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Research Article

A Scientometric Analysis of Carbon Nanotube Research Trends in SAARC Countries Using the Lens.org Database, from 2000 to 2025

Kannan G, Kanipriyan K*

Department of Library and Information Centre, Adhiyamaan College of Engineering, Hosur, Tamil Nadu, INDIA.

ABSTRACT

This study focuses on the research output of Carbon Nanotube (CNT) across the SAARC (South Asian Association for Regional Cooperation) countries during the period 2000 to 2025. The study examines annual scientific production, citation impact, the most productive and most cited authors and sources, author productivity through Lotka's Law, source concentration through Bradford's Law of Scattering, keyword co-occurrence and thematic mapping, and the country-wise, institution-wise and funding-agency-wise distribution of CNT research among the SAARC nations. A total of 16,813 documents published in 3,415 sources were retrieved from the Lens.org database and analysed using standard bibliometric indicators. The results reveal an average annual growth rate of 18.26% in CNT publications, with output peaking in 2021 (2,186 documents) before declining in the subsequent years. India dominates SAARC CNT research, contributing 84.22% of the total documents, followed by Pakistan (12.15%) and Bangladesh (2.69%), while Bhutan, Afghanistan and the Maldives recorded negligible output. RSC Advances appeared as the most productive and most impactful source, and Kumar A. was found to be the most prolific author. Additionally, Materials Science and Nanotechnology were identified as the dominant fields of study, with "carbon nanotubes", "nanoparticles", and "graphene" as the most frequently used keywords. The findings provide useful insight for researchers, institutions, funding bodies, and policymakers into the growth pattern and research direction of CNT studies in the SAARC region.

Keywords: Carbon Nanotube, Lens.org database, SAARC Countries, Scientometric Analysis.

Correspondence:
Mr. Kanipriyan K
Assistant Librarian, Central Library, Department of Library and Information Centre, Adhiyamaan College of Engineering, Hosur, Tamil Nadu, INDIA.
Email: kanipriyan112003@mail.com

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INTRODUCTION

Carbon nanotubes' mechanical, thermal, and electrical characteristics as well as their uses are highlighted. Since these structures will be essential to the creation of conducting polymers, nanotransistors, durable nanocomposites, sensors, storage devices, field emission sources, and smart materials, they have the potential to completely transform nanoscience materials in the next millennium (Terrones, 2004).

With the overarching goal of advancing the growth and development of every nation in the region, the South Asian Association of Regional Cooperation (SAARC) was established as an organization to create a connected and integrated South Asia. Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, and Sri Lanka were its founding members. There are currently eight members following Afghanistan's membership in the 13th summit, which took place in Dhaka in 2006.1 Kathmandu, Nepal is home to its secretariat.

The term "scientometrics," which was first used in the 1960s by Vassily V. Nalimov, has gained prominence and is used to characterize the study of science, including growth, structure, linkages, and production. Bibliometrics and informetrics are related to and share interests with scientometrics. The phrases "bibliometrics," "scientometrics," and " informetrics " refer to subfields that examine the dynamics of disciplines as they manifest in the creation of their literature. Research topics include tracking changes in an academic field's output over time and between nations, the challenge of maintaining output control in library collections, and the poor publishing productivity of many researchers (Hood and Wilson, 2001).

In order to support research, analysis, decision-making, and collaboration on a human-centered user experience built on an open web platform, Lens.org, with toolkits intended to maximize institutional effectiveness in problem solving, The Lens, the flagship project of the social enterprise Cambia, aims to source, merge, and link diverse open knowledge sets, including scholarly

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works and patents. Over 272 million scholarly works, 155 million global patent records, and over 495 million patent sequences are ingested, cleaned, aggregated, normalized, and served by The Lens, which has been developed for more than 20 years with support from well-known philanthropic organizations. The Lens' rich metadata, which is derived from a variety of data sources, includes the individuals and organizations that produce this knowledge as well as the connections between them. The Lens Meta Record is the foundation of the Lens architecture. Scholarly publications and patents are examples of "knowledge artifacts," which come in a variety of formats, dates, levels of accessibility, and quality. The best metadata may be gathered, normalized, and made public while preserving provenance and links by combining various identifiers and sources to create an open Meta Record (Figure 1).

REVIEW OF LITERATURE

Baer and Ganti (2025) examined the literature on nano-oncology, with a focus on global trends in nanoparticles and nanotubes between 2003 and 2025. Using terms like cancer, nanotechnology, nanomedicine, nanoparticles, and nanotubes, this bibliometric analysis collected data from the Web of Science Core Collection. Keywords, nations, and organizations from a total of 1,465 papers were the main focus of the obtained data shown in the VOSViewer tool and Web of Science Core Collection. Analysis shows that the advancement of nanotechnologies, especially in medication administration and imaging techniques, has led to a recent surge in research. The most common publishers were the United States, the People's Republic of China, and India, who frequently worked with other nations to concentrate on an integrated global society with shared issues and similar nanotechnological objectives.

Banerjee *et al.* (2024) carried out the study of 265,000 journal and patent articles in the field of Carbon Nanotube (CNT)-related research over the past 20 years (2003 to 2023) are presented in this paper. Finding and extracting significant patterns as well as establishing links, such those between materials and applications, are the goals of this study. We have discovered more than 80 new ideas in the field of Carbon Nanotubes (CNTs) using a Natural Language Processing (NLP)-based study. These ideas are shown in a "Trend Landscape" map and fall into three main categories: characteristics, materials, and applications. In recent years, the field has been propelled by an increase in interest in CNT composites, particularly involving other nanoscale materials like MXene and Metal-Organic Frameworks (MOFs), although early research efforts seemed to concentrate on synthesis techniques (including the now well-established and dominant technique of Chemical Vapor Deposition (CVD)). Investment data indicates commercial interest in the research and application of Carbon Nanotubes (CNTs) across a range of industries, including semiconductors, energy, and, to a lesser extent, the biomedical sector.

Zhang *et al.* (2024) conducted the study of bibliometric research on the creation of multi-scale carbon nanotube calculations, CiteSpace III software was utilized. By examining 1253 pertinent SCI publications the study patterns in this topic were thoroughly examined using an expanded database and techniques including keyword time zone map, literature co-cited network cluster analysis, keyword cluster network, etc. Research on multi-scale calculations of carbon nanotubes was shown to have advanced significantly between 1999 and 2023. The distribution of keywords per time zone showed how the study focus changed over time. We were able to comprehend the body of knowledge and significant study findings in this area thanks to literature co-citation network analysis. Finally, the hot research directions for the future, such as "free vibration," "graphene oxide," and "interfacial property," were projected using the keyword breakout analysis.

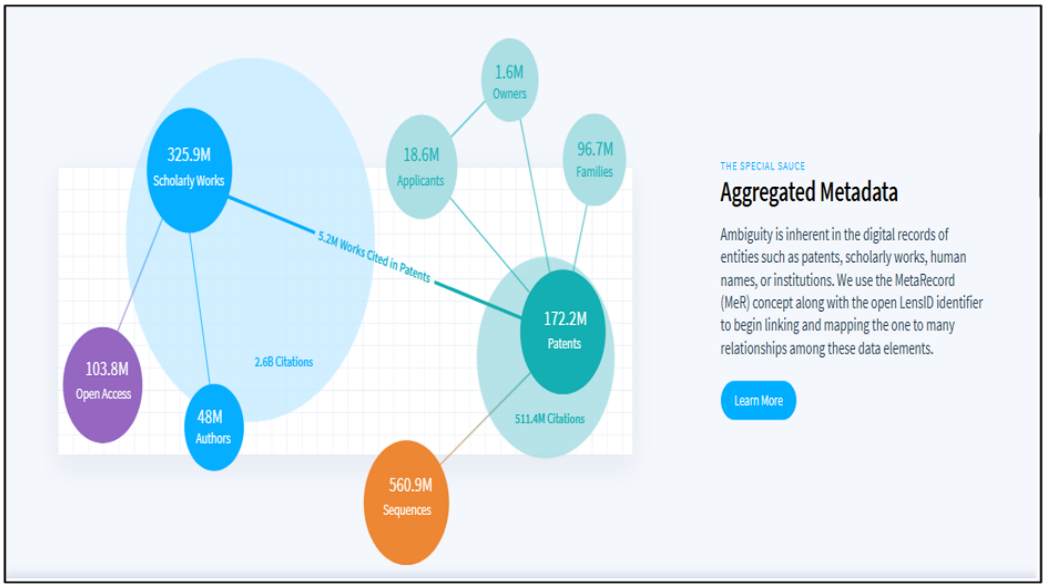


Figure 1: Overview of Lens.org database.

Aldhafi and Nandiyanto, (2021) discussed that the study of remarkable physical, chemical, mechanical, electrical, and optical capabilities of Carbon Nanotubes (CNTs) have prompted extensive research during the past ten years. The goal of this study is to use VOSviewer software to combine mapping analysis with bibliometric analysis in the manufacturing of carbon nanotubes. Mendeley is the application reference manager used to collect research data. The information gathered came from a search using the term "Synthesis Method of Carbon Nanotubes." 247 pertinent published articles covering the years 2018-2022 were discovered from the search results. The findings demonstrated that between 2018 and 2021, the number of articles examining the synthesis of carbon nanotubes increased. Eight articles were published in the beginning of 2022, though this figure may rise in the future. Due to the COVID-19 epidemic, which compelled researchers to reduce experiment activity and in-person interactions, research is still widely explored today. It is anticipated that this study will aid and serve as a reference for researchers when they conduct and choose the research themes.

Objectives

i. To examine the year-wise growth and annual scientific production of Carbon Nanotube (CNT) research among the SAARC countries during 2000-2025.

ii. To identify the country-wise, institution-wise and funding-agency-wise distribution of CNT research output in the SAARC region.

iii. To determine the most productive and most cited authors, sources and documents in the field of CNT research.

iv. To examine the applicability of Bradford's Law of Scattering in identifying the core journals, and Lotka's Law in analysing author productivity, in CNT literature.

v. To analyse the keyword co-occurrence pattern and identify the prominent research themes/fields of study in CNT research.

