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Bibliometric analysis using VOSviewer: Analysis of Steel Corrosion using EIS

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Abstract: This study aims to develop a bibliometric analysis using VOSviewer on Electrochemical Impedance spectroscopy (EIS) to study Steel corrosion. The data gathered from Scopus indicated that more than 11 000 documents were published and also the five most published authors are: Hammouti (314), Zarrouk (284), Quraishi (204) Ramezanzadeh (176), and Salghi 167. The visual density of VOSviewer indicated also that the Hammouti, Zarrouk and Salghi belonged to the same group interacting with Quraishi and Ebenso groups. Ramezanzadeh and Iranian group are known in the corrosion field on Natural plant's extracts. Fouda's showed more visibility to Egyptian Group. The presence of China team (Xiao et al.) five authors constituting the green-brown aggregate on the map.

Keywords: *Bibliometric Analysis; Corrosion; Steel; EIS; Scopus; VOSviewer.*

1. Introduction

Survey literature indicated that bibliometrics studies first appeared in the late 19th century by using statistical methods to bibliographic data to get more information on the authors, teams, universities, and countries as well as indicators to show scientific collaboration (Luy *et al.*, 2023; N'diaye *et al.*, 2022; José de Oliveira *et al.*, 2019; Hammouti *et al.*, 2010). To identify scientific topics and contributions, bibliometrics has examined the indicators of science publications through their communication systems (Mejia *et al.*, 2021; Petrovich, 2022). The effects and scientific activities of journals can be mapped using bibliometric methods. Understanding and showing how journals affect scholarly communication in conjunction with accumulating journals in the scientific community is important. These studies represent the evolution of journals over time and help scholars identify which subjects are popular and which journals they can best submit their papers (Mejia *et al.*, 2021; Steele, 2014). In addition, these studies reveal the hidden relations of information about fields shaped by scientific contributions (Belli *et al.*, 2020; Taşkın & Akça, 2016).

Since the 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.

Citation analysis is a commonly used bibliometric method based on constructing the citation graph (Langlais, 2023), a network or graph representation of the citations shared by documents. Many research fields use bibliometric methods to explore the impact of their field, the impact of a set of researchers, the impact of a particular paper, or to identify particularly impactful papers within a specific field of research. Bibliometrics tools have been commonly integrated into descriptive linguistics, the development of thesauri, and the evaluation of reader usage (Alharti *et al.*, 2023). Beyond specialized scientific use, popular web search engines, such as the PageRank algorithm implemented by Google, have been largely shaped by bibliometrics methods and concepts (Ali *et al.*, 2021).

Scientific literacy was first used by De Paul Hard Hurd, McCurry, and Rockefeller Brothers Pund in 1958 (Čipková *et al.*, 2019). Since 1958, Paul De Hard Hurd used scientific literacy as the goal of science education (Rudolph, 2024). A clear perspective emerges when Hurd illustrates that scientific literacy is an understanding of science and applies it to the experience of each individual as a citizen (Guerrero & Sjöström, 2024). The curriculum connection and the selection of appropriate teaching materials will provide students with opportunities to use scientific methods and apply them to personal, political, economic, and social problems as well as to develop an appreciation of science as a human effort in intellectual achievement (Tasquier *et al.*, 2022; Chowdhury, 2016). Scientific literacy is the ability to use scientific knowledge, identify questions, and draw conclusions based on existing evidence to understand and make decisions about nature and changes caused by human activities (Colonia, 2021; Diaz *et al.*, 2019). Scientific literacy is referred to as the achievement of science education. However, this goal is not accepted by some people (Jufrida *et al.*, 2019). Scientific literacy in recent decades has been measured using various assessment tools. In scientific literacy literature, many similar definitions have been used (Rusilowati *et al.*, 2018). All definitions focus on the skills of each individual to use scientific knowledge in life. Scientific literacy describes a person's ability to understand laws, theories, phenomena, and scientific matters which means that scientific literacy is required in every life (Laugksch, 2000; Guerrero & Sjöström, 2024). Lrhoul *et al*. analyzed the bibliographic data of the research publications issued by the Moroccan Journal of Chemistry (MJC) between 2013 and 2021 as an open-access country-based research journal with a narrow area of interest and international online exposure, to show that the patterns of the publications in the Moroccan Journal of Chemistry can play a major role in interconnecting researchers in Morocco and other collaborators. They also identified that the Moroccan Journal of Chemistry is an incubator for establishing new traditions of research collaboration between Moroccan institutions and target nations such as Asian and African countries (Lrhoul *et al*., 2023).

