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Citation swing dynamics in Indian Chemistry research trends 2015–2024

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This study analyzes citation patterns in Indian chemistry research (2015–2024) using advanced bibliometric indicators such as Total Citations, Citation Swing Factors, Fold of Excess Citations, and Fold of H-core Citations over Excess Citations. Data from six Web of Science-indexed Indian chemistry journals reveal temporal variations in citation behaviour, signalling dynamic shifts in research visibility and impact. Citation Swing Factors indicate declining citation momentum, while Total Citations show considerable dispersion across years. The Fold of Excess Citations remains relatively stable, though fluctuations in Fold of H-core Citations over Excess Citations suggest evolving high-impact research patterns. These results underscore the changing citation dynamics in Indian chemistry research, underscoring the value of Citation Swing Factor indicators for tracking diffusion patterns and informing strategies to enhance research impact and global visibility.

Keywords: *H-index, H-core citations, Excess citations, Citation trends, Indian chemistry research, Bibliometric indicators, Citation swing factor, Research impact analysis.*

1. Introduction

The landscape of scientific research is continuously evolving, driven by advances in methodologies, the introduction of new indicators, and the dynamic nature of academic publishing [1] [2]. As a cornerstone of the scientific community, chemistry plays a pivotal role in this

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transformation, particularly in India, where the field has seen significant growth and development over the past decade [3]. India is among the top contributors to global chemistry research, particularly in organic chemistry, materials science, and nanotechnology [4]. Indian chemistry research has long been recognized for its contributions to various subfields, from theoretical chemistry to applied industrial research. The concept of citation analysis has long been instrumental in assessing the quality and impact of research outputs. As academia continues to globalize and interdisciplinary research gains prominence, the limitations of traditional citation indicators, such as simple citation counts, the h-index, and the journal impact factor (JIF), have become increasingly apparent [4]. While widely used, these established metrics fail to capture the full complexity of research impact, especially in rapidly evolving fields like chemistry, where collaborative efforts, niche subfields, and societal relevance are all significant [5] [6]. Consequently, the need for more nuanced and sophisticated citation indicators has grown, giving rise to innovative metrics that reflect the multifaceted nature of research contributions. This is where new citation indicators, such as the Citation Swing Factor, Fold of Excess Citations, and Fold of H-core Citations Over Excess Citations, can offer deeper insights into the patterns and trends of citation behaviour [7].

The Citation Swing Factor is an innovative metric that quantifies the variability in citation counts over time [8]. It captures the oscillation in citations that a paper may experience after its initial publication. For instance, some papers may receive steady citations over several years, while others may experience a rapid rise followed by a plateau or decline. This indicator is particularly useful in identifying research that experiences delayed recognition, a phenomenon where ground-breaking work may not receive immediate attention but garners significant citations after a period of dormancy [9]. Another novel metric, the Fold of Excess Citations, compares the actual citation count of a paper to the expected citation count based on the average citations within its field [10]. This ratio provides a clearer picture of how a paper's impact compares to the baseline for its field, accounting for the inherent differences in citation practices across disciplines. For instance, fields like organic chemistry or theoretical chemistry might have different citation norms compared to applied fields like environmental chemistry or materials science [11]. The Fold of H-core Citations Over Excess Citations is a more specialized indicator that builds upon both the h-index and the excess citations concept [7]. The Fold of H-core Citations Over Excess Citations takes the analysis further by comparing the citation performance of papers that form the H-core with their excess citations [12]. The broader applicability of these new citation indicators can also be observed in the context of interdisciplinary research, which is becoming increasingly common in chemistry. Chemistry often intersects with fields such as physics, biology, environmental science, and engineering, making it difficult to apply traditional citation metrics consistently. Hence, the study seeks to explore the citation trends of Indian chemistry research during this period, employing a set of newly developed indicators that offer a fresh perspective on the impact and reach of scholarly work [13]. It also seeks to provide insights for policy decisions

and research strategies that will support the ongoing growth and international recognition of Indian scientific contributions.

