Scientific Output and Research Trends in *Portugaliae Electrochimica Acta* (2008–2024): A Bibliometric Analysis

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Abstract

This is a bibliometric study of *Portugaliae Electrochimica Acta* (PEA) from 2008 to 2024, encompassing 558 published documents within the scope of electrochemistry. The purpose was to systematically chart the scientific output and thematic development of the journal, marking the research focus, essential contributors and collaboration networks. Relevant data were retrieved from Scopus to ensure high-quality metadata and comprehensive coverage. The study's assessment included performance indicators such as publication and citation counts, as well as author activity measured through science mapping methods, including co-authorship, co-citation and keyword co-occurrence analysis. The results are anticipated to illustrate emergent contributing authors, institutions and countries, together with evolving research themes. Collaborative and intellectual structures are depicted through bibliometric mapping. This research helps to understand the role of the journal in the growth of electrochemical research. It provides information that can be relevant for editorial strategies, outlining prospective collaborations, or informing newcomers to the discipline.

***Keywords*:** bibliometric analysis; citation analysis; *Portugaliae Electrochimica Acta*; publication patterns; science mapping.

Introduction•

The academic publishing landscape has undergone drastic changes, and is evolving due to exponential growth of research in all fields of science. This large and complex knowledge network requires advanced analysis methods to extract general trends, determine most influential works and follow dynamic changes in research areas. Bibliometric analysis has become a crucial method for accomplishing this task, providing a solid quantitative basis for examining literature.

Portugaliae Electrochimica Acta (PEA) is a bi-monthly international journal published by the Portuguese Electrochemical Society since 1983. It contains original research articles, brief communications, reviews and letters on all aspects of electrochemistry, encompassing both theoretical and practical

• The abbreviations list is in page 498.

applications. The journal also accepts articles on topics such as the history of electrochemistry, science policy, education and other matters in the field, including both instruction and research. From 2008 to 2024, a total of 558 documents were successfully published.

History of bibliometric analysis

"Bibliometric studies first appeared in the late 19th century. They experienced significant development after the Second World War, in the context of the "periodic crisis" and the new technical opportunities offered by computing tools. In the early 1960s, the Science Citation Index of Eugene Garfield and the citation network analysis of Derek John de Solla Price laid the fundamental basis of a structured research program on bibliometrics" [17].

Bibliometric analysis is a quantitative technique that involves the application of statistical and mathematical tools to analyze published scholarly materials systematically. Its essence is to investigate trends in publications, citations, authors and institutions, offering a systematic description of research scenarios. This strategy can be linked to the 1930s and 1960s, when scholars began to evaluate scientific papers quantitatively using the number of citations. The original trigger for this development was to have a more objective concept of scholarly impact, rather than relying on perceptions, and to focus on identifying criticisms of prior articles, even if this involved uncritically quoting possibly tainted or outdated information.

The evolution of bibliometrics from its initial roots to its modern form, incorporating current computational methodologies and visualization tools, signifies a profound shift in scholarly assessment. As the number of research publications has increased, manual qualitative reviews have become difficult and could lead to individual bias. The introduction of specialized software tools, including VOSviewer and Bibliometric, has helped scientists process and visualize large datasets more effectively, allowing them to gain insight into the complex picture that was previously unavailable using conventional review approaches. This has meant that bibliometrics is being recognized as a valuable supplement to, rather than a substitute for, traditional peer review, as it has succeeded in eliminating some of the weaknesses present in such a system by being more transparent and reproducible in its evaluation of scholarly output.

Bibliometric reviews have significantly more value than descriptions, since they have become strategic tools for understanding the dynamics of research domains. These reviews enable researchers, academics and policymakers to make more informed decisions by summarizing trends, identifying emerging topics, mapping collaborator networks and pinpointing knowledge gaps. This analytic capacity is easily applied in practice, including customizing the prioritization of resources, developing strategic research plans and defining regions that are potentially open to

investment or cross-institutional collaboration. Direct contribution to academic, policy and institutional strategies is achieved through mapping research hotspots and collaborations. Therefore, strategies are tailored to where they can have the most significant effect and relevance. To the individual researcher, these analyses have the irreplaceable value of aiding in selecting high-impact journals for publication and providing a means of identifying potential partners for desired research projects, thereby facilitating their research careers and enhancing their profiles.

Portugaliae Electrochimica Acta -an overview

Portugaliae Electrochimica Acta (PEA), which is published by Portuguese Electrochemical Society, is a scientific journal containing original research articles and review articles related to electrochemistry. It's impact factor for 2024 is 0.6, Journal citation indicator is 0.14 and cite score is 2.4. It is ranked 49th out of 64 journals in the subject of Electrochemistry. It contributes to different subject areas, such as fundamental electrochemistry, electrochemical materials science, analytical electrochemistry, corrosion science and applied electrochemistry. This journal is crucial for disseminating new information and fostering scientific discussions within the global electrochemical community (Table 1).

Table 1: Main information on PEA.

Description (PEA)	Value
Timespan	2008–2024
Sources	1
Documents	558
Annual Growth Rate %	0.21
Document Average Age	9.52
Average citations per doc	12.33
References	17191
Author's keywords (DE)	1670
Authors	1635
Authors of single-authored docs	36
Single-authored docs	39
Co-Authors per Doc	3.93
International co-authorships %	17.74
Articles	548
Editorial	3
Note	1
Review	6

Literature review

A bibliometric analysis to describe trends in clinical learning environment (CLE) research in nursing and midwifery education has been presented by [3]. This analysis, conducted on 3077 articles from Scopus database, revealed that the United States and Australia make the most significant contributions in the field. Leading journals, such as Nurse Education Today, were identified as primary

resources for CLE research. Deployment of globalizing collaborations and co-authorship networks was performed using VOSviewer. These results indicate the increasing role of CLE in shaping the education and training of healthcare professionals.

A detailed bibliometric review of extensive data in healthcare, examining trends in research, investigator productivity and collaboration styles has been conducted by [4]. A study of 2,294 SCOPUS and Web of Science database articles has revealed an exponential growth in publications from 2012 to 2021, with a notable surge during 2019-2021 editions. Bibliometric analysis identifies key indicators, including output of authors, country productivity and most productive publications. Thematic mapping and co-occurrence of keywords were employed to identify new research hotspots and networks of collaboration. The results provide significant input on "the challenges and opportunities in the field, in which the direction of future research could be formed in the rapidly 22 developing spheres of big data in healthcare".