In this study, we aim to conduct a bibliometric analysis of steel corrosion between 2000 and 2024 using electrochemical impedance spectroscopy (EIS). There are several types of steel, with carbon steel and stainless steel being the most commonly used in industry. These steels have important mechanical and microstructural properties, making them suitable for use in various industrial fields. However, they are exposed to corrosive environments during their use, which has led many researchers to seek solutions to protect them. This led to the study of steel corrosion, first to understand their behaviour in different corrosive environments and then to proceed with their protection. Among the effective electrochemical methods to study steel corrosion, electrochemical impedance spectroscopy is one of the most prominent techniques. EIS is an electrochemical technique that emerged in the 19th century and was developed by numerous researchers, including Hans Bode, Walther Nernst, Norman Hackerman, Bernard J. West, David O'R. K. Prichard, and Keith H. Blanchard, to understand the electrochemical mechanisms and reactions occurring at the electrode-solution interface (steel-solution

in this case). This method involves applying a small amplitude potential or periodic current disturbance to excite the electrochemical system at various frequencies and measuring the system's response (current or potential) to this disturbance (Hallemans *et al.*, 2023; Arrousse *et al.*, 2021; Ghazoui *et al.*, 2014). In other words, EIS is applied to get more information from the electrochemical double layer, also known as the Helmholtz layer, is a nanoscale region at the interface between an electrode (a conductor) and an electrolyte (a solution containing ions). This region is characterized by a separation of charge, with ions in the electrolyte being attracted to the electrode surface. The impedance of an electrochemical system can be broken down into several components, including: 1. Solution resistance (R_s): The resistance of the electrolyte solution. 2. Charge transfer resistance (R_{ct}): The resistance associated with charge transfer across the electrode-electrolyte interface. 3. Double layer capacitance (C_{dl}): The capacitance associated with the electrochemical double layer. 4. Warburg impedance (Z_W): The impedance associated with mass transport limitations. By analyzing these impedance components, researchers and engineers can gain valuable insights into the behavior of electrochemical systems and optimize their performance (Bouklah, 2022). The results are then represented in Bode and Nyquist plots with an equivalent circuit. Through these steps, we can gain valuable insight into the various electrochemical phenomena occurring at that experiment, such as charge transfer and diffusion. Thus, making EIS an imperative for corrosion analysis, battery research, material characterization, and biosensing.

2. Methodology (Sourcing and preparation of data)

Data are gathered using Scopus source, and Scopus offers the analysis results at free access from the Euromed University of Fes. The focus was on retrieving and analyzing academic citations from research articles and studies specifically indexed by Scopus and categorized as journal articles. Data collection was meticulously limited to articles on steel corrosion using EIS, published between 2000 and 2024. The collected articles were then saved in CSV format, enabling their visualization and analysis by creating bibliometric maps using VOSviewer software. Data processing involved filtering specific terms for inclusion in the visualizations, which were created in three distinct types: network, density, and overlay. This study further explored the annual variations in the number of publications, the authors involved in these publications, and their respective countries.