2. Literature Review

Cross-field normalization of scientometric indicators is essential for conducting comparative analyses across disciplines, thereby ensuring that variations in citation practices do not compromise research evaluation[14]. In the field of chemistry, the evolving citation landscape mirrors a global transition towards more sophisticated methodologies for assessing research impact. This shift emphasizes not only publication counts but also the diverse means through which scientific contributions influence subsequent research and practical applications [9]. Traditional bibliometric indicators, including total citation counts, h-index, and journal impact factor (JIF), have attracted considerable criticism for their inability to adequately capture the interdisciplinary and dynamic essence of contemporary scientific research [15]. As a result, alternative citation metrics have emerged, providing a more nuanced perspective on research influence. Such metrics include overlay maps based on Mendeley readership data [16][17] and indicators that accommodate temporal, regional, and disciplinary variations in citation patterns [18]. Research has demonstrated that international collaborations significantly enhance citation impact within Indian chemistry research [1], while publication delays and subfield-specific citation practices further underscore the limitations of conventional metrics [18][19]. Bibliometric studies conducted in India reveal a consistent growth trajectory in chemistry publications and citations. For instance, Arunachalam, Madhan, and Gunasekaran [20] reported a compound annual growth rate of 8.9% in Indian chemistry publications from 1991 to 2015, although India's representation among the top one percent of highly cited papers remained notably low at 2.3% in 2014, particularly when compared to China's 38%. Sab, Parashappa, and Biradar [21] identified a total of 131,212 Indian chemistry papers that received 1,270,317 citations between 2002 and 2016, while also highlighting the most active research institutions.

The literature indicates the significance of innovative indicators that capture citation diffusion processes, including the transition from the H-core zone to the H-core excess zone [22], as well as the Citation Swing Factor (CSF), which quantifies changes in citation influence over time [8] [7]. Recent bibliometric analyses of Indian chemistry research conducted from 2015 to 2024 further illuminate trends in publication output, international collaboration, and research impact. For example, Ravi et al. [23] examined 1,429 polymer chemistry articles, noting a peak in 2013, with the USA leading followed by China, while India ranked eleventh. Lrhoul et al. [24] reported sustained growth in the Moroccan Journal of Chemistry, indicating strengthened Asian–African collaborations, a reduced reliance on French partnerships, and alignment with national research priorities through open-access dissemination. Kartimi et al. [25] and Saputra, Albar, and Soegoto [26] observed shifts in chemistry education and computational chemistry, noting that COVID-19 has accelerated the adoption of virtual laboratories and the emergence of molecular modeling as a

prominent research cluster. Garg, Kumar, and Bebi, [27] highlighted India's significant contributions to outputs in the Indian Journal of Chemistry and the Indonesian Journal of Chemistry, with China and Iran recognized as notable collaborators. Furthermore, Riandi, Permanasari, and Novia [28] and Zhang et al. [29] identified thematic diversification within biotechnology, green chemistry, nanotechnology, and medicinal chemistry, with both China and India leading in productivity and impact. Şen [30] and Irwanto, Afrizal, and Lukman [31] underscored the global leadership of the USA and the prominence of research in chemistry education, while Shannigrahi and Kirtania [32] noted that theoretical and computational studies predominantly account for highly cited papers, often facilitated by robust collaborative networks. Collectively, these findings underscore the inadequacies of traditional bibliometric indicators and emphasize the necessity for innovative tools, such as the CSF, to adequately capture the dynamic, multi-dimensional, and internationally collaborative nature of Indian chemistry research over the past decade.

3. Objectives

- To analyze citation trends in Indian Chemistry research from 2015 to 2024, focusing on temporal variations in key metrics.
- To assess annual fluctuations in total citations, h-core citations, and excess citations to identify significant research impact patterns.
- To evaluate bibliometric indicators such as FET, FHE, and CSF to understand their role in measuring research impact.
- To identify discrepancies between observed and expected citation behaviours, especially increasing unpredictability in recent citation trends.