METHODOLOGY

The present study adopts a quantitative scientometric approach to analyse Carbon Nanotube (CNT) research output of the SAARC (South Asian Association for Regional Cooperation) countries during the period 2000 to 2025. Bibliographic data were retrieved from the Lens.org database using the search term “carbon nanotube”, restricted to the eight SAARC member nations, namely Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan and Sri Lanka. A total of 16,813 documents published across 3,415 sources between 2000 and 2025 were downloaded and exported for analysis. The retrieved metadata, comprising authors, sources, citations, keywords, institutions, funding agencies and country affiliation, were cleaned, organised and analysed using standard bibliometric software (R-Studio Version) and techniques, including co-word and keyword network analysis. Standard bibliometric laws, namely Bradford's Law of Scattering, to determine the concentration and dispersion of the literature across journals, and Lotka's Law of Author Productivity, to examine the authorship pattern, were applied to the dataset. Citation-based impact indices such as the h-index, g-index and m-index were computed to evaluate the impact of authors and sources. The results are presented and interpreted with the help of descriptive tables and figures covering annual scientific production, citation trends, source and author productivity and impact, keyword and field-of-study analysis, and institution-wise, funding-agency-wise and country-wise distribution of CNT research.

Data Analysis and Interpretation

The bibliometric profile of Carbon Nanotube research retrieved from the Lens.org database spans a time span of 26 years (2000-2025), during which 16,813 documents were published across 3,415 distinct sources, including journals, books, and conference proceedings (Table 1). The dataset exhibits a robust annual growth rate of 18.26%, reflecting the rapid and sustained expansion of scholarly interest in this field. With an average document age of 8.1 years and an average of 41.72 citations per document, the corpus demonstrates a high degree of scholarly maturity and impact. The presence of 522,431 references and 13,469 unique keywords (both Keywords Plus and Author's Keywords) indicates a well-established and thematically rich knowledge base. Authorship data reveal that 48,487 authors have contributed to this literature, while only 432 of them have published single-authored documents, underscoring the highly collaborative nature of research in this domain.

This is further corroborated by a collaboration index of 6.27 co-authors per document and 578 single-authored documents, signifying that large, multi-author teams dominate Carbon Nanotube research. In terms of document types, journal articles constitute the overwhelming majority (14,811 documents,), followed by book chapters (949) and conference proceedings articles (473), confirming that peer-reviewed journals remain the primary and most credible outlet for disseminating research in this field.

Table 2 traces the year-wise growth trajectory of Carbon Nanotube publications from 2000 to 2025. The data reveal a slow and modest beginning, with only 11 documents published in 2000, gradually rising to 205 by 2008 and crossing the 500-document mark in 2011 (502 documents). A pronounced and sustained acceleration is visible from 2013 onward, with output rising from 693 documents in 2013 to a peak of 2,186 documents in 2021, the highest annual output recorded in the dataset. This represents nearly a two-hundred-fold increase over the study period, consistent with the 18.26% annual growth rate reported in Table 1 and reflecting the field's transition from an emerging niche area into a mainstream domain within materials science and

Table 1: Main Information on Carbon Nanotube Research in SAARC Countries.

Main Information About Data	
Timespan	2000:2025
Sources (Journals, Books, etc.)	3415
Documents	16813
Annual Growth Rate %	18.26
Document Average Age	8.1
Average citations per doc	41.72
References	522431
Document Contents	
Keywords Plus (ID)	13469
Author's Keywords (DE)	13469
Authors	
Authors	48487
Authors of single-authored docs	432
Authors Collaboration	
Single-authored docs	578
Co-Authors per Doc	6.27
Document Types	
Book	49
Book Chapter	949
Conference Proceedings	16
Conference Proceedings Article	473
Dataset	10
Dissertation	8
Editorial	1
Journal Article	14811
Journal Issue	16
Other	132
Preprint	232
Report	1
Review	4

nanotechnology. The noticeable decline in publication counts after 2021 (from 2,186 in 2021 to 728 in 2025) is not indicative of a genuine slowdown in research activity but is largely attributable to indexing and citation lag, since recently published articles typically take one to two years to be fully indexed in bibliometric databases such as Lens.org (Figure 2).

Table 3 and Figure 3 presents the citation performance of Carbon Nanotube publications on a year-wise basis using the Mean Total Citations per Article (MeanTCperArt), Mean Total Citations per Year (MeanTCperYear) and Citable Years. As is typical in citation analysis, articles published in the earliest years of the study period command the highest MeanTCperArt values; articles from 2000 record an average of 126 citations each, benefiting from a full 27-year citation window. This value declines steadily for more recent publication years, with 2025 articles showing a MeanTCperArt of just 4.54, not because these articles are of lower quality, but because they have had only 2 citable years to accumulate citations. When normalised for time using MeanTCperYear, a more stable and meaningful pattern emerges, with values ranging between approximately 2.27 and 6.78 citations per year across the period, and the years 2020 and 2021 recording the highest MeanTCperYear (6.37 and 6.78, respectively), coinciding with the years of peak publication output identified in Table 2. This indicates that the years in which Carbon Nanotube research grew most prolifically were also the years in which it attracted the greatest citation attention, and the apparent decline in citation averages toward 2022-2025 should be read as a well-recognised artefact of citation lag rather than as evidence of declining research quality or impact.

The Three-Field Plot shows a Sankey-style visualisation linking the most relevant Authors, Author Keywords, and Sources within the Carbon Nanotube research corpus. The width of each connecting flow indicates the relative strength of association among these three bibliometric dimensions, making it possible to visually trace which prolific authors are publishing on specific thematic keywords and in which journals they are doing so. Rather than yielding independent numerical findings, this plot complements the tabular analyses presented elsewhere in this study by revealing, in a single integrated view, the interconnected structure of authorship, thematic content, and publication venues that characterises this research field (Figure 4).

Table 4 and Figure 5 lists the fifteen most prolific authors contributing to Carbon Nanotube research. Kumar A leads with 399 articles (2.37% of total documents) and an article-fractionalised count of 86.18, followed by Kumar S (324 articles, fractionalised count 70.62) and Kumar R (262 articles, fractionalised count 52.76). The recurrence of the surname 'Kumar' among the top contributors (four of the fifteen listed authors) reflects the strong concentration of Indian researchers in this field, consistent with India's dominant share of SAARC regional output discussed later in this analysis. The considerable gap between raw article counts and fractionalised counts for most authors, for instance, Kumar A's 399 articles fractionalise to 86.18, further confirms the highly collaborative, multi-author character of Carbon Nanotube publications already noted in Table 1.

Table 5 and Figure 6 present the fifteen most cited authors within the local reference network of this dataset. Bose S tops the list with 1,023 local citations, followed by Singh BP (816 citations) and Ramaprabhu S (784 citations). Notably, several authors who do not feature among the most prolific publishers in Table 8, such as Rao CNR (633 citations) and Mathur RB (600 citations), nonetheless rank highly for local citation impact, indicating that a smaller number of highly influential, foundational publications

by these authors continue to shape the direction of subsequent Carbon Nanotube research, independent of overall publication volume.

Table 6 and Figure 7 examines author productivity patterns through Lotka's Law, comparing the observed proportion of authors at each productivity level against the theoretical distribution predicted by the inverse-square law. Of the 48,487 authors in the dataset, 34,319 (70.78%) have published only a single document, noticeably higher than the theoretical Lotka expectation of 61.23% for single-document authors. Correspondingly, the proportion of authors publishing 2 documents (13.32% observed versus 15.31% theoretical) and higher productivity levels tends to fall at or below theoretical expectations, with only 1,149 authors (2.37%) publishing more than 10 documents. This pattern indicates that Carbon Nanotube research is characterised by an even larger base of occasional, low-productivity contributors than Lotka's Law would typically predict, a common feature of large, rapidly

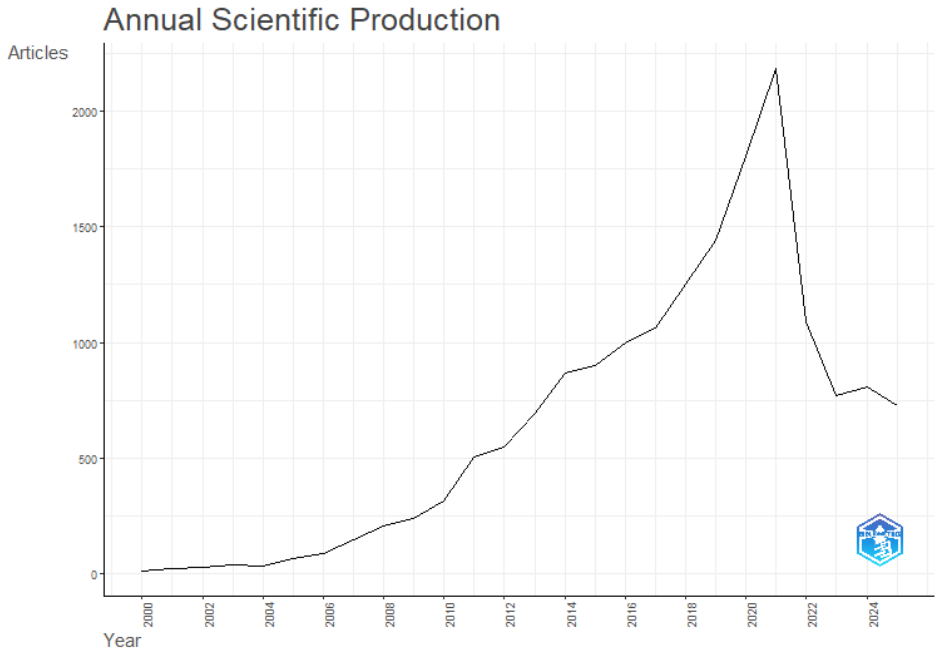


Figure 2: Annual Scientific Production.

