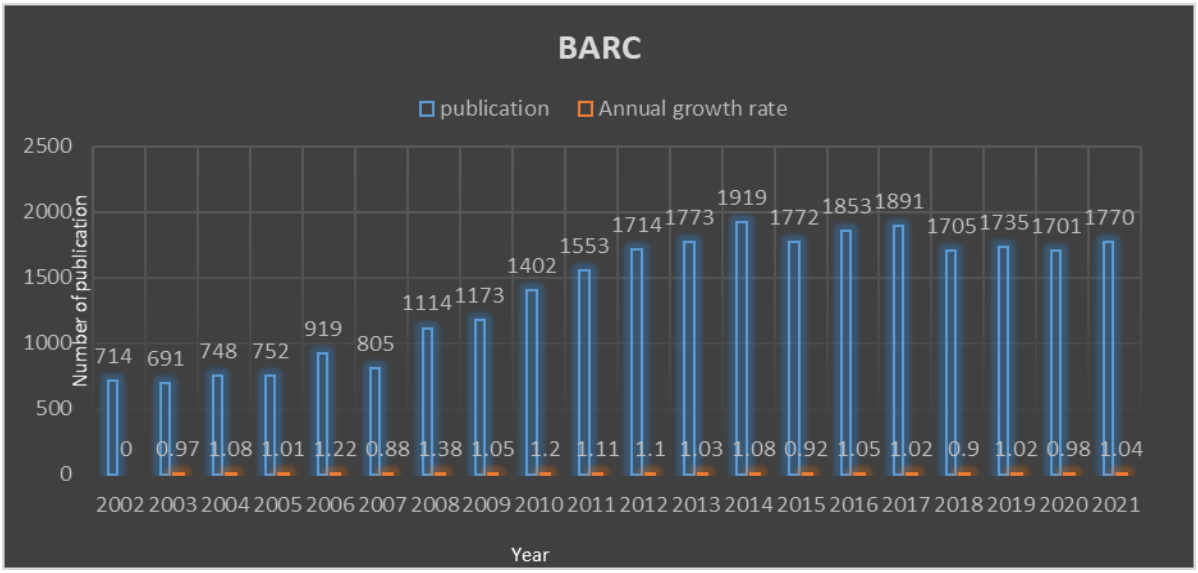

Figure 1: BARC growth of Literature from 2002-2021

5.2 Keyword analysis of publication title

The study was carried out at the macro and micro levels to identify the significant subdomains of BARC research activity where most of the studies have been done thus far. The map of primary phrases featured in titles between 2002 and 2021 is shown in Figure 2. The keyword map was created based on 53758 terms distributed in across 6 clusters. The four significant clusters have been denoted by the colors red, green, yellow, and blue. While a bubble's size denotes frequency, its colour denotes a similar group or cluster of connected phrases. The line's thickness shows how well the phrases cooperate, and the space between them shows close connection. Nearly 53758 important points were accessible from 27700 publications. By lowering the minimum frequency to 15 for a term, where 804 terms are present. Sixty percent of the most pertinent phrases are typically the default selection in VOSviewer. Out of 482 terms, synthesis (1107), measurement (1072), India (626), search (559), production (506), pp collision (394), solution (381), uranium (377), and thin film (361), noted as top term. It is found that many terms were used to describe atomic research, medical research, renewable energy, waste management, water treatment, etc.