4. Methodology

This research adopts a quantitative scientometric approach to investigate citation trends in Indian chemistry research from 2015 to 2024. Key metrics include H-core zone, excess citations, Citation Swing Factor (Observed [O] and Expected [E]), Time-Normalized Total Cited Ratio (TC), Cited-Uncited Ratio (CU), and Total Uncited Ratio (TU) [7]. Data were sourced from Web of Science using filters: SCIENCE CITATION INDEX EXPANDED (SCIE), CHEMISTRY, INDIA. Six journals met criteria: *Indian Journal of Chemistry, Indian Journal of Heterocyclic Chemistry, Indian Journal of Chemical Technology, Journal of Chemical Sciences, Journal of The Indian Chemical Society, and Proceedings of The National Academy of Sciences India Section A-Physical Sciences*. These journals produced ~5,200 papers (2015–2024), generating 42,350 citations analyzed in this study. Publication counts (n), cited papers (k), and citations (c) were extracted annually. Temporal variations in TC, CU, TU were computed via standard formulas: $TC = n/k/(y_2 - y_1)$; $CU = k/(n-k)$. Statistical analysis (means, medians, SD, kurtosis) assessed indicator distributions [8]. Anomalies (e.g., 2024 deviations) were noted, potentially attributable to short citation windows alongside impact shifts. Software: SciLab, Excel, SPSS, Origin for graphs/visualizations.

4.1 *Indicators Used*

The present study employs bibliometric indicators derived from the h-index framework to analyze citation diffusion and impact dynamics, distinguishing between core concentration and peripheral scattering.

- Total Citations (TC, R^2): Full citation aggregate across publications.
- h-core Citations (CU, h^2): Centrifugal clustering in symmetric h-core zone
- Total Excess Citations (TU, e^2): Peripheral citations (h-excess + tail), denoting scattering.

4.2 *Derived Metrics:*

- Fold of Excess Citations to Total Citations (FET, ϵ^2): Excess proportion measuring scattering
- Fold of h-core Citations over Excess Citations (FHE, θ^2): Core-excess balance indicating concentration
- Citation Swing Factor $\left(\frac{d\epsilon}{d\grave{e}}\right)$: rates Diffusion of Cited Items (DCI) across tail-core-excess zones.

TC/CU/TU (foundational) and FET/FHE/CSF (derived) form a robust framework for temporal impact analysis.

5. Scope and Limitations

The objective of this comprehensive research initiative is to meticulously analyze and interpret the citation patterns evident in Indian Chemistry research spanning the period from 2015 to 2024. The primary focus is directed towards six specific Indian chemistry journals that are indexed in the Web of Science. The aim is to illuminate the various citation behaviours and the resultant impact within the Indian chemistry research landscape. It is essential to note that the study is intentionally confined to the aforementioned journals and does not encompass other databases. This strategic approach, while facilitating a detailed examination of the selected journals, may inadvertently limit the scope, potentially leading to the inadvertent oversight of interdisciplinary contributions and the burgeoning research frontiers within the realm of Indian chemistry. Regarding 2024, the observed citation anomalies primarily stemmed from limited observation windows. Future studies incorporating extended citation lags are expected to clarify whether these patterns represent transient effects or reflect genuine changes in impact trajectories.

6. Data Analysis and Interpretation

Table 1, Figure 1, and Figure 2 provide key statistical parameters for Citation Swing Factors (CSF), including both observed (O) and expected (E) values, as well as Time-

Normalised Cited (TC), Cited-Uncited (CU), and Total Uncited (TU) ratios spanning from 2014 to 2024. Mean and Median: CSF (O) and CSF (E) exhibit negative mean values (-2.4464 and -2.4082, respectively) and medians, suggesting an overall downward trend in citation factors. On the other hand, the TC, CU, and TU ratios demonstrate positive mean values, with TU being the highest at 0.6943, indicating that uncited papers constitute a significant portion of the research output. The standard deviation is greatest for CSF (O) at 1.00395, indicating higher variability in observed citation swing factors compared to expected values (0.85003). Furthermore, the range is also highest for CSF (O) at 3.84, reaffirming the notable variability in observed citation behaviours. Among the ratios, TU displays the highest variability with a range of 0.81. The kurtosis values 4.248 and 9.751 for CSF (O) and CSF (E), respectively, indicate that the distributions are heavily tailed, pointing to extreme deviations in citation patterns. TU demonstrates negative Kurtosis (-1.834), suggesting a flatter distribution. Additionally, the coefficient of variation is highest for TC (0.722543), highlighting its relative instability over time.