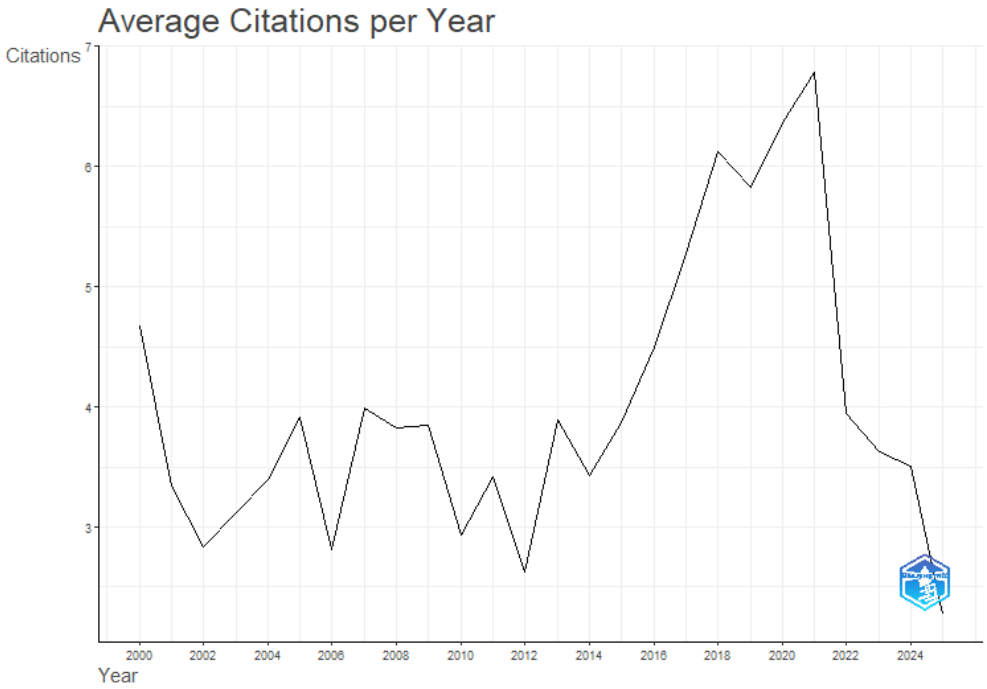


Figure 3: Average Citation Per Year. Three-Fields Plot Illustrating the Relationships among Cited References, Authors, and Keywords in Carbon Nanotube Research across SAARC Countries.

Table 2: Year-wise Scientific Productivity in Carbon Nanotube Research across SAARC Countries.

Sl. No.	Year	No. of Publications
1.	2000	11
2.	2001	18
3.	2002	27
4.	2003	37
5.	2004	32
6.	2005	63
7.	2006	84
8.	2007	143
9.	2008	205
10.	2009	236
11.	2010	313
12.	2011	502
13.	2012	549
14.	2013	693
15.	2014	868
16.	2015	897
17.	2016	995
18.	2017	1062
19.	2018	1250
20.	2019	1443
21.	2020	1805
22.	2021	2186
23.	2022	1091
24.	2023	770
25.	2024	805
26.	2025	728

growing, and highly collaborative interdisciplinary fields where many researchers contribute occasionally to joint, multi-author studies rather than establishing sustained individual publication programmes.

Table 7 and Figure 8 ranks authors by local h-index, g-index and m-index. Kumar A again leads with an h-index of 62, a g-index of 127, and 18,762 total citations across 399 articles beginning in 2001, confirming a sustained and high-impact publication record consistent with the prolific output identified in Table 8. Kumar R (h-index 57) and Rao CNR (h-index 55) follow, though Rao CNR's citation record beginning in 2000 combined with a relatively modest 127 articles yielding 14,056 citations reflects a smaller but exceptionally high-impact body of work. The m-index values, which normalise the h-index for career length, further highlight authors such as Kumar S (m-index 2.00, active since 2001) and Bose S (m-index 2.33, active since 2006) as maintaining a consistently strong and steady citation trajectory throughout their publishing careers in this field.

Table 8 and Figure 9 lists the fifteen most cited documents globally. The single most influential publication is by Théry C (2018, Journal of Extracellular Vesicles), which has accumulated 10,085 total citations, an average of 1,120.56 citations per year, far exceeding all other entries in the list. This is followed by Rao CNR (2009, Angewandte Chemie International Edition) with 3,893 citations and Langer J (2019, ACS Nano) with 3,650 citations, the latter showing a notably high normalised citation rate of 78.27 given its shorter citation window. The presence of foundational, highly cited works spanning diverse sub-domains, extracellular vesicles, nanotechnology in medicine, graphene-based materials, and toxicology illustrates the interdisciplinary reach of Carbon Nanotube-related research and its influence extending well beyond core materials science into biomedical and environmental health applications.

Table 9 and Figure 10 presents the documents that are most frequently cited within the local citation network of this dataset, providing a view of intellectual influence that is specific to the Carbon Nanotube research community rather than to the wider global literature. Mathur RB (2008, Composites Science and Technology) tops the local citation ranking, followed by Rao CNR (2009, Angewandte Chemie International Edition) and Srivastava A (2004, Nature Materials). The prominence of these particular works within the local network, several of which do not appear among the top-ranked global citations in Table 12, indicates that they function as foundational reference points specifically for researchers working within the Carbon Nanotube field, shaping the internal intellectual structure and citation practices of this specialised research community.

Table 10 and Figure 11 identifies the fifteen most productive journals publishing Carbon Nanotube research. RSC Advances leads the ranking with 459 articles, followed by Scientific Reports with 261 articles and Materials Today: Proceedings with 259 articles. ACS Omega (226 articles) and Carbon (138 articles) round out the top five. Collectively, these ten leading sources account for a meaningful share of total output, with a visible concentration of publications in high-volume, multidisciplinary open-access journals such as RSC Advances and ACS Omega alongside domain-specific titles such as Carbon and the Journal of Nanomaterials.

Table 11 and Figure 12 applies Bradford's Law of Scattering to the 3,415 journal sources publishing Carbon Nanotube research, dividing them into three zones of equal productivity (approximately 5,600 articles each). Zone 1, the Nucleus, comprises just 63 highly productive core journals contributing 5,572 articles, whereas Zone 2 (the Radiant zone) spans 356 moderately productive journals yielding 5,693 articles, and Zone 3 (the Peripheral zone) is composed of a much larger tail of 2,996 low-productivity journals contributing 5,548 articles. This steep concentration, with less than 2% of journals (Zone 1) yielding roughly one-third of all output, is the classical signature

Table 3: **Year-wise Average Citation Impact of Carbon Nanotube Research in SAARC Countries.**

Sl. No.	Year	Mean TC per Art	N	Mean TC per Year	Citable Years
1.	2000	126	11	4.67	27
2.	2001	86.78	18	3.34	26
3.	2002	71	27	2.84	25
4.	2003	74.86	37	3.12	24
5.	2004	78.28	32	3.4	23
6.	2005	86.02	63	3.91	22
7.	2006	58.99	84	2.81	21
8.	2007	79.7	143	3.99	20
9.	2008	72.83	205	3.83	19
10.	2009	69.38	236	3.85	18
11.	2010	49.86	313	2.93	17
12.	2011	54.7	502	3.42	16
13.	2012	39.36	549	2.62	15
14.	2013	54.48	693	3.89	14
15.	2014	44.61	868	3.43	13
16.	2015	46.43	897	3.87	12
17.	2016	49.49	995	4.5	11
18.	2017	52.76	1062	5.28	10
19.	2018	55.1	1250	6.12	9
20.	2019	46.63	1443	5.83	8
21.	2020	44.59	1805	6.37	7
22.	2021	40.69	2186	6.78	6
23.	2022	19.76	1091	3.95	5
24.	2023	14.52	770	3.63	4
25.	2024	10.52	805	3.51	3
26.	2025	4.54	728	2.27	2

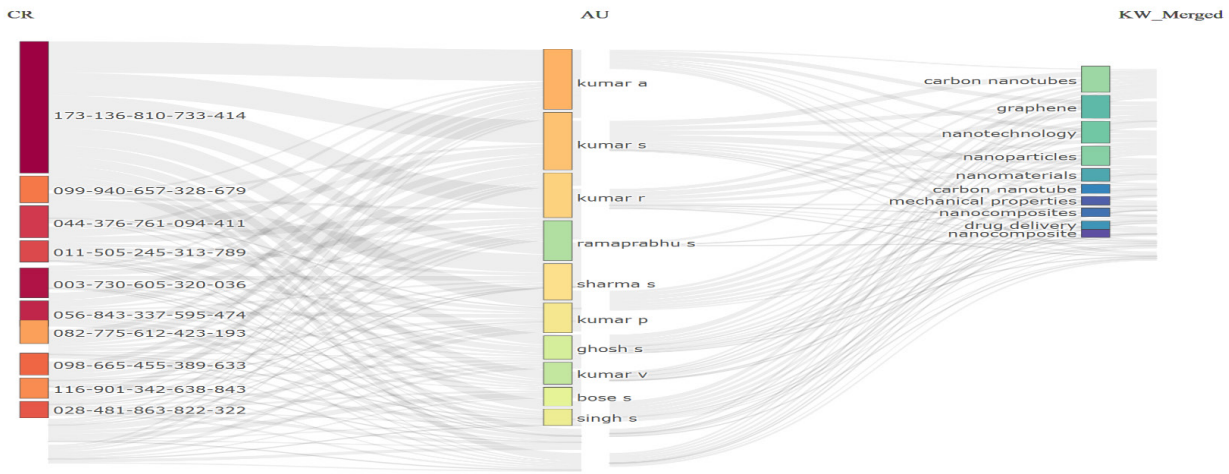


Figure 4: Three Key Fields Plot.

Table 4: Most Relevant Authors in Carbon Nanotube Research across SAARC Countries.

Sl. No.	Authors	Articles	Articles Fractionalized
1.	Kumar A	399	86.18
2.	Kumar S	324	70.62
3.	Kumar R	262	52.76
4.	Sharma S	192	44.67
5.	Kumar P	190	39.27
6.	Singh S	171	39.06
7.	Bose S	160	41.53
8.	Ghosh S	152	35.57
9.	Kumar V	152	28.60
10.	Ramaprabhu S	146	53.27
11.	Singh A	145	28.55
12.	Das S	141	25.59
13.	Sharma A	135	32.94
14.	Kumar D	131	31.28
15.	Kumar M	131	28.91

Table 5: Most Locally Cited Authors in Carbon Nanotube Research across SAARC Countries.