Inter-organizational learning (IOL) has been reviewed by [16] with bibliometric methods, analyzing 208 articles in Scopus, proposed trends, influential authors and directions for future research. This study examines the evolution of IOL as a method for knowledge transfer and innovation, with the goal of achieving a competitive advantage. The authors employed science mapping methods to identify research hotspots and intellectual foundations in the field. This is the first literature review of IOL to offer developmental insights and identify areas for future research. These results will aid in planning future research on IOL areas that have yet to be determined.

A study by [19] has provided an extensive bibliometric and content review of global research tendencies regarding paver blocks. The evaluation of 379 articles in 174 journals shows that the number of publications is expected to increase considerably from 2016 to 2024, with India being the most prolific country and the U.S. being the most influential. Among the main themes are the use of sustainable materials, waste management and innovative design features, such as permeable and photocatalytic paver blocks. This review highlights the shift from conventional to green materials, which refers to gaps in research, such as lack of in-depth performance evaluations and life cycle studies. This suggests future sustainability and resiliency guidelines, incorporating paver blocks within cities' larger planning frameworks.

A research by [14] has performed a bibliometric review of ASEAN STEM education research, which included 175 Scopus articles published from 2000 to 2019. The results demonstrated a significant increase in the number of publications over the last three years, as 67.43% of the studies were published within this period. Leading contributions originated at the best regional

universities, and the research was conducted in undergraduate STEM, engineering education and educational computing, frequently in Q3-Q4 journals.

Objectives of the research

The aim of this study was to discuss multi-year dynamics of the publications by PEA from 2008 to 2024. With this goal, the idea was to assess the productivity of this journal during the time frame and locate the moments of its considerable increase, maintenance or decrease in the number of published publications, including: to find the journal's most influential authors with their corresponding citations, which was done to emphasize major contributions that have received significant attention, and to identify researchers who have contributed most to the content and influence of the journal; to visualize the network of collaborations among authors, institutions and countries that have contributed to the journal, focusing at the social structure of the research that visualizes collaboration patterns of co-authorship and demonstrates hubs in collaboration and international research collaborations; to discover and map the thematic landscape and research hotspots of PEA throughout the study. This study aims to identify dominant and emerging research themes that are interconnected, as well as the journal's changing or consistent intellectual focus over the years.

Methodology

This section outlines the methodology employed in the bibliometric study, ensuring transparency in the disclosure of the research design, data collection efforts, pre-processing and analysis methods (Fig. 1). This type of precise documentation is essential for academic rigor, and allows other investigators to replicate and validate the study findings.

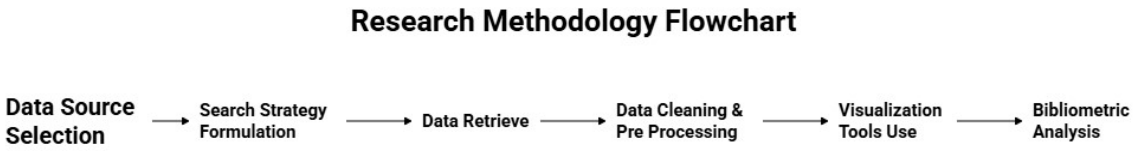

Figure 1: Research methodology flowchart.

Study design

This study used a quantitative, retrospective, bibliometric analysis design of PEA within a specified time interval: "The primary aim of this study was to conduct a systematic review of the scientifically published literature in the journal" [19].

This design prioritizes academic rigor and transparency, providing a comprehensive description of methods, materials, procedures and expected outcomes. Although this is not a formal obligation, it is designed to overcome inherent limitations of bibliometric analysis, such as biases that may be

introduced due to incomplete database coverage or differences in terminology. By carefully describing all steps in the methodology, the study minimizes its bias and leaves a specific trace by which peers can analyses and approve it. This is specifically relevant to a Scopus-indexed publication, since this level of detail will enable other researchers to gain a clearer picture of a certain study and determine how it was conducted, and therefore assess it and possibly repeat it, which may either prove the validity of its initial conclusions or allow some of them to be expanded. In the present context, rigor in scientific writing entails the unbiased nature of the experimental design, analysis, interpretation and reporting of the findings. Transparency, in turn, means that all steps of the research procedure, including data collection and final analysis, are documented in a clear, detailed, and explicit manner to facilitate proper audit of the research processes and outcomes.

Searching strategy and data source

Database selection

"The Scopus database was chosen as the best source for bibliometric analysis because of its wide coverage of peer-reviewed literature, high" [20] metadata quality and strong coverage of citations, which are essential for carrying out a complete bibliometric analysis. Although it is not the only academic database with a high influence on the academic world (Web of Science and Google Scholar are also widely used in bibliometric research), Scopus has several benefits when applied to journal-specific analysis over an extended period. Its advantages include its comprehensive collection and well-developed metadata, as well as being a constantly enhanced database with a wide range of possibilities for data analysis and manipulation. Each feature makes it highly applicable to a wide range of publications in a single journal and to the retrieval of elaborate bibliographic data required in analytical methods. It is worth noting that no single database can be used to publish complete scholarly articles, as they often span multiple disciplines and geographical areas. Nonetheless, the selective nature of Scopus and the interest in peer-reviewed publications create an extremely trusted basis for determining established academic work. To conduct a wide variety of bibliometric analyses that this research intends to pursue, it is essential to export full metadata from Scopus, thereby directly impacting the reliability and validity of the results.

Search query

Access to Scopus database was a diligent undertaking since the title of the journal was used as the most crucial search factor, such that the search would retrieve all the documents that the journal has directly published. The search query syntax was selected as the most precise and relevant to the target publication period. The actual query used was PEA and 2008-2024. This query is explicit because it asks Scopus to find all the documents that contain the word

PEA as the source title (SRCTITLE) and, as publication year (PUBYEAR), the year in the last twenty-six years between 2008 and 2024.
To make the set of data sufficiently refined and consistent to carry out the analysis, the following filters were introduced.

Type of documents
The different types of research publications published in PEA include articles, reviews, editorials and notes (Table 2). Articles are the most dominant document type (98.21%), which is preferred by the researchers to publish their research findings.

Table 2: Type of documents.

SN	Document type	Number	Percentage (%)
1	Article	548	98.21
2	Review	6	1.081
3	Editorial	3	0.54
4	Note	1	0.18

Language
Out of the total publications, 96.59% (539) papers are in English, followed by 3.23% in Spanish and 0.18% in Portuguese. This indicates that the coverage of this journal is not limited to Portugal rather having a global exposure (Table 3).