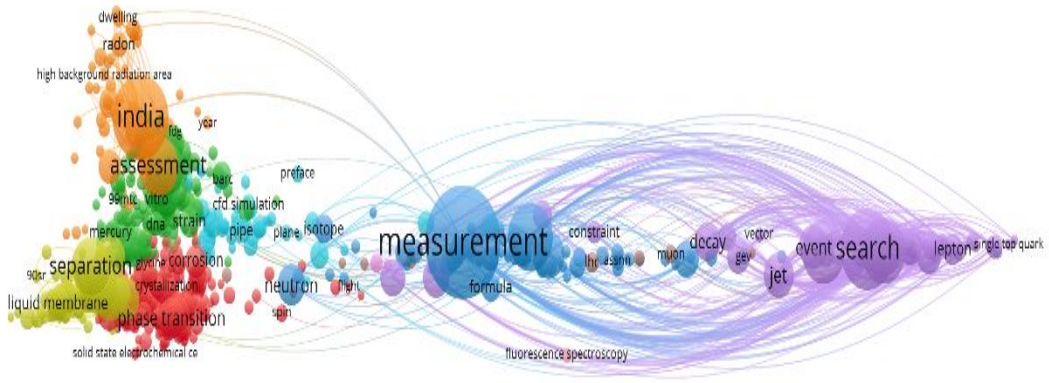

Figure 2: Network visualization of title

5.3 Co-occurrence of keywords network

The co-occurrence analysis of a keyword network is a text analysis approach that involves visually representing possible connections between ideas represented by keywords and other things inside the textual content. Collocation refers to the frequency at which two neighbouring phrases appear in a text corpus in a certain sequence. For analysis, the threshold of 10 minimum terms has been selected, yielding 6999 terms. As shown in Figure 3, all keywords have been visible into five clusters (red, green, blue, yellow, and purple), indicating BARC research sub-domains. It must be noted that in VOS viewer, terms having similar shades indicate clusters or groups of related terms. Cluster 1 (red) included the keyword, 'X-ray difference, (occurrence 1530, links 891, link strength 16275), scanning electron microscope (occurrence 977, links 865, link strength 10654) nanoparticle, (occurrence 995, links 868, link strength 11348). In Cluster 2 (green) dealing with uranium (occurrence 1530, links 787, link strength 8887), radioactive waste (occurrence 391, links 688, link strength 4229), metal ion (occurrence 512, links752, link strength 6292), etc. Cluster 3 (blue) has terms like controlled study (occurrence 1932, links 955, link strength 32892), unclassified drug (occurrence 1581, links 955, link strength 26638), nonhuman (occurrence 1386, links 858, link strength 24940), etc. Cluster 4 (yellow) represents keywords like neutron scattering (occurrence 627, links 664, link strength 5986), kinetics (occurrence 479, links 849, link strength 6040), micelle (occurrence 429, links 542, link strength 4574), etc. In Cluster 5 (purple), human (occurrence 1590, links 889, link strength 23536), male (occurrence 617, links 593, link strength 10503), adult (occurrence 413, links 473, link strength 6272), etc.