Sl. No.	Author	LocalCitations
1.	Bose S	1023
2.	Singh BP	816
3.	Ramaprabhu S	784
4.	Rao CNR	633
5.	Mathur RB	600
6.	Kumar R	575
7.	Govindaraj A	547
8.	Kumar A	538
9.	Gupta VK	523
10.	Hayat T	467
11.	Kumar S	448
12.	Sood AK	444
13.	Dhakate SR	436
14.	Alsaedi A	430
15.	Bhattacharyya AR	363

of Bradford scattering and confirms that a small, well-defined set of core journals can be targeted for efficient and comprehensive literature coverage of this field. The mathematical verification of this fit is presented below.

Mathematical Analysis

To determine the "fit" of the law, we calculate the Bradford Multiplier (n), which is the ratio of the number of journals between successive zones.

Step 1: Calculate n_1 (Ratio between Zone 2 and Zone 1)

$$n1 = = \frac{356}{63} = 5.65$$

Step 2: Calculate n_2 (Ratio between Zone 3 and Zone 2)

$$n2 = = \frac{2996}{356} = 8.42$$

Step 3: Determine the Mean Multiplier (n)

$$\text{Mean (n)} = \frac{5.65 + 8.42}{2} = 7.03$$

Verification of the "Fit"

In this analysis, we compare the Actual Distribution of our research journals against the Theoretical Distribution predicted by Bradford's 1: n: n^2 formula.

Theoretical Distribution (1: 7.03: 7.03^2):

63: (63* 7.03): (63*49.42) **63: 443: 3113**

Actual Distribution:

63: 356: 2996

Analysis of Fit for Journals:

Zone 2 Deviation:

$$\text{Percentage Deviation} = \frac{Actual - Theoretical}{Theoretical} * 100$$

$$= \frac{356 - 443}{443} = \frac{-87}{443} = -0.1964$$

$$= -0.1964 * 100$$

Percentage Deviation = - 19.64 %

Zone 2 Deviation: -19.64 % (Slightly fewer journals than expected).

Zone 3 Deviation:

$$\text{Percentage Deviation} = \frac{Actual - Theoretical}{Theoretical} * 100$$

$$= \frac{2996 - 3113}{3113} = \frac{-117}{3113} = -0.0375$$

$$= -0.0375 * 100$$

Percentage Deviation = - 3.75 %

Zone 3 Deviation: -3.75 % (Extremely close to the theoretical prediction).

Analysis of Fit for Articles:

Articles in Zone 1 (Nucleus): 5,572

Total Articles: 16,813

Divide the Zone 1 articles by the total articles:

$\frac{5572}{16813} = 0.33141$

Percentage: 0.33141 * 100 = **33.1%**

Similarly,

Zone 2: 33.9%

Zone 2: 33.0%

Test	Result	Verdict
Multiplier Consistency	5.65 vs 8.4	Moderate
Zone 3 Deviation	3.75 %	Excellent
Graphical Linearity	Constant Slope	High Fit

The analysis reveals that there is very much conformity within the dataset, based on the very high conformity in the journal distribution as demonstrated by the fact that the theoretical distribution of 63:443:3113 closely approximates the empirical distribution of 63:356:2996. This suggests that the literature within this dataset has a high level of bibliographic organization. A mean multiplier (n) of 7.03 was obtained, which acts as the growth constant, meaning that for every journal in the core nucleus, there are approximately 7 journals in the next tier, and roughly 49 journals in the peripheral tier.

In terms of deviations, Zone 2 has a deviation of -19.64%, indicating that this zone concentrates its articles within a smaller, highly efficient selection of mid-tier journals. Crucially, the exceptionally low deviation in Zone 3 of just -3.75% demonstrates excellent structural alignment with traditional Bradfordian distribution expectations. The primary takeaway for researchers is that the 63 core journals constitute the high-productivity "Nucleus," yielding roughly one-third (33.1%) of the total literature body, making them the most critical targets for literature searches and collection development.

Table 12 and Figure 13 ranks journal sources by local impact, measured through the h-index, g-index, m-index and Total Citations (TC) within the dataset. RSC Advances again emerges as the leading source, with an h-index of 76, a g-index of 134, and 25,900 total citations accumulated from 459 articles since 2012. Scientific Reports follows closely with an h-index of 73 (16,214 citations, 261 articles), while ACS Omega records the highest m-index in the list (6.00), reflecting an unusually rapid citation accumulation rate relative to its shorter publication history beginning in 2017. Notably, several journals with comparatively fewer published articles, such as Polymers (71 articles but 8,240 citations) and Biosensors and Bioelectronics (56 articles but 5,334 citations), display disproportionately high citation-to-article



Figure 5: Most Prolific Authors.

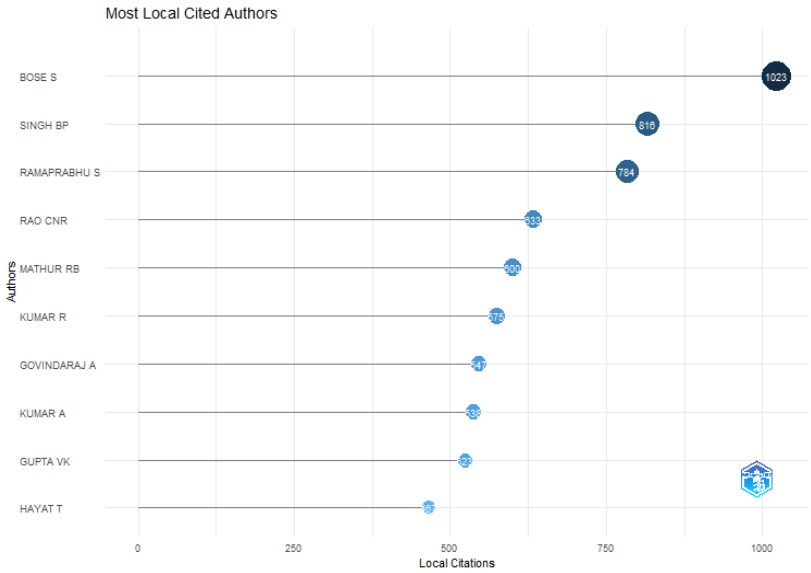


Figure 6: Most Local Cited Authors.

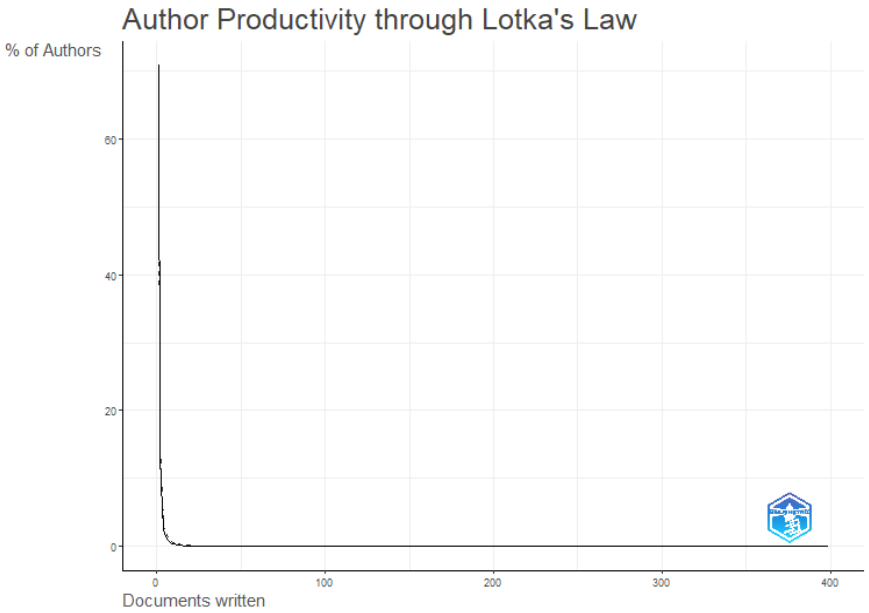


Figure 7: Author Productivity through Lotka's Law.

Table 6: Application of Lotka's Law to Author Productivity in Carbon Nanotube Research.

Sl. No.	Documents written	N. of Authors	Proportion of Authors	Theoretical
1.	1	34319	0.70779797	0.612333
2.	2	6457	0.13316972	0.15308325
3.	3	2613	0.05389073	0.068037
4.	4	1341	0.0276569	0.03827081
5.	5	886	0.01827294	0.02449332
6.	6	581	0.01198259	0.01700925
7.	7	424	0.00874461	0.01249659
8.	8	303	0.0062491	0.0095677
9.	9	232	0.00478479	0.00755967
10.	10	182	0.00375358	0.00612333
11.	Above 10	1149	0.00338235	0.0050606

Table 7: Evaluation of Author Impact and Citation Performance Based on H-Index, G-Index, and M-Index.

Sl. No.	Author	h_index	g_index	m_index	TC	NP	PY_start
1.	Kumar A	62	127	2.38	18762	399	2001
2.	Kumar R	57	115	3.00	14553	262	2008
3.	Rao CNR	55	118	2.04	14056	127	2000
4.	Ramaprabhu S	54	89	2.25	8592	146	2003
5.	Kumar S	52	107	2.00	13449	324	2001
6.	Bose S	49	94	2.33	9540	160	2006
7.	Kumar P	48	96	2.53	9681	190	2008
8.	Sharma S	43	129	2.26	16755	192	2008
9.	Singh BP	42	75	2.21	5850	104	2008
10.	Govindaraj A	41	91	1.52	11660	91	2000
11.	Hayat T	41	65	2.73	4453	91	2012
12.	Kumar V	41	76	1.95	6106	152	2006
13.	Singh A	41	75	1.58	5970	145	2001
14.	Gupta VK	40	49	1.48	13889	49	2000
15.	Singh S	40	76	1.74	6276	171	2004

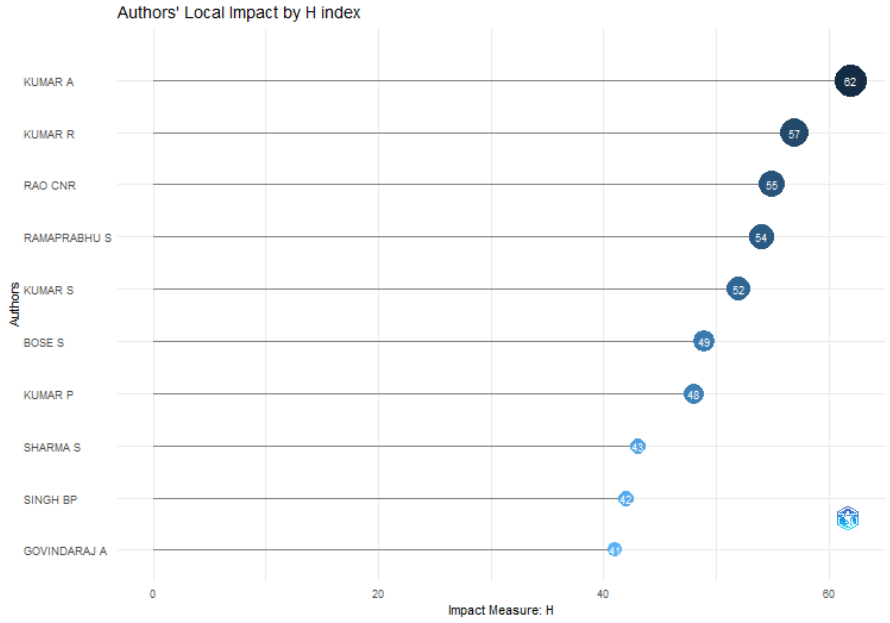


Figure 8: Author's Local Impact.

ratios, indicating that citation impact within this field is not governed by publication volume alone but also by the specific thematic relevance and visibility of the venue.