Table 3: Language.

SN	Language	Number	Percentage (%)
1	English	539	96.59
2	Spanish	18	3.23
3	Portuguese	1	0.18
Total		**558**	**100.00**

Pre-processing and data collection

Exporting data
The documents were exported after searching for and applying applicable filters using Scopus. It was preferred to export in BibTeX and CSV formats because these formats are compatible with the specialized bibliometric analysis software used in this project, allowing for the inclusion of as many fields as possible in metadata. It is essential to ensure that all metadata fields (names of authors, affiliations, titles, abstracts, keywords, publication year, references, etc.) are covered by exports since numerous bibliometric methods are based on different subsets of metadata.
Information can be lost in data cleaning and refinement. In bibliometric analysis, data quality is the most essential factor and primary determinant of the

correctness and totality of obtained results. Even exported database data, such as Scopus, can be highly inconsistent and erroneous, requiring cleaning and refinement. This preprocessing stage, which is carefully carried out and typically time-consuming, is crucial for producing reliable and interpretable knowledge.

To address this, duplicate removal following was done, since there is a chance that duplicate entries may occur due to different indexing procedures or errors, even when the search is restricted to a single journal. Therefore, all duplicate records in the dataset were scanned and systematically removed. This can be achieved with tools (such as R, using functions like duplicated) or reference management programs (EndNote, Mendeley and Zotero). Duplication would cause the publication of duplicates to be synthetically inflated, and other measures to be unreliable, which would endanger the validity of performance evaluations.

Also, author name disambiguation was performed, since, sometimes, authors' names in a database are entered in various forms (e.g., full name, initials, spelling variations and different capitalization styles). This may lead to an improper assessment of the overall productivity of a particular author or a misrepresentation of the h-index. Author names were standardized for h-index calculations to ensure accurate attribution of publications. This was achieved by cleaning duplicate cases, where one person appeared in the records under different names, and then merging them. This critical step was performed using tools such as Biblio Magika or manual evaluation.

Regarding Affiliation, given the similarities in the case, institutional and country affiliations can also be characterized by inconsistencies in their representations (e.g., various forms of abbreviations for affiliations, full names and slight discrepancies). These names must be standardized to successfully map collaboration networks and achieve precision in the publication of research from a particular institution or country. This makes it countable, ensuring that contributions to geography and institutions are accurately captured at all times.

For addressing missing data, data were also checked against missing bibliographic data (e.g., missing abstracts or keywords). Although it was impossible to fully impute all instances, an attempt was made to fill significant gaps where possible, as missing data may introduce bias in the analysis, particularly in co-word analysis, where keyword and abstract information are major determinants.

The validity of this bibliometric result depended solely on the validity of the cleansed dataset. Inaccuracies in the names of authors or entities, such as those suggesting inconsistency, would result in disintegrated collaboration networks or an inaccurate estimate of an author's complete output, thus severely affecting the validity of the performance analysis and science mapping results. Therefore, this data-cleaning exercise is critical for the reliability and orientation of bibliometric analysis.

Analytical tools

The elaborate bibliometric mapping of Portuguese PEA was followed up with a suite of specialized bibliometric software tools, all chosen based on their functional complementation in data representation, processing and analysis capabilities. This multi-tool method offers the potential for a more comprehensive and nuanced understanding of a journal's scholarly landscape, effectively addressing various research questions.

VOSviewer

This open-source, free software was primarily used for the development and visualization of bibliometric networks. VOSviewer excels at creating visually understandable maps of co-authorship, co-citations and keyword co-occurrence. The usefulness of text-mining features for retrieving and drawing key terms from titles and abstracts cannot be understood, especially when creating effective co-occurrence networks. The software's overall tendency to respond to a large number of sources and offer more complex options, such as cluster identification and temporal trend visualization, makes it suitable for mapping both social and intellectual patterns of research activity.

Bibliometrix R package (and Biblioshiny)

A versatile R-functional platform in bibliometrics encompasses descriptive analysis, performance and the creation of matrices to facilitate various network-related tasks. Bibliometrix is primarily applicable when importing data from Scopus and Web of Science. It provides a range of functions to retrieve data, and clean it, calculating a multitude of bibliometric indicators. It is accompanied by a user-friendly web-based graphical interface called Biblioshiny, which enables researchers with limited coding knowledge to perform complex bibliometric analyses. The tool plays a significant role in creating core statistical measures and preparing data for display networks.

The rationale behind choosing these instruments is reflected in their strengths, including comprehensiveness, as well as the capacity of the tools to yield a more detailed analytical framework.

VOSviewer is best suited for static visualization of a network, and it has strong statistical and data-handling functions that are most useful when statistical analysis and time trends are required.

By combining these tools, the analysis can become more than a mere quantitative enumeration to show the complexity of the intellectual and social networks that have defined the research activity in PEA. This strategy was designed to inform the study, ensuring it took a broad enough scope to assess the varied research questions and provide a more textured account of how the journal represented itself in the field of electrochemistry.

Use of bibliometric analysis techniques

Bibliometric analysis employs two primary methods: performance analysis and scientific mapping. All of these methods present a multi-angled perspective on the journal's output, influence and thematic organization.

Performance analysis

Performance analysis targets a quantitative evaluation of the effects and productivity of research entities, including the journal itself, articles, authors, research institutions and countries. The leading indicators and studies carried out within this category are as follows.

Publication output

Published articles per year and number can be followed in an annual basis, which will provide basic knowledge concerning the development of the journal and the stages it passed through during the study period (Fig. 2). This indicator helps recognize the publishing business's expansion, stabilization or possible contraction.