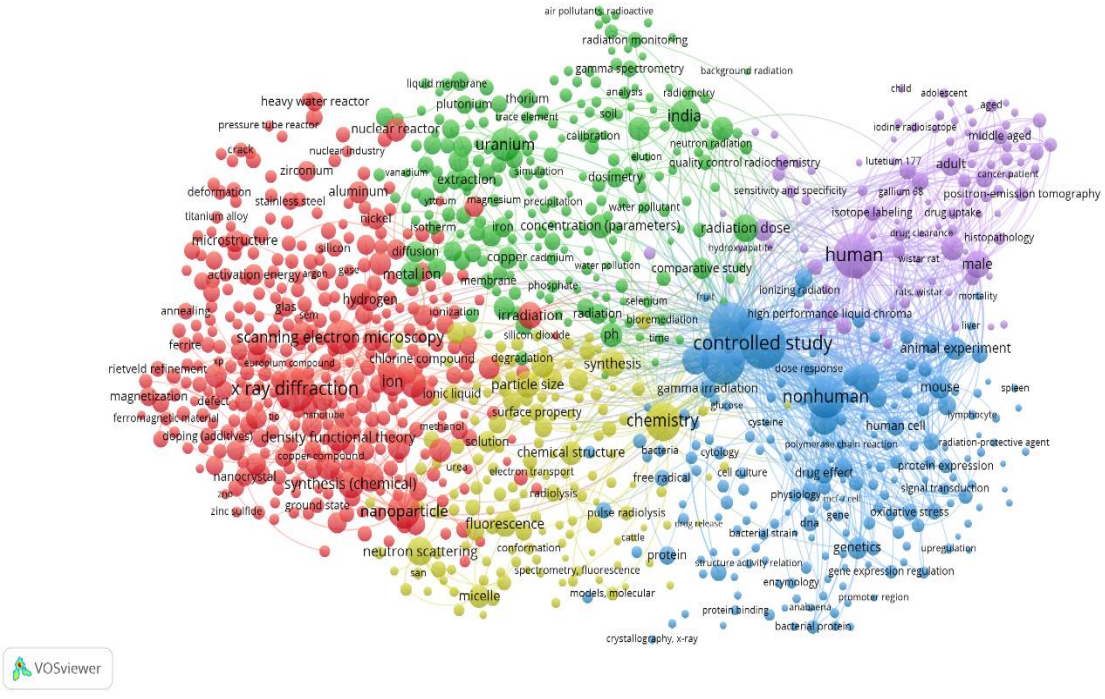

Figure 3: Keyword co-occurrence network visualization

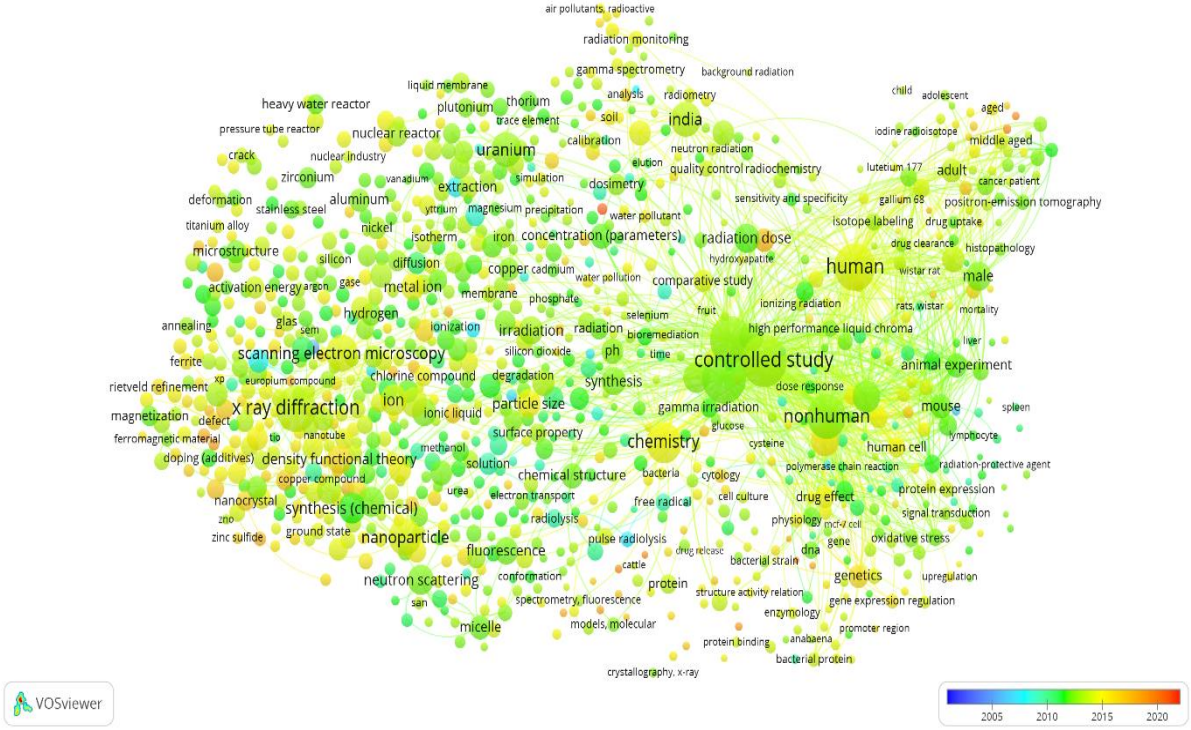

Figure 4: Keyword co-occurrence based on average publication per year

The identification of a research front within a specialised topic can be found by the use of cluster analysis. This analytical technique enables the identification of a cohesive set of heavily cited publications, often known as core papers. The early research front of BARC shows a broad focus on applied research like nanoparticles (occurrence 230, links 651, link strength 3148), and later, the identification of burning research field, controlled drug delivery (occurrence 53, links 306, link strength 860) was the focus of the scientists' primary research. These research fronts have altered to study many other areas while new research disciplines have evolved. These are molecular docking (occurrence 53, links 268, link strength 849), and further attempts were directed to targeted drug delivery (occurrence 49, links 293, link strength 879), enzyme inhibition (occurrence 62, links 333, link strength 1097), and energy dispersive x-ray (occurrence 88, links 504, link strength 1317).