3. Results and Discussion

2.1. Scopus analysis

Figure 1 shows the evolution of the document number published in indexed journals at Scopus from 2000 to 2024 concerning the corrosion of steels using EIS. It's clear that the increase is observed in this century because of the Scopus database in 1995, and efforts can be made to fill these years before the Year 2000. The production from 2000 to 2024 may be assimilated as a linear shape with a slope of 56 papers per year. The details of the authors' production are shown in **Figure 2**. The team of Professor Hammouti, including Zarrouk and Salghi from Morocco, has been well-marked during this period. Prof Quraishi from India and Saud Arabia in the second rank (**Figure 3**), followed by Ramezanzadeh from Iran, Ebenso from Nigeria, Lgaz and Oudda from South Korea and Morocco, respectively, Fouda from Egypt and Galai from Morocco. The countries conducting more research in this field are China, India, Iran and Morocco, followed by Saudi Arabia, as indicated in **Figure 3**. The Scopus analysis indicated that Solmaz et al. possessed the most cited paper, with 862 citations (Solmaz *et al.*, 2008). The second and third cited papers belonged to Alourani *et al.*, (2009) and Jüttner (1990), respectively. This corrosion research specifically focused on studying the behavior and protection of

steel using various types of inhibitors, such as heterocyclic compounds (Guendouz *et al.*, 2024; Ettahiri *et al.*, 2024; Nahlé *et al.*, 2022; Salim *et al.*, 2017), amino acids (Aouniti *et al.*, 2017; Barouni *et al.*, 2014; Aouniti *et al.*, 2013), plant extracts (green inhibitors) (Hbika *et al.*, 2023; Elmsellem *et al.*, 2019; Elmsellem *et al.*, 2014), and polymers (Beniken *et al.*, 2022; Chetouani *et al.*, 2004). By applying the EIS technique for corrosion studies, they were able to analyze the corrosion and inhibition mechanisms, assess the effectiveness of the inhibitors, examine the formation of protective films on the steel surface (especially in the case of stainless steel), and gather information about the steel's resistance to corrosion. The corrosive medium chose were different, they focused mainly on hydrochloric acid (HCl), sulfuric acid (H_2SO_4) and saline environment (NaCl). These corrosion documents have been produced in different fields, as shown in **Figure 4**. They begin with material science and chemistry, moving to chemical engineering and physics, then we find environmental science, biochemistry, geology, earth and planetary science, multidisciplinary fields, and others in a low percentage.