Table 1

Statistical Parameters of the Indicators' Values from 2015-2024							
	Mean	**Median**	**Std. Deviation**	**Kurtosis**	**Coefficient of variation**	**Range**	**Std. Error of Kurtosis**
CSF (O)	-2.4464	-2.6446	1.00395	4.248	1.00791	3.84	1.334
CSE (E)	-2.4082	-2.6385	0.85003	9.751	0.72254	2.82	1.334
TC	0.1663	0.092	0.23037	9.935	0.05307	0.74	1.334
CU	0.4014	0.363	0.21336	-0.506	0.04552	0.67	1.334
TU	0.6943	0.5166	0.31218	-1.834	0.09746	0.81	1.334

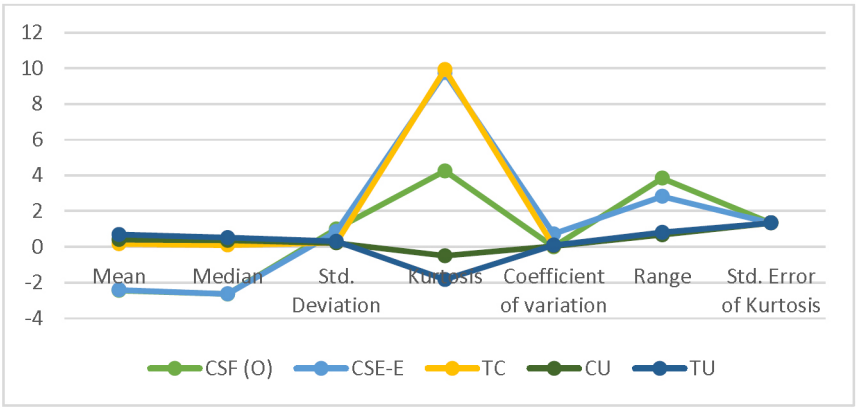


Figure 1

Statistical parameters of the indicators' values from 2015-2024

The dataset in Table 2 and Figures 2 & 3 showcase the temporal fluctuations in key citation metrics. During this period, total citations (T), H-core citations (H), and excess citations (E) demonstrate significant variations. For instance, citations reached their peak in 2016 at 3,568 but drastically declined to 34 by 2024. Similar trends are observed in h-core and excess citations, highlighting the fluctuating research impact. The Fold of Excess Citation FET (ε) and the Fold of H-core Citation over Excess Citations FHE (Θ) are calculated on an annual basis. FET generally remains stable at around 0.83-0.89, with a slight increase to 0.9235 in 2024, indicating a consistent excess citation factor. In contrast, FHE exhibits more variation, reaching its peak in 2016 at 0.7325 and notably declining to 0.4152 in 2024, reflecting changes in the h-core to excess citation ratio. The annual shifts in these folds are highlighted by the Continuous Variable of Fold (dε and dΘ) values, where dε displays minor fluctuations with an increase in 2024, while dΘ reveals more volatility, especially with a significant drop in 2024. Observations of the Citation Swing Factors (CSF) in both Observed (O) and Expected (E) demonstrate notable discrepancies, particularly in the latter years. The % of Errors dramatically spiked in 2023 (28.96%) and 2024 (18.75%), indicating a growing disparity between observed and expected citation behaviours. This suggests that the predictability of citation trends has diminished, possibly due to evolving research dynamics or external factors influencing citation patterns.