5.4 Co-authorship analysis

Through analysis of 27700 works in the particular field, it was discovered that BARC research mainly incorporates either national or international collaboration. A single author has just published 8.24% of the articles. We applied the network visualization technique to determine the collaboration pattern. This function was implemented to investigate the collaboration trends among the authors, organizations, and nations.

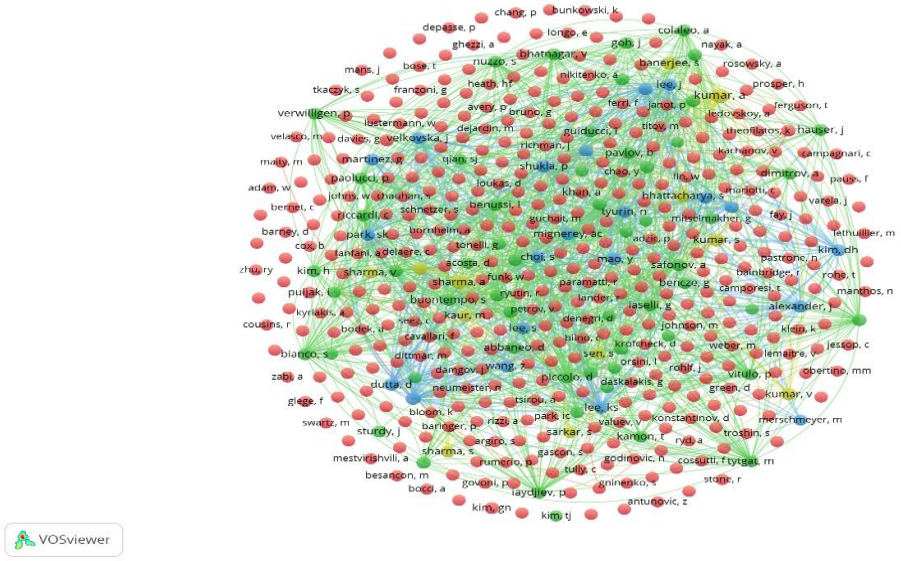

Figure 5: Author co-occurrence network visualization

The co-authorship network of the 43975 authors for 27700 publications is shown in figure 5. It was discovered that 14062 authors met the requirement for having at least five publications. The top 500 authors have been chosen in order to illustrate the author graph. The collaboration network is represented in Figure 5 by four distinct clusters in four different colours. Cluster 1 (red) consists of 411 authors, including Abdullin, S., Adam, W., Ahuja, P., Aziz, T., while cluster 2 (green) indicating 56 authors including Bansal, S., Cavallo, F., Pant, M., etc. Cluster 3 (blue) has 21 authors, including Choi, S., Shukla, P., Park, SK., and cluster 4 (yellow) consists of 12 authors, including Banerjee, S., Bhattacharya, S., Das, S., Kumar, A. etc. Table 1 displays the total number of articles, Citations, and link strength for highly productive authors.

Table 1: Top five productive authors

S.N.	Author	Article	Citation	TLS
1	Kumar, A	1781	80301	541830
2	Sharma, A	1589	79722	541233
3	Banerjee, A	1495	77962	541950
4	Bhattacharya, S	1390	75534	541361
5	Dutta, D	1299	84475	541186

The highly productive author (Kumar, A) is not highly cited, as shown in the table 1. However, highly productive authors have substantial collaboration networks, which makes their connection strengths more significant. However, authors with significant number of citations collaborated with various groups of co-authors in the majority of their publications; as a result, these authors do not show up in co-authorship networks.

5.5 Co-authorship network of institute and country collaboration

Figure 6 displays a visualization map of institutional collaboration based on top 500 research institute. A minimum of 10 publications were selected for each research institute for the visualization, where 1307 out of 14234 finally selected.