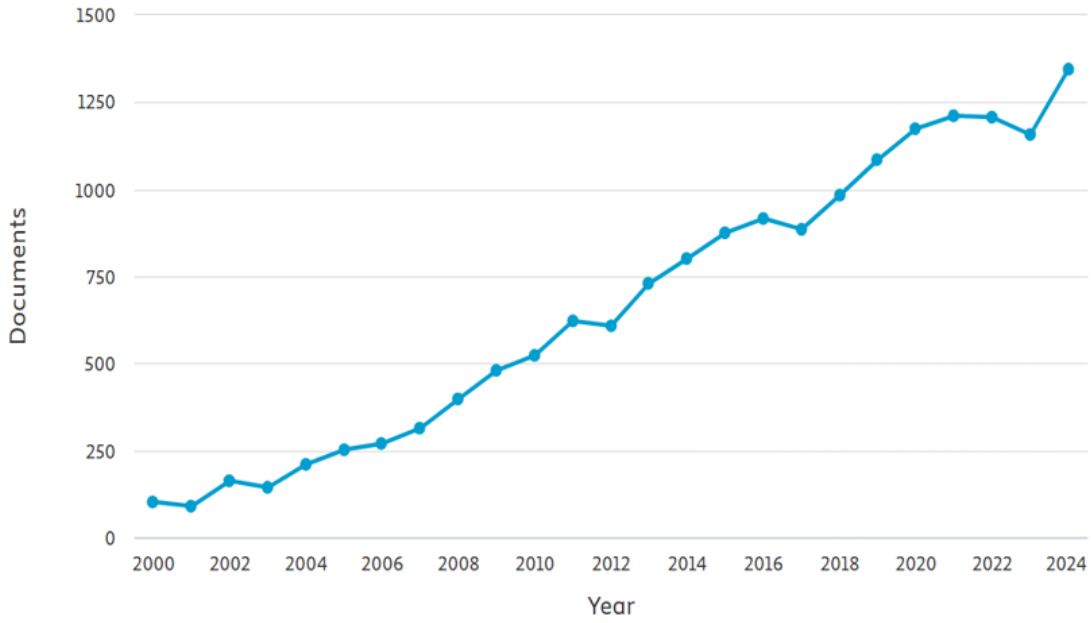

Figure 1: Production evolution from 2000 to 2024

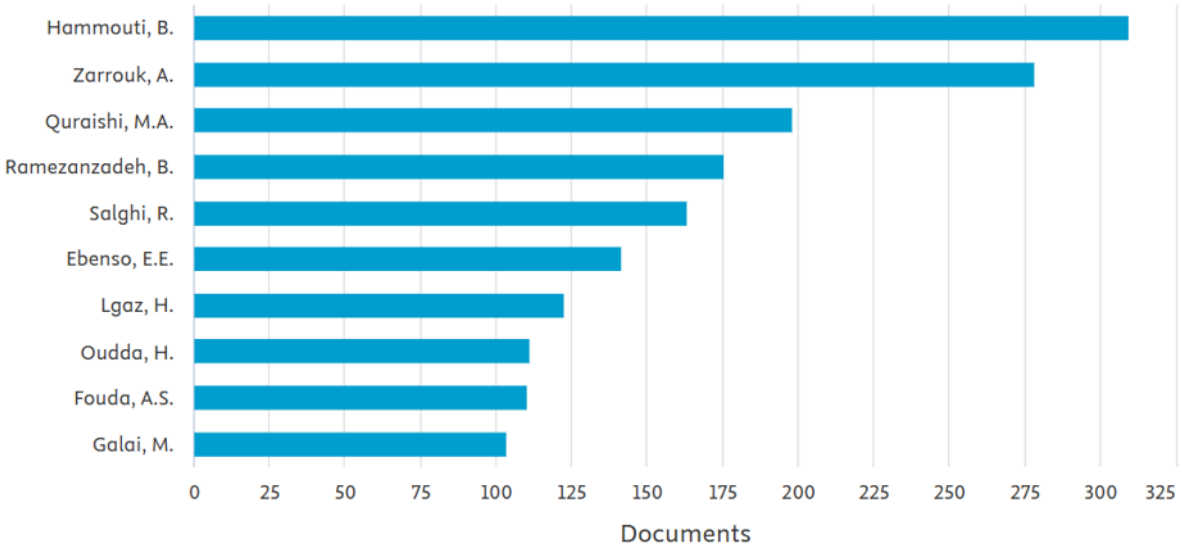

Figure 2: Authors production from 2000 to 2024

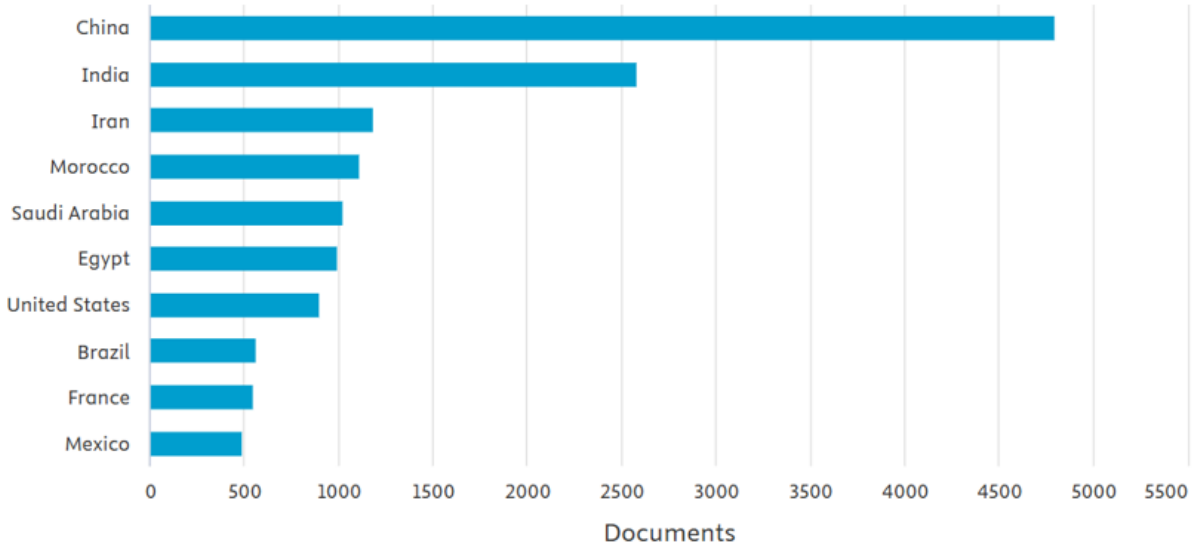

Figure 3: Production by Countries from 2000 to 2024

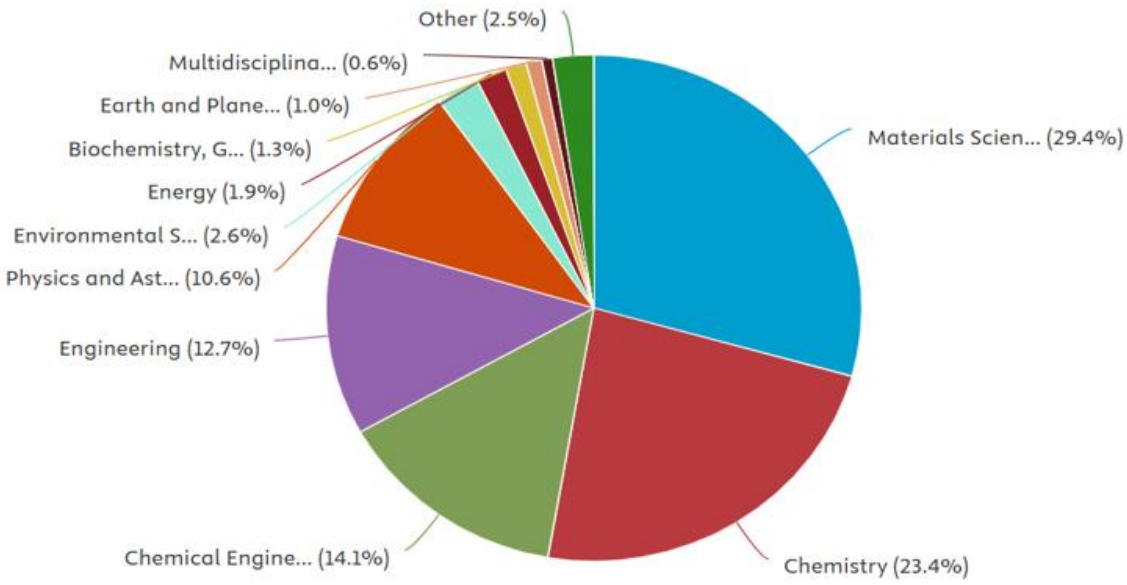

Figure 4: Major Topics of the production from 2000 to 2024

2.2. VOSviewer analysis

This network visualization represents the interconnected relationships between researchers and their work in Analyses of Steel Corrosion by EIS, illustrated by lines linking these actors. The VOSviewer analysis highlights a research landscape structured into several distinct clusters, each represented by a coloured circle (**Figure 5**). The size of the circles and text is proportional to the frequency of each researcher's appearance in the analyzed publications. Thus, larger circles and text represent the most prolific or highly cited researchers. Among them, "hammouti, b." stands out as the most influential researcher, with the most publications or citations in this field. The figure also reveals other significant clusters centered around key researchers such as "ramezanzadeh, bahram", "quraishi, m.a.", and "zarrouk, a.", who actively contribute to different aspects of Steel Corrosion by EIS.