Table 2

Temporal Variations of CSF from 2015 to 2024 in Indian Chemistry Research										
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
T	2992	3568	3216	2381	2380	1914	2598	3963	1612	34
H	618	1211	982	687	733	371	659	884	441	5
E	2374	2257	2234	1694	1647	1543	1939	3079	1201	29
FET (ε)	0.890758	0.795341	0.833458	0.843484	0.831876	0.897867	0.863912	0.88144	0.863155	0.923548
FHE (Θ)	0.510216	0.732498	0.663001	0.636827	0.667122	0.490348	0.58298	0.535823	0.605965	0.415227
dε	0	-0.09542	0.038117	0.010027	-0.01161	0.065992	-0.03396	0.017529	-0.01828	0.060393
dΘ	0	0.222282	-0.0695	-0.02617	0.030295	-0.17677	0.092633	-0.04716	0.070142	-0.19074
CSF (O)	0	-2.32959	-1.82326	-2.61042	-2.60962	-2.67874	-2.72808	-2.69033	-3.83612	-3.15829
CSF (E)	0	-2.77311	-2.71352	-2.60516	-2.61666	-2.60387	-2.81747	-2.66035	-2.72521	-2.56617
% of Error	0	19.03851	48.82797	0.201454	0.269893	2.795009	3.277017	1.11437	28.9592	18.7482

T-Total Citation **H**- H core Citations **E**- Excess Citation
FET (ε)- Fold of Excess citation **FHE (Θ)**- Fold of h-core citation over Excess citations
dε- Continuous Variable of Fold of Excess citation
dΘ- Continuous Variable of Fold of h-core citation over Excess citations
CSF (O)-Citation Swing Factors (O) Observed Value
CSF (E)- Citation Swing Factors (E) Expected Value
% of Error

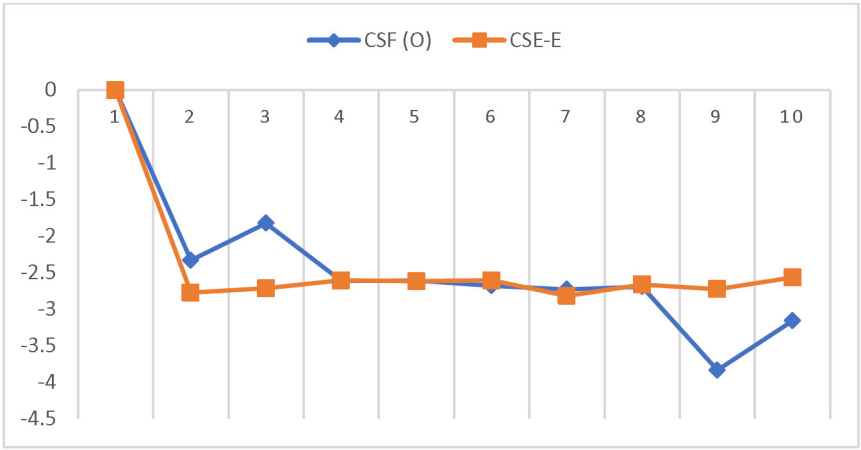


Figure 2

Temporal variation of CSF (O) and CSF (E)

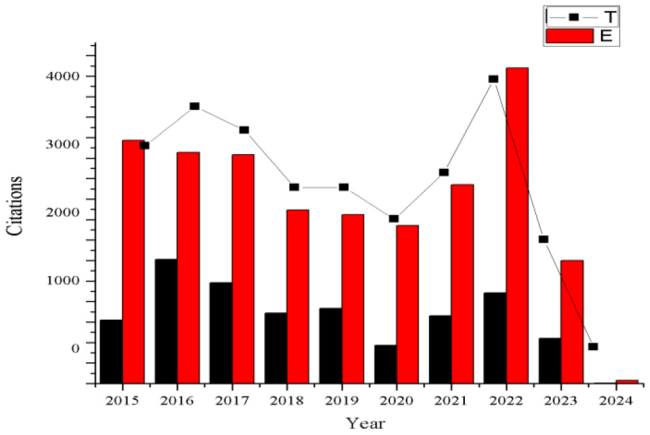


Figure 3

Year-wise growth of Publications and Citations

Table 3 and Figure 4 illustrate the temporal changes in the Time-Normalised Total Cited Ratio (TC), Cited-Uncited Ratio (CU), and Total Uncited Ratio (TU). The TC remains relatively steady from 2015 to 2023, fluctuating between 0.0819 and 0.1174. However, there is a remarkable increase in 2024, soaring to 0.8211, attributed to a sharp decline in the number of cited papers (k) compared to total publications (n). This implies that while the citation impact remained consistent throughout the decade, the 2024 data indicates either an exceptional year or a significant shift in research visibility or impact. The CU exhibits noticeable fluctuations, rising from 0.1734 in 2015 to a peak of 0.7535 in 2022 before plunging to 0.0824 in 2024. The high CU in 2022 indicates a strong citation pattern, with