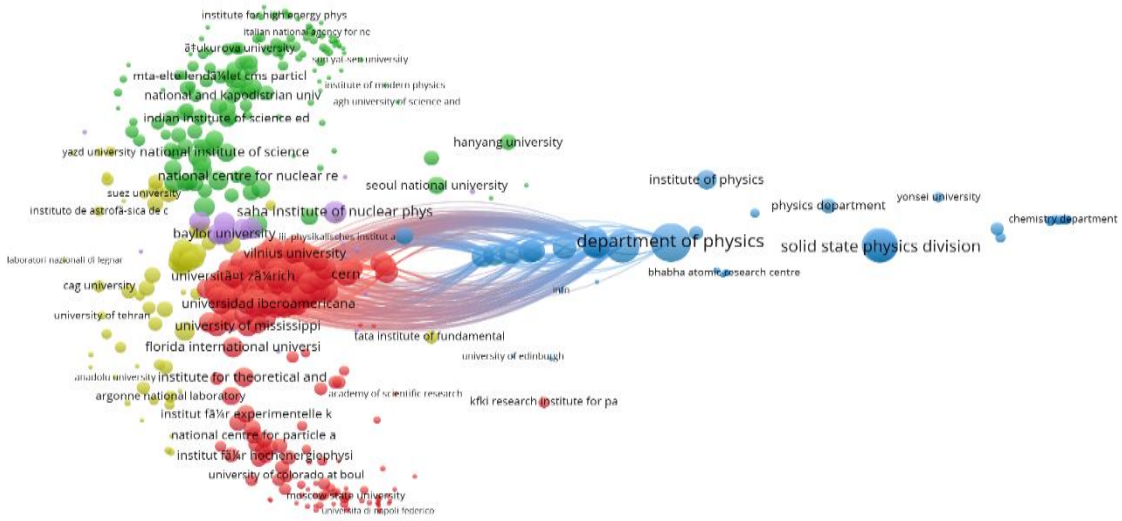

Figure 6: Co-authorship network of organizations

Department of Physics (documents 3548, citation 111990, TLS 233424), Homi Bhabha National Institute (documents 2954, citation 17578, TLS 556), Bhabha atomic research center (247 documents 2591, citations 100405, TLS 237902), Korea University (documents 1313, citations 105849, TLS 237535), Florida State University (documents 1282, citations 86027, TLS 237137) University of Tennessee (documents 1278, citations 86440, TLS 236710) noted as most significant organisation. Besides these pioneered organizations and research centers some others also found which are Charles University, University of Maryland, CERN, University of California, Helsinki Institute of Physics, etc.

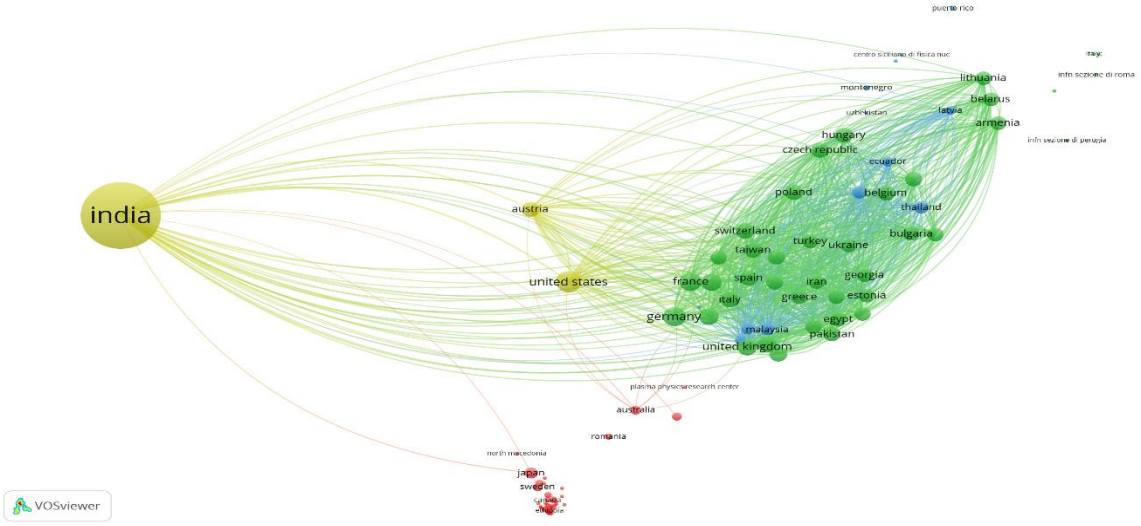

Figure 7: Co-authorship network of the country

The country collaboration network of the country analysed for 125 out of 179 total countries. As shown in Figure 7, countries are aligned through four clusters in four colours. The USA is depicted as a most collaboration country (Publication, 2593, Link 120; Link Strength 53599), followed by Austria (Publication, 1368, Link 120; Link Strength 49370), Germany (Publication, 2142, Link 120, Link Strength 53116), France (Publication, 1961, Link 119,