Table 13 and Figure 14 ranks the ten most frequently occurring author keywords in the dataset. 'Carbon nanotubes' is unsurprisingly the dominant term, occurring 275 times (1.64% of all 16,813 documents), followed by 'nanoparticles' (233 occurrences, 1.39%) and 'nanotechnology' (222 occurrences, 1.32%). The presence of 'graphene' (165 occurrences) and 'nanoc omposites'/'nanocomposite' (94 and 72 occurrences, respectively) among the top ten terms indicates a strong thematic overlap between Carbon Nanotube research and adjacent nanomaterial domains, while the appearance of 'drug delivery' (112 occurrences) as the sixth most frequent keyword highlights the substantial and growing application-oriented research stream connecting Carbon Nanotubes to biomedical and pharmaceutical uses.

Table 14 and Figure 15 presents a co-word network analysis, characterising the fifteen most central keyword nodes by betweenness, closeness and PageRank centrality, all of which fall within a single dominant cluster (Cluster 1). 'Carbon nanotubes' occupies the most central position in the network, recording the highest betweenness centrality (241.03) and PageRank score

Table 8: Most Globally Cited Documents in Carbon Nanotube Research.

Sl. No.	Paper	DOI	Total Citations	TC per Year	Normalized TC
1.	Théry C, 2018, Journal of Extracellular Vesicles	10.1080/20013078.2018.1535744; 10.1080/20013078.2018.1535750	10085	1120.56	183.03
2.	Rao CNR, 2009, Angewandte Chemie (international ed. in English)	10.1002/anie.200901678	3893	216.28	56.11
3.	Langer J, 2019, ACS Nano	10.1021/acsnano.9b04224	3650	456.25	78.27
4.	Das A, 2008, Nature Nanotechnology	10.1038/nnano.2008.67	3532	185.89	48.50
5.	Graf D, 2007, Nano Letters	10.1021/nl061702a	2581	129.05	32.38
6.	Klionsky DJ, 2021, Autophagy	10.1080/15548627.2020.1797280	2553	425.50	62.75
7.	Singh J, 2018, Journal of Nanobiotechnology	10.1186/s12951-018-0408-4	2352	261.33	42.69
8.	Oberdörster G, 2005, Particle and Fibre Toxicology	10.1186/1743-8977-2-8	2055	93.41	23.89
9.	Chen H, 2016, Progress in Polymer Science	10.1016/j.progpolymsci.2016.03.001	1983	180.27	40.07
10.	Mitra S, 2022, Journal of King Saud University - Science	10.1016/j.jksus.2022.101865	1780	356.00	90.08
11.	Thomas B, 2018, Chemical Reviews	10.1021/acs.chemrev.7b00627	1593	177.00	28.91
12.	Gupta VK, 2012, RSC Advances	10.1039/c2ra20340e	1536	102.40	39.03
13.	Ali A, 2016, Nanotechnology, Science and Applications	10.2147/nsa.s99986	1483	134.82	29.97
14.	Din F, 2017, International Journal of Nanomedicine	10.2147/ijn.s146315	1470	147.00	27.86
15.	Karimi, 2016, Chemical Society Reviews	10.1039/c5cs00798d	1466	133.27	29.62

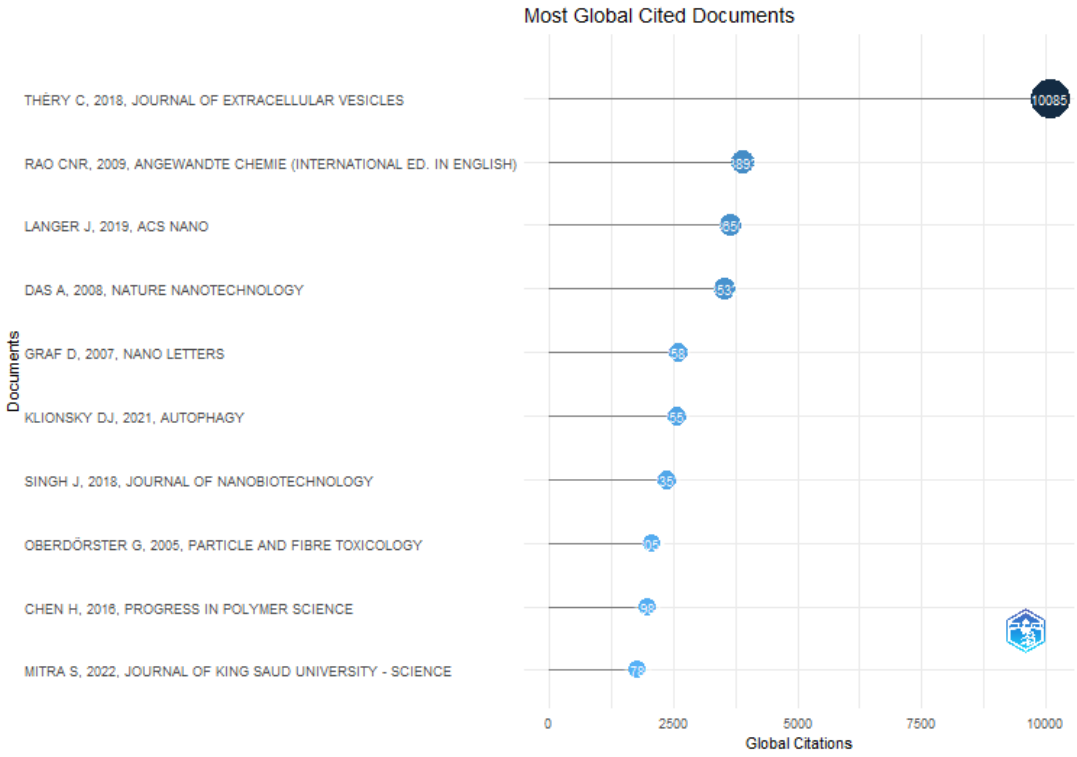


Figure 9: Most Globally Cited Documents.

Table 9: Most Locally Cited Documents in Carbon Nanotube Research.

Sl. No.	Document	DOI	Year	Local.Citations	Global.Citations	Ratio	Normalized.Local. Citations	Normalized.Global.Citations
1.	Mathur RB, 2008, Composites Science and Technology	10.1016/j.compscitech.2008.02.020	2008	89	334	26.65	19.51	4.59
2.	Rao CNR, 2009, Angewandte Chemie (International Ed. In English)	10.1002/anie.200901678	2009	65	3893	1.67	16.32	56.11
3.	Srivastava A, 2004, Nature Materials	10.1038/nmat1192	2004	57	627	9.09	11.92	8.01
4.	Rao CN, 2001, Chemphyschem: A European Journal of Chemical Physics and Physical Chemistry	10.1002/1439-7641(20010216)2:2<78::aid -cphc78>3.3.co;2-z; 10.1002/1439-7641(20010216)2:2<78::aid-cp hc78>3.0.co;2-7	2001	56	597	9.38	8.20	6.88
5.	Gupta TK, 2013, Journal of Materials Chemistry A	10.1039/c3ta11611e	2013	54	323	16.72	16.51	5.93
6.	Gupta VK, 2010, Journal of Hazardous Materials	10.1016/j.jhazmat.2010.08.053	2010	52	979	5.31	14.64	19.64
7.	Shaijumon MM, 2003, Chemical Physics Letters	10.1016/s0009-2614(03)00741-3	2003	52	95	54.74	11.38	1.27
8.	Geetha S, 2009, Journal of Applied Polymer Science	10.1002/app.29812	2009	52	1112	4.68	13.06	16.03
9.	Ghosh S, 2003, Science (New York, N.Y.)	10.1126/science.1079080	2003	51	785	6.50	11.17	10.49
10.	Ellahi R, 2015, Ieee Transactions on Nanotechnology	10.1109/tnano.2015.2435899	2015	47	227	20.70	16.95	4.89
11.	Beg S, 2011, The Journal of Pharmacy and Pharmacology	10.1111/j.2042-7158.2010.01167.x	2011	46	302	15.23	12.61	5.52
12.	Haq RU, 2015, Physica B: Condensed Matter	10.1016/j.physb.2014.09.031	2015	45	210	21.43	16.23	4.52
13.	Bose S, 2009, Composites Science and Technology	10.1016/j.compscitech.2008.10.024	2009	44	199	22.11	11.05	2.87
14.	Imtiaz M, 2016, International Journal of Heat and Mass Transfer	10.1016/j.ijheatmasstransfer.2016.05.114	2016	43	204	21.08	19.29	4.12
15.	Gupta VK, 2013, Advances in Colloid and Interface Science	10.1016/j.cis.2013.03.003	2013	43	1209	3.56	13.15	22.19

Table 10: Source-wise Distribution of Carbon Nanotube Research Publications.