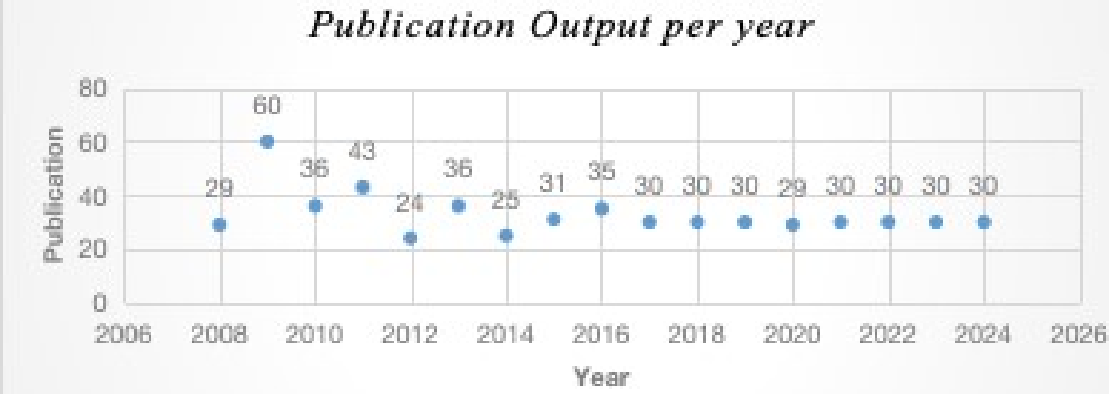

Figure 2: Publication output per year.

Total citations and average citations per article

These values measure the importance of all the journal's publications, showing whether the material has been cited in other literature and how often. "In 1997, Robert D. Cameron called for the development of an open database of citations that would completely alter the condition of science communication" [17]. 'Imagine a universal bibliographic and citation database linking every scholarly work ever written—no matter how published—to every work that cites and every work that cites it' [1].

Between 2008 and 2024, total 558 research documents were published, indicating the volume of scholarly work in the field studied. Since then, 7130 citations have been given to these publications, thus demonstrating their academic world status. The average of 12.33 citations per document indicates that a work has a moderate citation impact. This index suggests that the study

generated a stable level of interest and awareness among colleagues. Although the total number of documents was relatively low, citation effectiveness is evidence of the gradual spread and use of published information.

Most cited articles

"Discovering the most frequently cited articles reveals the most influential studies published in the journal" [19], which implies that significant ideas published have attracted an essential number of references from the scientific world. The most cited article of PEA in shown in Table 4.

Table 4: Most cited article.

Authors	Title	Year	Volume	Issue	Cited by	DOI	Open Access	Source
Lahhit N Bouyanzer A Desjobert JM Hammouti B Salghi R Costa J Jama C Bentiss F Majidi L	Fennel (*Foeniculum Vulgare*) essential oil as a green corrosion inhibitor of carbon steel in hydrochloric acid solution	2011	29	2	148	10.4152/pea 201102127	All Open Access; Bronze Open Access; Green Open Access	Scopus (145 Cited)

Most Productive Authors, Institutions, and Countries are ranked based on their number of publications and their impact on the journal's content. This has enabled the authors of the present study to identify the most productive individual scholars, academic hubs and national contributors who continually interact with and influence the journal's publishing activities.

It is worth noting that citation counts since, in some way, it measures the popularity and influence of a paper, but does not directly indicate the quality of the paper or the reason it is cited. To illustrate, one may cite an article to add credence or even discuss poor findings. In addition, younger papers are most likely to accumulate fewer citations because they have not yet had sufficient time to do so, which tends to bias them in favor of historical articles. Therefore, these measures need to be implemented with careful contextualization, especially considering the differences among disciplines in terms of citation cultures, as practices may vary significantly across disciplines. These measures can also be affected by what might be called the Matthew Effect, the tendency of authors who are already famous or individual papers that have been heavily cited to be cited even more frequently. Thus, a critical line of reasoning should be adopted to counteract the overgeneralization of the implications of writing more citations.

Science mapping

"Science mapping is a bibliometric tool to analyze and mine scientific output" [2]. Science mapping methods facilitate easy quantification of the number, investigate the structure of the research field, as well as its dynamics, and identify connections and intellectual ties. The essential methods used were as follows.

Co-Authorship analysis

"Co-authorship is a tangible, well-documented form of scientific collaboration. Almost every aspect of scientific collaboration networks can be reliably tracked by analyzing co-authorship networks using bibliometric methods" [19]. This method maps collaborative networks among authors, institutions or countries. Observing cases in which two or more organizations co-author a publication reveals social forms of research, identifies highly collaborative units and possible research communities within the journal network. These networks demonstrate the international scope of the journal and the core of its most critical partners.

Authors' co-citation analysis

"Co-citation Analysis is used when intellectual" [19] clusters are identified based on how often a third publication cites two publications. The greater magnitude of the co-citation relation between two works indicates that they are intellectually linked more closely with each other, revealing underlying concepts and the intellectual taxonomy of the subject as manifested in the journal. Out of the total authors, 191 authors have shared 2 common citations with other, 77 authors shared 3 co-citations, 43 authors shared 4 co-citations and 32 authors have shared 5 co-citations with other authors. Fig. 3 demonstrates the 32 authors who are linked to each author with the minimum number of 5 citations.

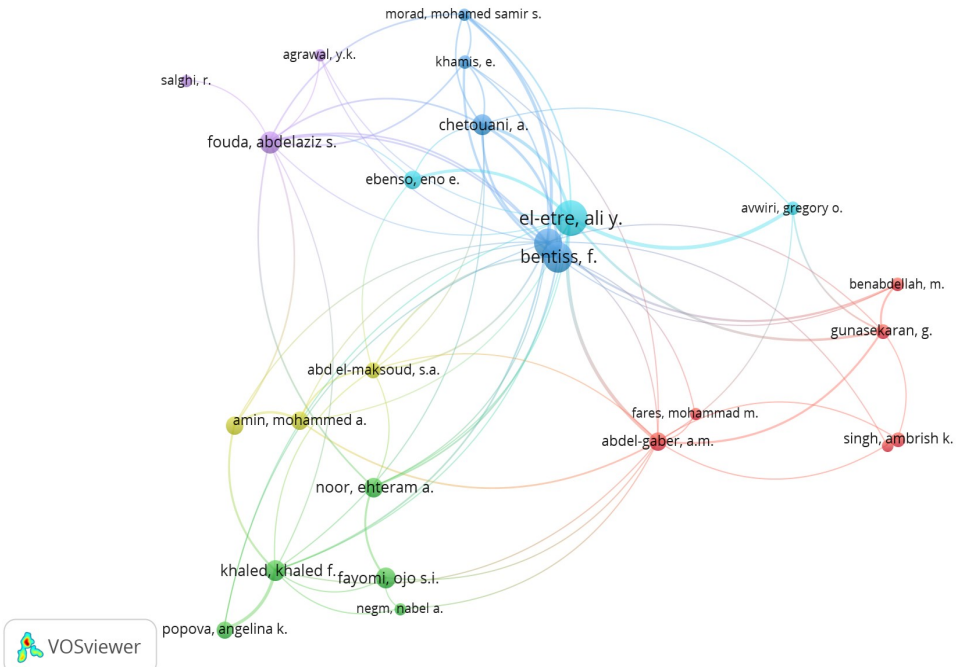

Figure 3: Co-citation analysis of 32 authors.