cited papers significantly outnumbering uncited ones. The abrupt decline in 2024 aligns with the spike in TC, indicating a substantial decrease in the relative citation of the papers. The TU follows a similar trajectory, escalating from 0.2734 in 2015 to over 1.0 in 2022 and 2023, before stabilizing at 1.0824 in 2024. This reveals that in the later years, the number of uncited papers surpasses those cited, particularly in 2024, where the TU ratio is almost at parity. The data indicates general stability in citation trends until 2023, with a significant deviation in 2024. These patterns suggest a shift towards fewer citations per paper in the later years, indicating either a reduction in research impact or a potential delay in citation accrual. The 2024 data call for further investigation to comprehend the factors contributing to this sharp change.

Table 3

Temporal Variations of TC, CU, and TU from 2015 to 2024										
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
n	730	540	572	569	598	701	617	1014	789	381
k	463	412	435	410	398	415	453	703	420	29
n/k	1.576674	1.31068	1.314943	1.387805	1.502513	1.689157	1.362031	1.44239	1.878571	13.13793
(y_2-y_1)	10	9	8	7	6	5	4	3	2	1
TC	0.098542	0.081917	0.082184	0.086738	0.093907	0.105572	0.085127	0.090149	0.117411	0.821121
(n-k)	267	128	137	159	200	286	164	311	369	352
k/(n-k)	1.734082	3.21875	3.175182	2.578616	1.99	1.451049	2.762195	2.26045	1.138211	0.082386
CU	0.173408	0.357639	0.396898	0.368374	0.331667	0.29021	0.690549	0.753483	0.569106	0.082386
n/(n-k)	2.734082	4.21875	4.175182	3.578616	2.99	2.451049	3.762195	3.26045	2.138211	1.082386
TU	0.273408	0.46875	0.521898	0.511231	0.498333	0.49021	0.940549	1.086817	1.069106	1.082386

TU-Time-Normalised Total Uncited Ratio
CU- Time-Normalised Cited Uncited Ratio
TC-Time-Normalised Total Cited Ratio (TC)
n- Total number of publications
k- Total number of publications that received citations.

Table 4 and Figure 5 data indicate that the Journal of the Indian Chemical Society (JICS) has the highest WIF at 0.43, demonstrating its significant online presence and visibility. Following closely is the Journal of Chemical Sciences (JCS) with a WIF of 0.32, and the Proceedings of the National Academy of Sciences India Section A-Physical Sciences (PNAS) with a WIF of 0.29. The Indian Journal of Chemistry (IJC) has a WIF of 0.12, while the Indian Journal of Chemical Technology (IJCT) and the Indian Journal of Heterocyclic Chemistry (IJHC) have WIFs of 0.08 and 0.07, respectively, indicating relatively lower online visibility.

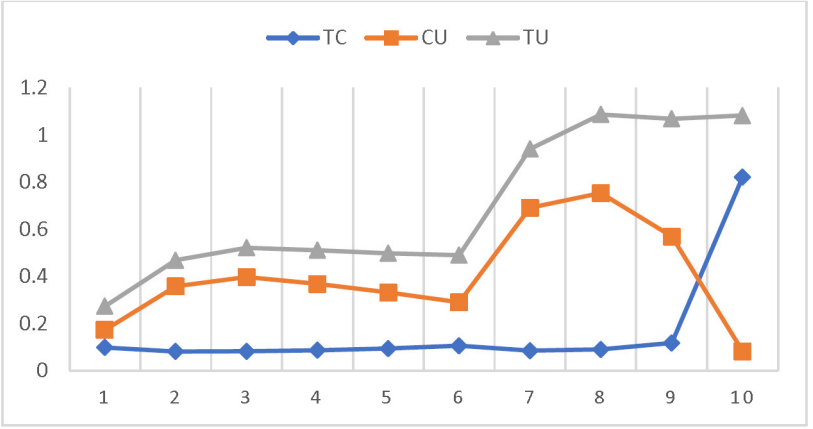


Figure 4

Temporal Variations Of TC, CU, and TU From 2015 To 2024

Table 4

Web Impact Factor of Journals		
Journal Name	**AB.**	**Web Impact Factor**
Indian Journal of Chemistry	IJC	0.12
Indian Journal of Heterocyclic Chemistry	IJHC	0.07
Indian Journal of Chemical Technology	IJCT	0.08
Journal of Chemical Sciences	JCS	0.32
Journal of The Indian Chemical Society	JICS	0.43
Proceedings of The National Academy of Sciences India Section A-Physical Sciences	PNAS	0.29