Link Strength 53153), United Kingdom (Publication, 1602, Link 119, Link Strength 50007) Brazil (Publication, 1354, Link 119, Link Strength 49610) Saudi Arabia (Publication, 388, Link 114; Link Strength 15636) Malaysia (Publication, 837, Link 118; Link Strength 35098) Taiwan (Publication, 1313, Link 117, Link Strength 48529) Japan (Publication, 767, Link 112; Link Strength 5917). Collaboration analysis of country shows that BARC has strong collaboration with European countries and the USA. In Asia, Japan, Singapore, Taiwan, Malaysia, etc. are noted as the most collaborating countries. BARC has no collaboration with China and Pakistan, which shows research collaboration's strategic and security concerns.

5.6 Bibliographic Coupling of journals

A citation network in bibliometric analysis commonly represents research collaborations. The citation network can be created by displaying co-citation networks or bibliographic coupling between related articles, authors, or keywords. Presumably, two authors with citations or similar research interests are more associated. A method to "create a likeness of the link between documents, institutions, and authors," as defined by Kessler, is known as bibliographic coupling (Kessler, 1963). A network of works (ABC) is created when two works (a, b) frequently refer to work (c). To determine the scope and extent of the research community, this network illustrates how an author, publication, or organization is related to a domain. It also offers comprehensive insights into scientific activity. A network of bibliographic coupling can be built and viewed using VOSviewer. The purpose of utilizing VOSviewer visualization for journals was to determine which journals are most closely related to BARC research. Table 2 displays the top 5 journals, articles, citations, and link strengths from the 2801 BARC research publications. Figure 8 coupling network across all 427 journals considered for analysis.

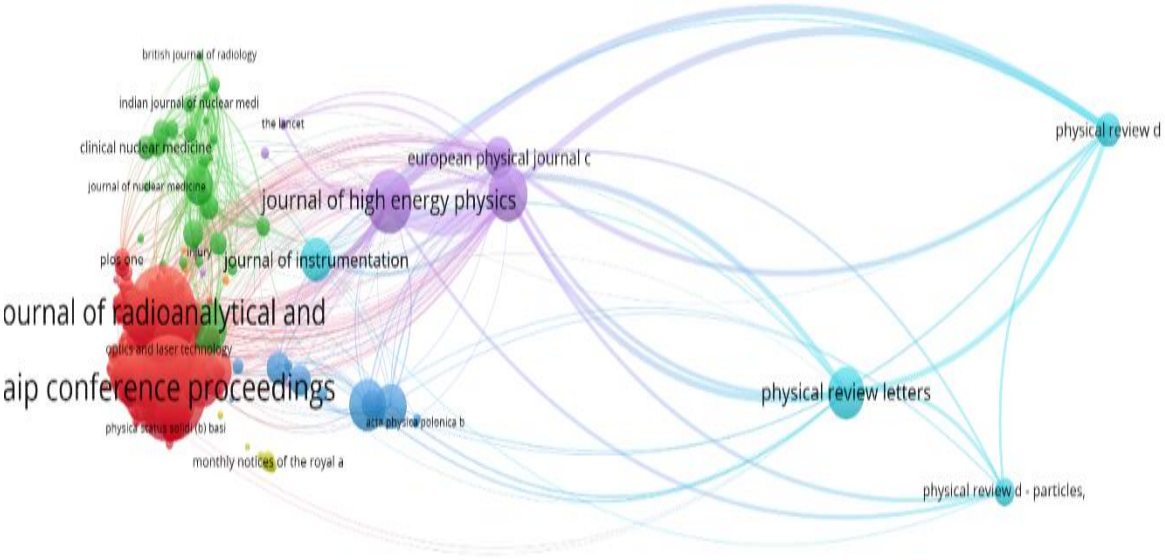

Figure 8: Bibliographic coupling of Journals

Table 2: Top five productive journals Vs cited journals

Highly productive journal				Highly cited journal			
Journal	Article	Citation	TLS	**Journal**	Article	Citation	TLS
AIP Conference Proceedings	993	1123	36357	The Lancet	12	22692	29702
Journal of Radio Analytical and Nuclear	824	5861	96266	Physics Letters section B	279	20631	276491
Journal of Alloy and Compounds	373	6606	48282	Physics Review Letter	237	16734	23346
Journal of High Energy Physics	368	15418	44365	Journal of High Energy Physics	368	15418	45364
RSC Advances	367	5249	33717	Journal of Instrumentation	169	12495	98263