Sl. No.	Sources	No. of Articles
1.	RSC Advances	459
2.	Scientific Reports	261
3.	Materials Today: Proceedings	259
4.	ACS Omega	226
5.	Carbon	138
6.	International Journal of Hydrogen Energy	132
7.	Journal of Nanomaterials	122
8.	Bulletin of Materials Science	117
9.	Electrochimica Acta	116

(0.0732), confirming its role as the principal bridging concept connecting other thematic keywords in the field. 'Graphene' follows as the second most central node (betweenness 140.25, PageRank 0.0613), reflecting the close conceptual and material relationship between these two nanomaterials in literature. The clustering of nearly all listed keywords into a single cluster suggests a thematically cohesive and tightly interconnected research field, in which concepts such as nanocomposites, adsorption, supercapacitors, and electrochemical sensors are all closely tied to the central carbon nanotube and graphene research theme rather than forming distinct, isolated sub-fields.

Table 15 and Figure 16 categorises the dataset's documents by field of study, based on Open Alex-derived subject classification. Materials science is by far the dominant field, associated with 12,957 documents (77.07% of the total 16,813 documents), followed by the specific sub-field of 'Carbon nanotube' itself (8,619 documents, 51.27%) and Nanotechnology (5,332 documents, 31.72%). Given that individual documents are typically tagged with multiple overlapping fields, subjects such as Composite material (4,991 documents, 29.68%), Chemical engineering (4,150 documents, 24.69%) and Chemistry (3,656 documents, 21.75%) also register substantial shares, confirming that Carbon Nanotube research functions as a genuinely interdisciplinary field situated at the intersection of materials science, chemistry, and engineering, with Physics (1,446 documents, 8.60%) and Electrochemistry (1,219 documents, 7.25%) representing smaller but still significant contributing disciplines.

Table 16 and Figure 17 identifies the fifteen most productive institutions contributing to Carbon Nanotube research. The Indian Institute of Science leads with 884 documents (5.26% of total output), followed by the Council of Scientific and Industrial Research (627 documents, 3.73%) and the Indian Institute of Technology Madras (484 documents, 2.88%). Of the fifteen listed institutions, ten are Indian (including six IITs, the CSIR, IISc, VIT University, and Banaras Hindu University), while the remainder includes Quaid-i-Azam University from Pakistan and King Abdulaziz University and King Saud University from Saudi Arabia. This distribution highlights the overwhelming dominance of Indian academic and research institutions in driving Carbon Nanotube scholarship within the SAARC region, a pattern that is further confirmed by the country-wise production figures presented later in this analysis.

Table 17 and Figure 18 presents the ten funding agencies most frequently acknowledged in Carbon Nanotube publications. The Science and Engineering Research Board leads with 547 acknowledged documents (3.25% of total output), followed closely by the Department of Science and Technology under the Ministry of Science and Technology, India (296 documents, 1.76%) and the University Grants Commission (294 documents, 1.75%). It is notable that Indian funding agencies, the Science and Engineering Research Board, two separate listings for the Department of Science and Technology, the University Grants Commission, the Council of Scientific and Industrial Research (India), and the Ministry of Human Resource Development, together account for six of the ten entries in this list, reinforcing the substantial role that Indian public research funding plays in sustaining Carbon Nanotube research, alongside international

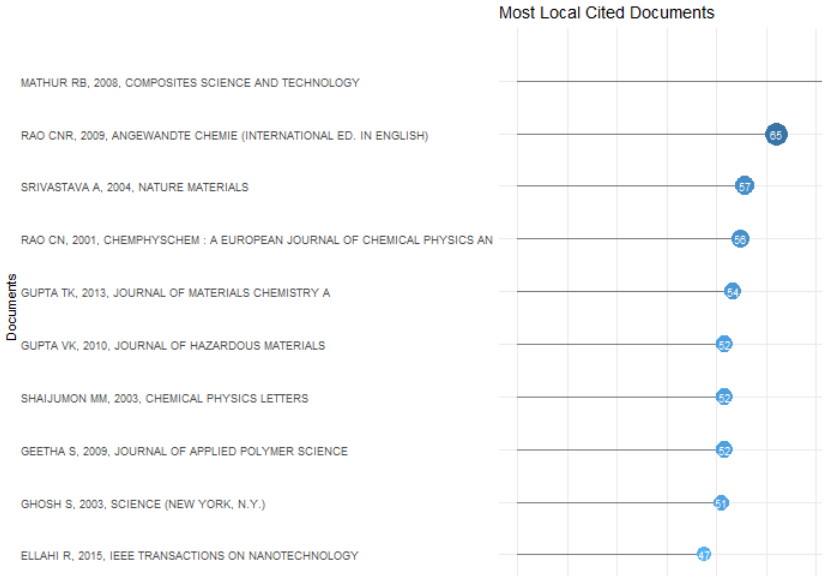


Figure 10: Most Locally Cited Documents.

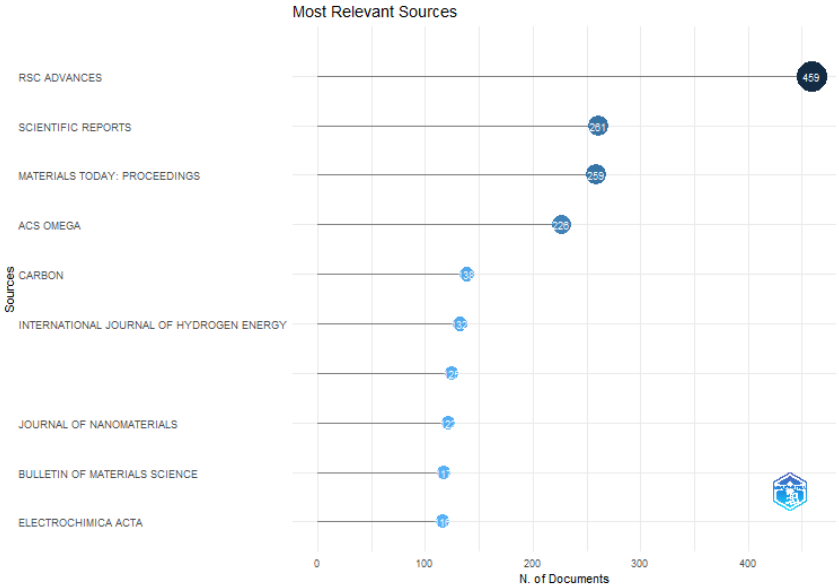


Figure 11: Most Relevant Sources.

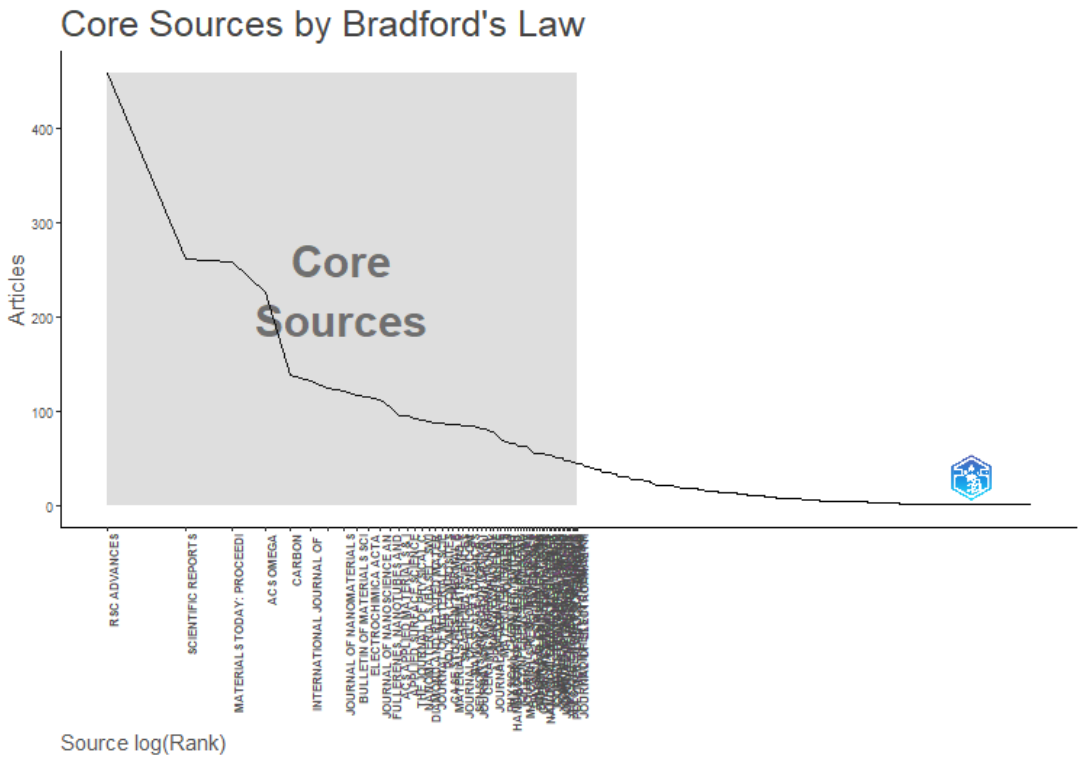


Figure 12: Core Sources by Bradford's Law.

Table 11: Bradford's Law Analysis of Journal Productivity.

Zone	Journals (k)	Articles (f)	Description
Zone 1 (k_1)	63	5572	The Nucleus: Highly productive core journals.
Zone 2 (k_2)	356	5693	The Radiant: Moderately productive journals.
Zone 3 (k_3)	2996	5548	The Peripheral: Journals with low productivity on this topic.
Total	3415	16813	

Table 12: Evaluation of Source Impact Using H-Index, G-Index, and M-Index.