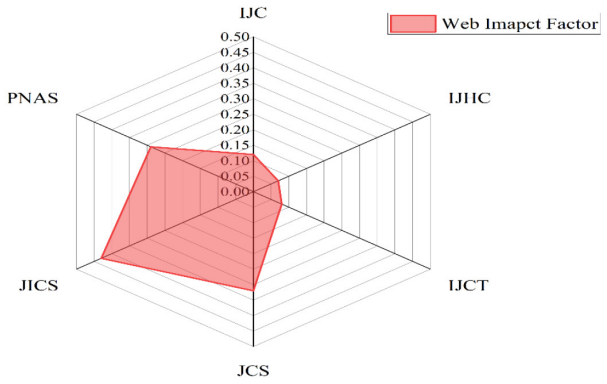


Figure 5

Web Impact Factor of Journals

7. Major Findings

The examination of temporal changes in the Time-Normalized Total Cited Ratio (TC), Cited-Uncited Ratio (CU), and Total Uncited Ratio (TU) from 2015 to 2024 in Indian Chemistry research uncovers several significant trends:

- The TC remained relatively steady, fluctuating around 0.08 to 0.12, indicating consistent citation performance during these years. However, the substantial spike to 0.8211 in 2024 indicates an anomaly or a major shift in citation dynamics.
- The CU displayed variability, reaching its peak in 2022 at 0.7535, reflecting a high proportion of cited papers. The significant drop in CU in 2024 to 0.0824 highlights a sudden decline in the ratio of cited to uncited papers.
- The TU shows an upward trend, particularly after 2020, exceeding 1.0 in 2022 and 2023. This indicates that uncited papers began to outnumber cited ones, reaching a stabilization at 1.0824 in 2024.
- The year 2024 exhibits a noticeable deviation in all three indicators, suggesting a potential shift in research visibility or impact that merits further investigation.

These findings indicate a stable citation environment until 2023, followed by significant changes in 2024, potentially signalling a new trend in citation behaviour.

8. Suggestions

- The notable deviations in TC, CU, and TU in 2024 necessitate a thorough investigation. Researchers must delve into potential causes such as alterations in publication practices, citation behaviours, or external factors, including shifts in research focus or funding.
- To address the increasing number of uncited papers, it is recommended that researchers and institutions should advocate practices that enhance visibility and citation, such as publishing in high-impact journals, engaging in interdisciplinary collaborations, and utilizing open access platforms.
- The data indicate potential shifts in research impact. It is vital to recognize and support emerging research areas that may be underrepresented or slow in accumulating citations.
- It is advisable to continue monitoring citation trends beyond 2024 to ascertain whether the observed changes signify a new trend or are merely an outlier. This will facilitate informed decisions regarding research priorities and funding allocations.

9. Conclusion

This study presents a thorough analysis of citation trends in Indian Chemistry research from 2015 to 2024. It employs a scientometric approach to assess key metrics such as the

H-core zone, Excess Citations, Citation Swing Factors (O and E), and Time-Normalized Ratios (TC, CU, and TU). The findings uncover consistent citation patterns across most of the studied period, with noticeable deviations in 2024, indicating potential shifts in research impact or visibility. The study underscores the value of utilizing advanced bibliometric indicators to gain deeper insights into research performance, providing a nuanced understanding of how citations change over time. Despite limitations such as its focus on a restricted number of journals and reliance on Web of Science data, the results contribute valuable knowledge to the field of scientometrics and stress the significance of ongoing monitoring and analysis of citation patterns to inform decision-making in research management and policy.

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