Table 3: Top five productive authors Vs. highly-cited authors

Highly productive author				Highly cited author			
Author	Article	Citation	TLS	Author	Article	Citation	TLS
Kumar, A	1781	80301	541829	Alexander, J	1244	85301	542462
Sharma, A	1589	79722	541215	Dutta, D	1299	84475	541370
Banerjee, S	1495	77962	541949	Kim, dh	1189	81418	541591
Bhattacharya, S	1390	75534	540097	Mao, Y	1269	80342	540945
Dutta, D	1299	84475	541370	Kumar, A	1781	80301	541829

AIP Conference Proceeding is the crucial publication source for BARC researchers, as seen in the table and image. The most vital links were found in the journal Physics Letters section B. This signifies that the primary source of additional publications in this field is related to these journals. It is depicted in the table that highly productive journals are not in nature highly cited journals. Only the Journal of High Energy Physics is noted as a fourth highly effective and highly cited journal. It is observed that journals The Lancet published only 12 articles, but it has the highest number of citations, which shows the quality of this journal even though it is the highest Impact factor journal for BARC authors.

5.7 Citation pattern of article

A total of 440064 citations (citation per article 15.16) were received till January 10, 2022, and the top 10 highly cited articles received 8.39% of the total citations. Five of the ten highly cited papers were published in The Lancet Journal (IF 79.32), and others five in the journal Physics Review Letter B (IF: 4.771), Nuclear Physics (IF: 2.24), Journal of Instrumentation (IF: 2.08), and Indian Journal of Physics (IF: 1.947). The top 46 articles (0.16%) received 10% of all citations, indicating that the citation rate is significantly influenced by the few often cited articles. Roughly 46% of articles received fewer than ten citations, and about 17% of publications have no citations. The findings showed a significant relationship between impact factor (IF) and citations, and the observation is that "the most cited articles are often published in journals that are on the top of the IF list (Callaham, Wears, & Weber, 2002). However, exceptionally productive authors may not always require high connection strength.

6. Findings and Conclusion

The recent research trend of BARC indicates that more than 1700 publications were published every year during 2018-2021. The study shows that synthesis is the most performed subdomain of research, followed by measurement, India, search, production, pp collision, solution, uranium, thin film, etc. The most preferred research areas are the controlled study followed by human, unclassified, x-ray difference, uranium, nonhuman, and scanning electron microscope. The Research front focused on applied research, like nanoparticles and controlled drugs. With the appearance of the new research field, these research fronts have further changed into several other domains like molecular docking, targeted drug, enzyme inhibition, and energy dispersive x-ray. The Co-authorship analysis of authors shows that a single author has published only 8.24% of the articles. Kumar A is the highest productive author (1781), followed by Sharma, A. (1589) and Banerjee, S. (1495). When examining the collaboration patterns in published literature, it was found that while highly productive authors have strong and fixed networks of collaborators, favourably cited authors lack a selected group of collaborators. As a result, they exhibit weak link strength.

Collaboration analysis of institute indicates that Korea University is the most collaborated organization for BARC, followed by Florida State University, University of Tennessee, Charles University etc. It is found that BARC is participating actively in various multi-national research projects like artificial sun (international nuclear fusion research), Large hadron collider, and finding Higgs boson (god particles). Furthermore, it was noted that the two mega-clusters displayed collaboration paths mostly involving authors from the USA and Austria when looking at the country-collaboration network. Alliances between developing and industrialized nations are uncommon, just as in several other fields of science. The country collaboration shows that the USA is the most preferred country in atomic research, followed by Austria, Germany, France, United Kingdom, Brazil, Saudi Arabia, Malaysia, Taiwan, and Japan. The article's citation pattern revealed that top 46 (0.16%) articles accounted for 10% of all citations, indicating that few publications are regularly cited. Total 17% of publications received no citations, and 46% of articles obtained fewer than ten citations. The present bibliometric analysis revealed a rapid expansion in the research, which is noted between the years 2008 and 2014, and from 2015 onwards, no drastic change was observed in terms of literature.

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