Bibliographic coupling

Unlike co-citation, bibliographic coupling (Fig. 4) connects articles not by their relationship to each other, but by their shared references, since they share similar themes, as they frequently cite numerous older works. Such a methodology helps discover the coherence of thematically connected publications. Herein, five articles with a minimum of 10 citations were calculated.

“Bibliographic coupling is finding conceptual similarities in citing a document. It also considered recently published research articles with fewer citations. A document is said to be bibliographically coupled when cited in two or more documents' references"[4]. 255 authors shared 1 document with common reference while only 14 authors shared 2 documents as common reference points. The 255 authors form 19 clusters with 880 link strength and 1091 total link strength.

Figure 4: Bibliographic coupling among 14 authors.

Keyword co-occurrence analysis

This analysis (Fig. 5) helps to determine how frequently keywords (author-supplied and Keywords Plus) co-occur in publications. This is an effective means of following primary themes, identifying emerging areas of interest, and mapping conceptual relationships between ideas. This method outlines areas of hot research and informational leaks. “To analyze the selected literature, we collected bibliometric data of the 558 selected papers from Scopus – the world's largest abstract and citation database.” [5].

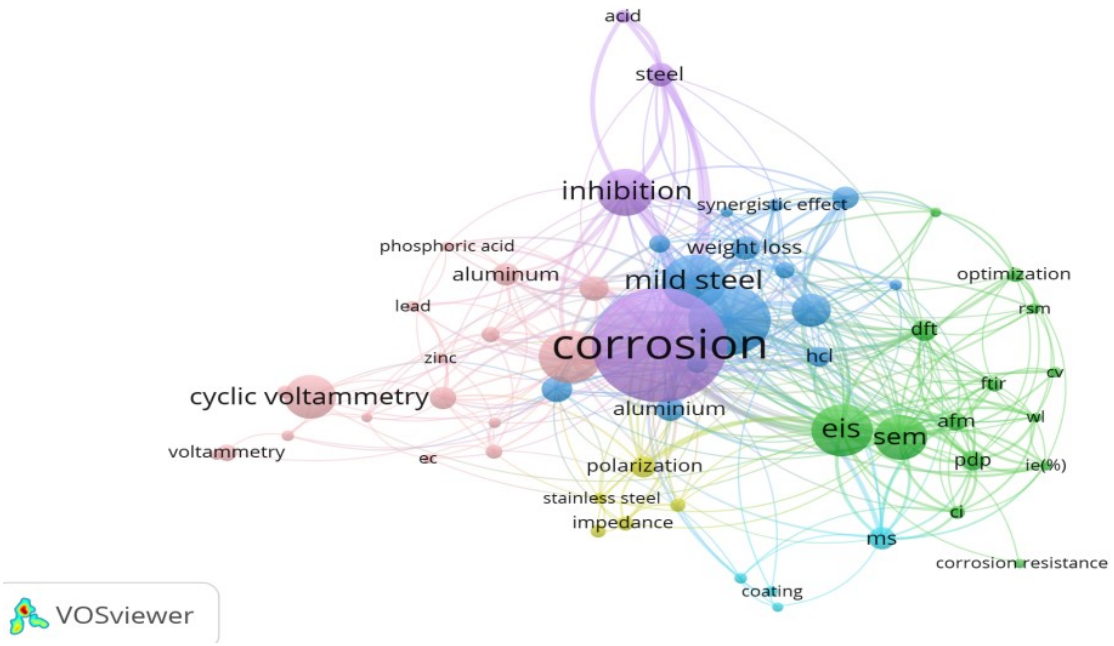

Figure 5: Keyword co-occurrence analysis.

The total number of authors keywords was 1668 and 58 keywords occurred minimum of 5 times, each ranging from 5 to 110. Corrosion, corrosion inhibition and mild steel are the top three keywords with maximum appearances of 110, 60 and 43, respectively. There are total 8 clusters; corrosion, which occurred in cluster 7 has linked to 43 other keywords with 195 total link strength (TLS); and both corrosion inhibition and mild steel are in cluster 2, with link strength of 29, 23, and TLS of 101 and 79, respectively.

Results

This section contains bibliometric results based on the analysis of professionals producing in PEA's journal from 2008 to 2024. The results were presented objectively, without discussion or interpretation, using a combination of descriptive text, tables and figures. To be as clear as possible, and by the requirements of scientific reporting, each visual element is presented and summarized in concise words and phrases to highlight its significant points. The separation of results and their interpretation is a hallmark of rigorous scientific reporting. Careful adherence ensured that the actual findings were reported accurately and without interruption. Readers can understand the results before proceeding with the following discussion.

Trends of publication in a year

The number of issues released annually by PEA from 2008 to 2024 showed particular developmental tendencies during the analysis period. Table 1 provides a quantitative summary of the number of articles published per year, the total number of articles published to date, and the total number of citations gained by the journal's publications in the same year, in more detail.

Scientific production: sixteen-year review (2008-2024)

A total number of 558 papers were published over the period encompassing 2008 to 2024. 2009 saw the highest number of articles (60), which then decreased to 36 in 2010. In the following years, 2012 had the lowest production, reaching only 20 articles per year; otherwise, production fluctuated between 24 and 43 articles per year. The evidence suggests that research output exhibits varying rates, indicating a somewhat stable trend, albeit not a consistent increase in scientific productivity over this decade.

Annual publication trend

Annual publication trend of PEA (2008-2024) is depicted in a line chart plotting the data in Fig. 6, which indicates the number of publications by the year. Those data are modeled in Table 1 as a line graph depicting the annual number of publications, in which X-axis represents the years (2008-2024) and y-axis refers to the number of publications. The graph is titled with clear data-point indication symbols and gridded to facilitate readability. Colors are not excessive, and lines are distinguished by grey scale or patterns in the case of several data series.