Sl. No.	Source	h_index	g_index	m_index	TC	NP	PY_start
1.	RSC Advances	76	134	5.06	25900	459	2012
2.	Scientific Reports	73	111	4.86	16214	261	2012
3.	ACS Omega	60	87	6	10512	226	2017
4.	ACS Applied Materials and Interfaces	52	84	3.25	7324	96	2011
5.	Carbon	50	82	1.92	7370	138	2001
6.	International Journal of Hydrogen Energy	50	76	2	7023	132	2002
7.	Electrochimica Acta	45	71	1.66	568.9	116	2000
8.	Sensors and Actuators B: Chemical	45	74	2.25	5634	84	2007
9.	Polymers	44	71	4	8240	71	2016
10.	The Journal of Physical Chemistry C	44	70	2.09	5228	93	2006
11.	Biosensors and Bioelectronics	43	56	2.04	5334	56	2006
12.	Nanomaterials (Basel, Switzerland)	43	74	3.07	5642	90	2013
13.	Journal Of Molecular Liquids	42	75	2.8	5642	83	2012
14.	Composites Part B: Engineering	39	53	2.4375	3788	53	2011
15.	Applied Surface Science	38	59	1.46	3944	95	2001

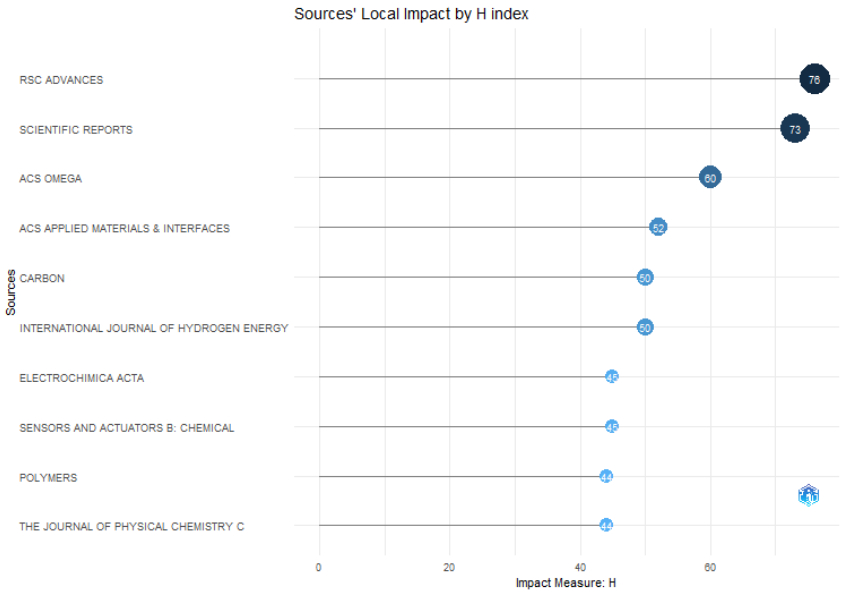


Figure 13: Source Local Impact.

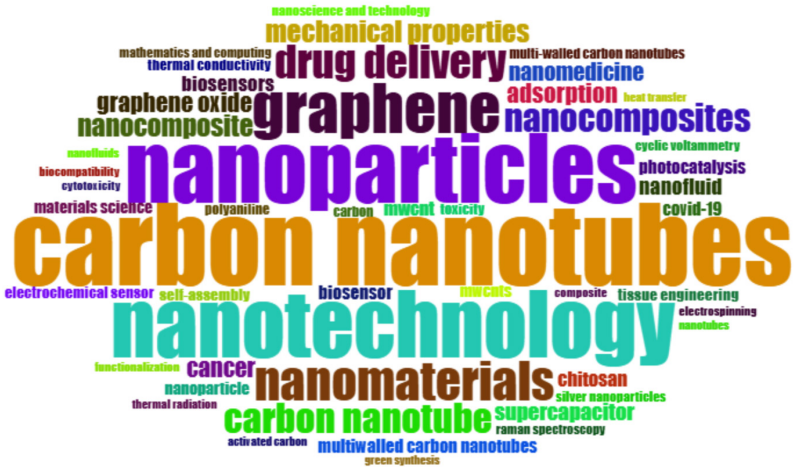


Figure 14: Most Used Keywords.

Table 13: Most Relevant Keywords in Carbon Nanotube Research.

Sl. No.	Words	Occurrences
1.	Carbon nanotubes	275
2.	Nanoparticles	233
3.	Nanotechnology	222
4.	Graphene	165
5.	Nanomaterials	131
6.	Drug delivery	112
7.	Carbon nanotube	101
8.	Nanocomposites	94
9.	Mechanical properties	74
10.	Nanocomposite	72

funders such as the National Natural Science Foundation of China (135 documents) and the National Research Foundation of Korea (124 documents).

The SAARC country-wise production table reveals a highly skewed regional distribution of Carbon Nanotube research output. India overwhelmingly dominates the region, contributing 14,158 of the 16,813 total documents (84.21%), followed at a considerable distance by Pakistan with 2,043 documents (12.15%) and Bangladesh with 452 documents (2.69%). The remaining SAARC member countries, Nepal (72 documents, 0.43%), Sri Lanka (69 documents, 0.41%), Afghanistan (13 documents, 0.08%) and Bhutan (6 documents, 0.04%), together contribute less than 1% of total regional output, while the Maldives records no publications in this field at all. This extreme concentration of research activity in India, further corroborated by the institutional data in Table 18 and the author-level data in Tables 8 and 9, underscores the considerable disparity in research infrastructure, funding, and scientific capacity for nanomaterials research across the SAARC region, and highlights an opportunity for greater regional collaboration and capacity-building in Carbon Nanotube science among the less-represented member states (Figure 19).

Table 14: **Keyword Co-Occurrence Network in Carbon Nanotube Research.**

Sl. No.	Node	Cluster	Betweenness	Closeness	PageRank
1.	Carbon Nanotubes	1	241.03	0.014	0.0732
2.	Graphene	1	140.25	0.014	0.0613
3.	Carbon Nanotube	1	34.82	0.011	0.0258
4.	Nanocomposites	1	18.11	0.011	0.0293
5.	Mechanical Properties	1	24.91	0.011	0.0175
6.	Nanocomposite	1	22.74	0.011	0.0204
7.	Adsorption	1	26.19	0.010	0.0191
8.	Graphene Oxide	1	30.63	0.012	0.0277
9.	Supercapacitor	1	15.66	0.011	0.0199
10.	Mwcnt	1	10.29	0.010	0.0112
11.	Multiwalled Carbon Nanotubes	1	2.66	0.009	0.0080
12.	Photocatalysis	1	0.17	0.010	0.0100
13.	Mwcnts	1	0.26	0.008	0.0061
14.	Electrochemical Sensor	1	2.75	0.010	0.0088
15.	Polyaniline	1	37.57	0.011	0.0187

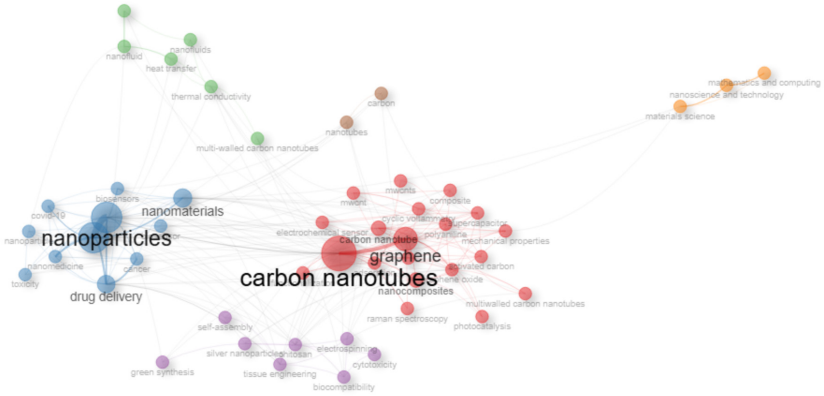


Figure 15: Co-words Network Analysis.

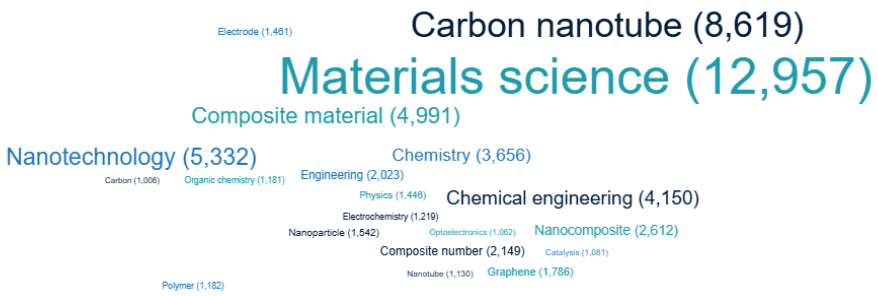


Figure 16: Major Fields of Study.

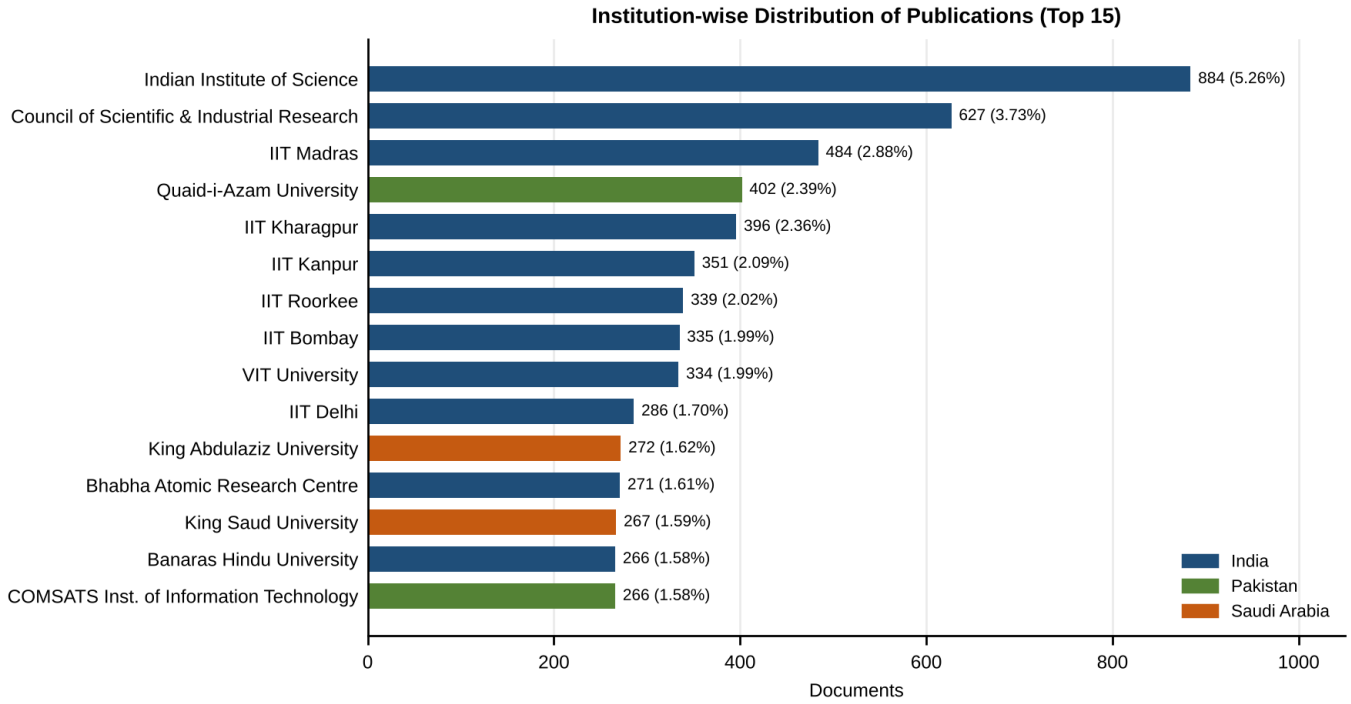


Figure 17: Institution-wise Distributions of publications.