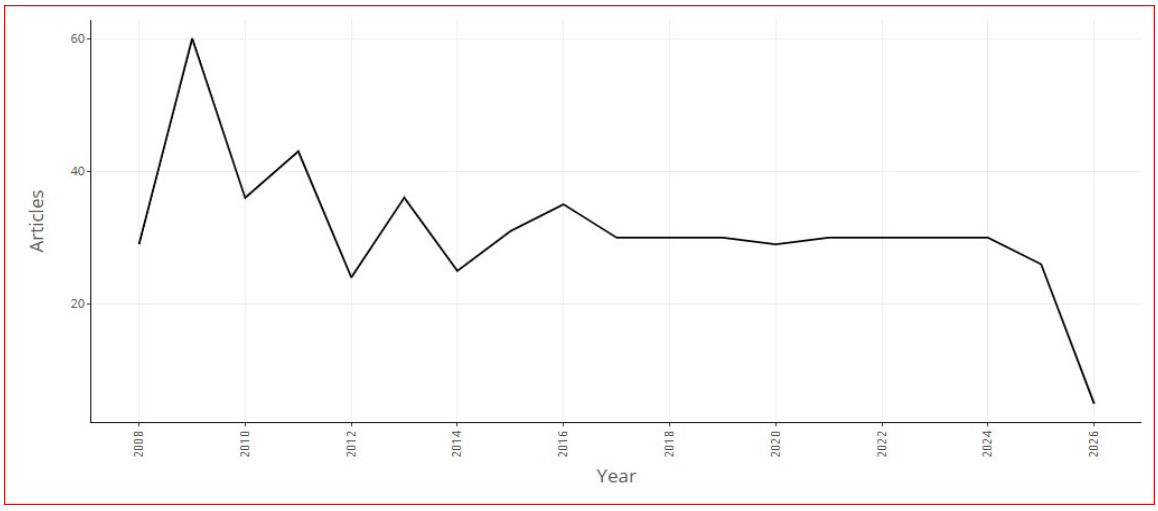

Figure 6: Annual scientific production.

Open Access

Open-access publishing is a notable element of modern scientific publications that aims to make research publications freely available. Statistics showed that the total number of open-access articles was 517. In this category, there were 303 open-access articles of type Gold and 207 articles of Bronze. Additionally, the number of Green Open-Access publications was 382. Such numbers provide clues to how the journal has been adopting various open-access models and how much of its scientific output is freely available (Table 5).

Table 5: Open Access.

Open Access	Documents	Percentage (%)
All Open Access	517	36.69
Gold	303	21.50
Bronze	207	14.69
Green	382	27.11

Impact of citation and quality works

Assessment of the number of citations determines the most high-impact studies published in the journal PEA over the time frames of the current research. Table 6 shows the top 10 most-cited articles.

Table 6: Top 10 most cited articles in PEA.

SN	Authors	Title	Year	Volume	Issue	Cited by
1	Lahhit N, Bouyanzer A, Desjobert J-M, Hammouti B, Salghi R, Costa J, Jama C,	Fennel (*Foeniculum Vulgare*) essential oil as green corrosion inhibitor of carbon steel in hydrochloric acid solution [6]	2011	29	2	145
2	Abdel HRS	Ranitidine drugs as non-toxic corrosion inhibitors for mild steel in hydrochloric acid medium	2011	29	4	117
3	Oguzie EE	Corrosion inhibitive effect and adsorption behaviour of Hibiscus sabdariffa extract on mild steel in acidic media" [7]	2008	26	3	115
4	Khadom AA, Yaro AS, Altaie AS, Kadum AAH	Electrochemical, activations and adsorption studies for the corrosion inhibition of low carbon steel in acidic media" [8]	2009	27	6	103
5	Elmsellem H, Basbas N, Chetouani A, Aouniti A, Radi S, Messali M, Hammouti B	Quantum chemical studies and corrosion inhibitive properties of mild steel by some pyridine derivatives in 1 N HCL solution	2014	32	2	94
6	Zarrok H, Zarrouk A, Salghi R, Oudda H, Hammouti B, Ebn Touhami M, Bouachrine M, Pucci O.H.	A combined experimental and theoretical study on the corrosion inhibition and adsorption behaviour of quinoxaline derivative during carbon steel corrosion in hydrochloric acid [9]	2012	30	6	87
7	Vinutha Mthe R, Venkatesha TV	Review on mechanistic action of inhibitors on steel corrosion in acidic media	2016	34	3	82
8	Hsissou R, Benzidia B, Hajjaji N, Elharfi A	Elaboration and electrochemical studies of the coating behavior of a new nanofunctional epoxy polymer on E24 steel in 3.5 % NaCl	2018	36	4	81
9	Herrag L, Chetouani A, Elkadiri S, Hammouti B, Aouniti A	Pyrazole derivatives as corrosion inhibitors for steel in hydrochloric acid	2008	26	2	75
10	Eddy NO	Ethanol extract of *Phyllanthus amarus* as a green inhibitor for the corrosion of mild steel in H_2SO_4	2009	27	5	70

Some of these main contributions have attracted significant academic interest.

Analysis of productivity behind major entities

The analysis also revealed the most prolific individual and institutional/national contributors to PEA. Table 7 enlists the ten most productive authors and their sustained involvement and production in the journal from 2008 to 2024. Hammouti B emerged as the most influential author both in terms of publication and impact, i.e., with 28 papers that received 1100 citations and the highest h index-20 and g index-28.

Table 7: Top ten authors.

Rank	Author	TP	TC	h-index	g-index	m-index	PY-start
1	Hammouti B	28	1100	20	28	1.111	2008
2	Salghi R	16	517	10	16	0.667	2011
3	Rajendran S	16	245	9	15	0.529	2009
4	Touhami M	12	396	9	12	0.529	2009
5	Aouniti A	9	333	8	9	0.444	2008
6	Eddy N	9	277	8	9	0.471	2009
7	Jodeh S	9	195	7	9	0.636	2015
8	Sahoo P	9	104	7	9	0.467	2011
9	Lgaz H	7	153	6	7	0.6	2016
10	Obot I	6	271	6	6	0.333	2008

Table 8 depicts the contribution of authors or authors' productivity as per Lotka's Law, where if the number of n authors contributed one paper each, then $n*(1/2^2)$ number of authors will produce 2 papers, and so on. However, in the current set of papers, the estimated number of authors is not as per the actual number of authors, thus Lotka's law does not fit to it.

Table 8: Authors' productivity through Lotka's Law.

Documents written	N. of Authors	Proportion of Authors	Estimated Authors
1	1309	0.821	-
2	179	0.112	327.25
3	61	0.038	145.44
4	15	0.009	81.81
5	8	0.005	52.36
6	3	0.002	36.36
7	1	0.001	26.71
8	7	0.004	20.45
9	6	0.004	16.16
10	1	0.001	13.09
12	1	0.001	9.09
13	1	0.001	7.75
16	2	0.001	5.11
28	1	0.001	1.67

Top contributing countries and institutions

A total of 523 institutions from 45 countries contributed to the publications of 558 papers in PEA. The top countries that contributed and received the highest citations are Morocco, India, Nigeria, Egypt, Malaysia and Portugal. Table 9 presents the distribution of the ten leading contributing institutions, which can be used to illustrate the geographical dispersion of research contributions and the institutions with a significant number of research contributions to the journal.

Table 9: Top 10 Contributing institutions for PEA (2008-2024).

Sl. No.	Affiliation	Country	Articles
1	Ibn Tofail University	Morocco	56
2	Université Mohammed Premier Oujda	Morocco	32
3	Faculté des Sciences d'Oujda	Morocco	27
4	Covenant University	Nigeria	19
5	Tshwane University of Technology	South Africa	18
6	Ecole Nationale des Sciences Appliquées - Agadir	Morocco	16
7	Université Hassan - Settat	Morocco	14
8	Cairo University	Egypt	13
9	Université Libanaise	Lebanon	13
10	Université Sidi Mohamed Ben Abdellah	Morocco	13

Collaboration networks

Research science in PEA is presented in the social structure of the co-authorship net. In Collaborative networks, the figure illustrates the pattern of collaboration between authors or institutions, where individual authors or institutions serve as nodes, and the edges represent the strength of co-authorship relationships between the respective authors or institutions (e.g., the number of co-authored papers). The network often reveals distinct groups of collaborators that are colour-coded in its structure, so one should see the visual image of the research groups in which the journal is part (Fig. 7).

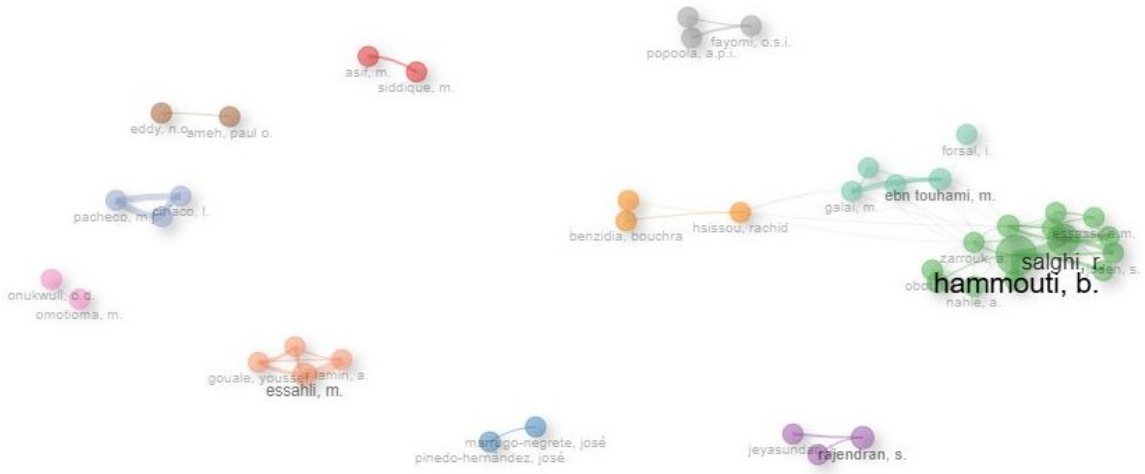

Figure 7: Collaboration networks.

Co-authorship Network of PEA, which is a VOSviewer-style network map that helps understand the pattern of collaboration of authors or institutions, is shown in Fig. 8. The nodes represent authors/institutions, and the edges indicate the strength of the partnership. Colours also identify clusters that signify individual working groups. Node size (e.g., number of publications) and edge thickness (e.g., collaboration strength) were clearly explained with readability in mind (e.g., revealing important collaborative groups within the journal network).

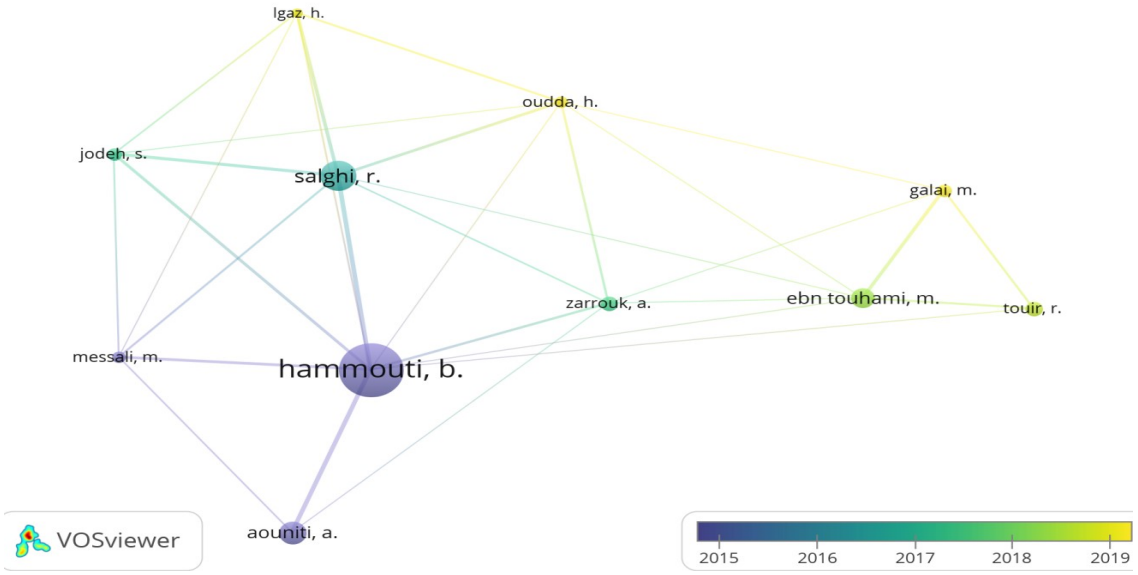

Figure 8: Co-authorship.

Topics of research and thematic development

The keyword co-occurrence network (a VOSviewer-style keyword co-occurrence network map) illustrates the journal's thematic development and conceptual structure. A few figures and tables represent thematic clusters, and the following significant findings are presented. This map displays nodes, which are keywords (created by the author and Keywords Plus), and edges indicating the frequency of their co-occurrence in publications. The color coding of clusters accentuates separate thematic workshops that identify prominent areas, intersections and developments in the subject of study.