Table 15: Major Fields of Study in Carbon Nanotube Research.

Sl. No.	Field of Study	Document Count
1.	Materials science	12957
2.	Carbon nanotube	8619
3.	Nanotechnology	5332
4.	Composite material	4991
5.	Chemical engineering	4150
6.	Chemistry	3656
7.	Nanocomposite	2612
8.	Composite number	2149
9.	Engineering	2023
10.	Graphene	1786
11.	Nanoparticle	1542
12.	Electrode	1461
13.	Physics	1446
14.	Electrochemistry	1219
15.	Polymer	1182

Table 16: Analysis of Institutional Contributions in Carbon Nanotube Research.

Sl. No.	Institution Name	Document Count
1.	Indian Institute of Science	884
2.	Council of Scientific and Industrial Research	627
3.	Indian Institute of Technology Madras	484
4.	Quaid-i-Azam University	402
5.	Indian Institute of Technology Kharagpur	396
6.	Indian Institute of Technology Kanpur	351
7.	Indian Institute of Technology Roorkee	339
8.	Indian Institute of Technology Bombay	335
9.	VIT University	334
10.	Indian Institute of Technology Delhi	286
11.	King Abdulaziz University	272
12.	Bhabha Atomic Research Centre	271
13.	King Saud University	267
14.	Banaras Hindu University	266
15.	COMSATS Institute of Information Technology	266

Findings

- The CNT research literature of the SAARC countries comprised 16,813 documents published in 3,415 sources between 2000 and 2025, with an annual growth rate of 18.26% and an average of 41.72 citations per document (Table 1).
- Year-wise analysis shows a continuous rise in publications from 11 documents in 2000 to a peak of 2,186 documents in 2021, followed by a decline during 2022-2025 (Table 2).
- Source-wise analysis reveals RSC Advances (459 articles) as the most productive journal, followed by Scientific

Reports (261) and Materials Today: Proceedings (259) (Table 3).

- The application of Bradford's Law of Scattering shows that 63 core "nucleus" journals account for about one-third (33.1%) of the total literature, with a Zone 3 deviation of just -3.75%, indicating an excellent fit with the theoretical distribution (Tables 4 and 5).
- RSC Advances also recorded the highest source impact, with an h-index of 76, followed by Scientific Reports (73) (Table 6).

Table 17: Major Funding Agencies in Carbon Nanotube Research in SAARC Countries.

Sl. No.	Funding	Document Count
1.	Science and Engineering Research Board	547
2.	Department of Science and Technology, Ministry of Science and Technology, India	296
3.	University Grants Commission	294
4.	Department of Science and Technology, Ministry of Science and Technology	273
5.	Council of Scientific and Industrial Research, India	138
6.	National Natural Science Foundation of China	135
7.	Council of Scientific and Industrial Research	133
8.	National Research Foundation of Korea	124
9.	Department of Science and Technology	94
10.	Ministry of Human Resource Development	80

- Author-wise analysis identifies Kumar A. as the most productive author with 399 articles, followed by Kumar S. (324) and Kumar R. (262), while Bose S. recorded the highest local citations (1,023) (Tables 7 and 8).
- Author productivity, tested through Lotka's Law, shows that 70.78% of the authors contributed only a single paper each, closely following the theoretical Lotka distribution (Table 9).
- Kumar A. also holds the highest author h-index (62), while the paper by Théry C. (2018) published in the Journal of Extracellular Vesicles recorded the highest global citation count (10,085) (Tables 10 and 11).
- Keyword and co-word network analysis identifies "carbon nanotubes" (275), "nanoparticles" (233) and "nanotechnology" (222) as the most frequently occurring keywords, with "carbon nanotubes" and "graphene" occupying the most central positions in the network (Tables 13 and 14).

Table 18: SAARC Country-wise Distribution of Research Publications in Carbon Nanotube.

Sl. No.	Country	Document Counts
1.	India	14158
2.	Pakistan	2043
3.	Bangladesh	452
4.	Nepal	72
5.	Sri Lanka	69
6.	Afghanistan	13
7.	Bhutan	6
8.	Maldives	0



Figure 18: Distribution of Publications with Funding Agencies' Support.

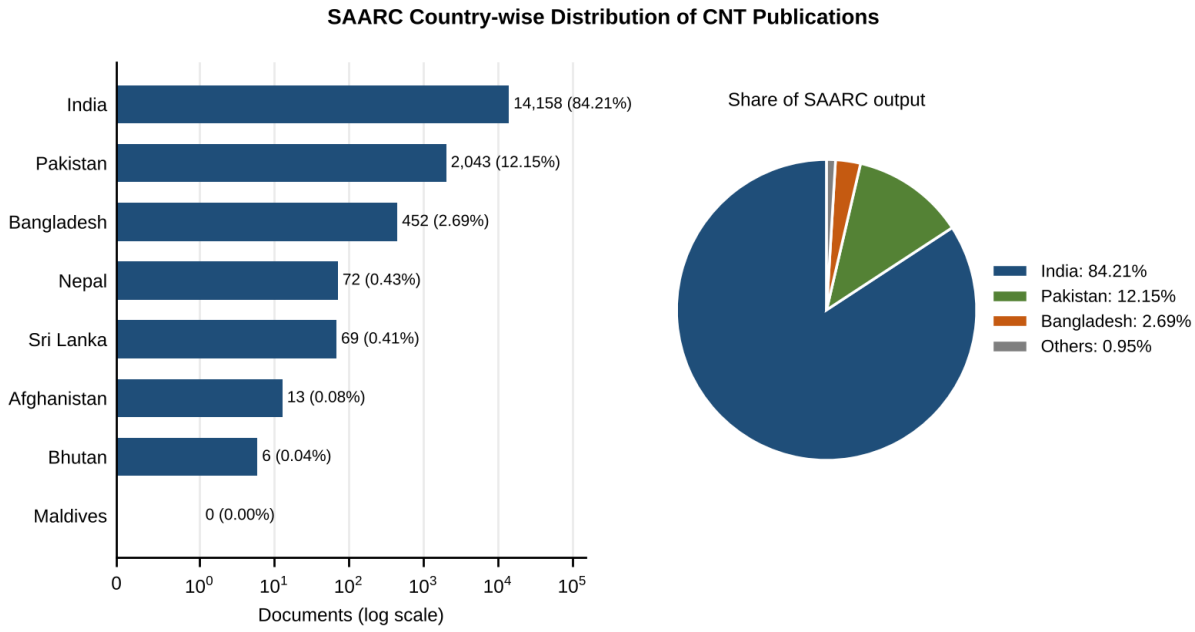


Figure 19: SAARC Country wise Distribution.

- Field-of-study analysis shows Materials Science (12,957 documents) and Carbon Nanotube (8,619) as the dominant subject areas of research (Table 15).
- Institution-wise distribution shows the Indian Institute of Science (884 documents) as the leading contributing institution, followed by the Council of Scientific and Industrial Research (627) (Table 16).
- Funding-agency analysis identifies the Science and Engineering Research Board, India (547 documents), as the leading funding body supporting CNT research (Table 17).
- Country-wise distribution shows that India overwhelmingly dominates CNT research in the SAARC region, contributing 14,158 documents (84.22%), followed distantly by Pakistan (2,043; 12.15%), Bangladesh (452; 2.69%), Nepal (72; 0.43%), Sri Lanka (69; 0.41%), Afghanistan (13; 0.08%) and Bhutan (6; 0.04%); no CNT publication output was recorded from the Maldives (Table 18).

CONCLUSION

The study reveals that Carbon Nanotube (CNT) research within the SAARC region has grown considerably since 2000, registering an annual growth rate of 18.26%, with a marked surge in output up to 2021 followed by a decline in the most recent years, which may partly reflect indexing lag rather than an actual fall in research activity. India stands out as the clear leader in the SAARC region, contributing more than four-fifths of the total CNT literature, driven largely by institutions such as the Indian Institute of Science and the premier Indian Institutes of Technology, and supported chiefly by national funding bodies such as the Science and Engineering Research Board and the Department of Science and Technology. Pakistan emerges as the second major contributor, while Bangladesh, Nepal, Sri Lanka, Afghanistan, and Bhutan show comparatively limited research activity, and the Maldives has yet to produce any CNT-related publication. The Bradford's Law and Lotka's Law analyses confirm that the literature is well structured, with a concentrated set of core journals and a research community dominated by low-frequency, single-paper contributors. Thematically, the field continues to be anchored around materials science, nanocomposites, and graphene, with growing application in areas such as drug delivery, sensors, and energy storage, indicating both foundational and applied research strength. The study underscores the need for greater research collaboration among SAARC nations, capacity building, and increased funding support in countries with limited CNT research output, to promote a more balanced and regionally inclusive advancement of nanotechnology research in South Asia.

ABBREVIATIONS

CNT: Carbon Nanotube; **SAARC:** South Asian Association for Regional Cooperation.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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