Keywords are indicated as nodes, and the frequency of co-occurrence is depicted as an edge. The clusters were colour-coded to show clear thematic blocks. The size of nodes (e.g., frequency of keywords) and edge thickness (e.g., strength of co-occurrence) are explained with a clear legend, focusing on the visualization of thematic development and areas of hot topics in the journal's publications.

Discussion

This section is a detailed exegesis of PEA's bibliometric results (2008 to 2024) and their correspondence to the current scholarly discussion. Concomitant inferences and limitations of the methodology were also investigated. This

interpretive stage extends beyond data presentation documents to reveal general meaning and implications of noted patterns.

Findings problem interpretation

A comparison of annual publishing patterns shows the amount of publishing and dynamics of increase/decrease over the 16 years during which the journal was published. For example, an apparent rise in the number of articles in a year may indicate a concomitant increase in interest in the areas covered by the journal, an extended ability to solicit contributors, or an effective policy for soliciting contributors. However, stagnation or a lack of progress may indicate external fluctuations in electrochemical research or internal obstacles within the journal's operations. These growth stages are essential for understanding and appreciating the journal's response to the changing nature of research and how it can maintain a steady supply of scholarly material.

The two highly cited articles (Table 2) are the most influential in PEA. Such articles also tend to be historical, employ innovative experimental methods, offer significant experimental discoveries, or cover important areas of concern that have broader appeal to the electrochemistry community. Their high citation counts may have multiple causes; they may represent pioneering contributions that influence all subsequent work or generally accepted experimental procedures, or form authoritative reviews that define the research area as reference sources. Although the number of citations helps estimate the popularity of papers, one should bear in mind that they do not necessarily reflect the objective value of a paper or the actual reason for citing it, as papers may be mentioned because of their criticism or methodological use. Additionally, due to their age, older papers are likely to receive more citations during their lifetime, which can introduce bias when ranking solely by the number of citations.

The productivity of the authors is demonstrated by the primary individual authors who consistently wrote for PEA. These prolific authors are typically at the center of their related sub-disciplines, and thus bring a significant contribution to the content of journals, and may be able to introduce others through their networks. Their enduring interest makes journals rank highly in terms of their capacity to hold top researchers. Similarly, the generous donors of the top ten institutions and countries reveal the geographical and institutional distribution of research, allowing us to identify the major research centers in various parts of the world and the nations that excel in the field of electrochemistry, which is often published in the journal—this is an overview of the journal's reach and its relationship with international and regional centers of excellence.

A co-authorship network (Fig. 8) visually reflects the social structure of a journal's research. The thick clusters indicate that they are strong collaborative groups, comprising existing academic teams and national and/or inter-institutional collaborations. As the central nodes of such networks, authors may become key mediators between knowledge circulation and the development of

new partnerships. As shown in this network, the degree of national or international collaboration can help illuminate the journal's internationalization and facilitate networking among researchers geographically.
This information is presented in the keyword co-occurrence network to visualize the conceptual framework and evolution of themes within the journal's content. The co-occurrence of keywords exhibiting clustering patterns is a key research topic and a well-established area of interest in electrochemistry. The emergence of new small clusters or peripheral nodes over time may indicate new growing fields, research fronts, or interdisciplinary relations. For example, a change in keyword prominence may be related to the emergence of new technologies for electrochemical processes, a greater emphasis on environmental solutions, or further advancements in the fundamental understanding of electrochemical processes. This insight enables us to identify hotspots and potential information gaps in a research field, providing a dynamic picture of the intellectual landscape of PEA.

Comparison to previous literature

Comparison of results of the current work with bibliometric reviews of other journals related to the field of electrochemistry or any other field, or with trends of scientific publishing (in general), is an essential factor to understand how PEA is positioned in the realm of scientific publishing. Assuming that the journal is similarly rising and thematic, like other well-known journals in electrochemistry, it can be said that there is a vibrant and growing field of research with PEA opportunely keeping abreast of the growth and changes in the discipline. However, significant deviations could indicate a niche created by the journal and, thus, a distinctive editorial strategy, according to which the journal is unique or influenced by outside factors that shape the volume and direction of its publications. With the help of this comparative study, the authors of the present study will be able to benchmark PEA's performance with similar journals, and compare the findings of this study with existing knowledge, thereby reinforcing the argument about the journal's unique path and contribution to the scientific community. For example, another bibliometric analysis of publications on electrochemistry demonstrates an extensive interest in the field of energy storage. An analysis of PEA also reveals a high rate of publications and citations in the same field, which strengthens the topicality and significance of the journal in this sub-discipline.

Conclusions

A bibliometric study conducted on *Portuguese Electrochimica Acta* from 2008 to 2024 elucidates publication patterns, impact metrics and thematic development within the journal, as well as its bibliometric features. The journal has yielded a steady publication output, interspersed with notable peaks that likely reflect growing academic interest, responsiveness to emerging trends, or a combination of both.

The journal has facilitated critical advancements in research, particularly for experimental techniques and interdisciplinary applications in electrochemistry, as evidenced by the number of citations stemming from a few selected articles. However, these citation metrics must be addressed carefully.

The authorship and institutional analyses reveal that the journal attracts the foremost scholars and prestigious institutions, highlighting regional strengths due to geospatial clustering. Co-authorship networks reveal strong national and international collaboration, positioning the journal as a prominent and readily accessible scholarly hub.

The focus of keyword analysis reflects the growing prominence of the field, adding greater emphasis to the domains of environmental electrochemistry, energy storage and sustainable technologies in conducting research. The global relevance of these topics is related to the evolving adaptability of the journals.

The remaining themes marked the applicability and relevance of Portuguese journal PEA, which supports the notion of convergence between global shifts in electrochemistry concepts. PEA has expanded its thematic scope and international reach, actively building its bibliometric footprint and enhancing its historical significance, while contributing to the evolving landscape of electrochemical research.

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Authors' contributions

Jogen Sharma: collected data from Scopus, analysis data though Biblioshiny and MS Excel; wrote the manuscript. **Namita Mahapatra**: analysis data though Biblioshiny; wrote the manuscript.

Abbreviations

CLE: clinical learning environment
IOL: inter-organizational learning
PEA: *Portugaliae Electrochimica Acta*
TLS: total link strength

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