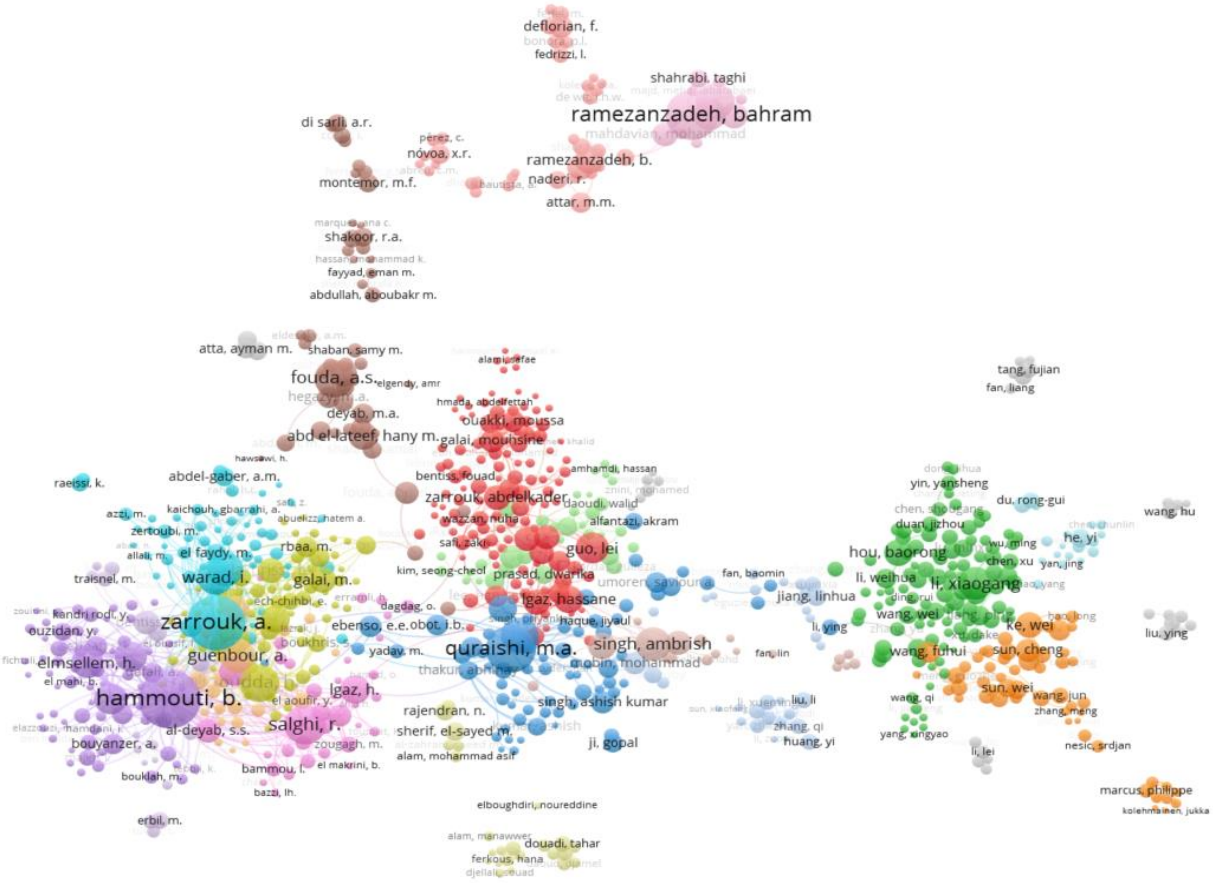

Figure 5. Network visualization of analyses of Steel Corrosion by EIS keywords

Overlay Visualization of analyses of Steel Corrosion by EIS keyword

This overlay visualization provides a dynamic overview of the evolution of research in the field of Steel Corrosion Analysis by EIS from 2000 to 2024. It reveals annual research trends and the interconnected relationships between researchers and their work (**Figure 6**).

The colour gradient, ranging from blue (older publications) to yellow (more recent publications), allows for a clear visualization of the recency of research. Yellow-coloured nodes, representing the most recent studies, highlight research areas that have gained importance or are undergoing new explorations in recent years. For instance, the activity surrounding "ramezanzadeh, bahram" may indicate a progression from more fundamental research in the early 2000s to more specific applications or recent methodological developments. This visual representation enables the tracking of collaboration trends, the emergence of new researchers, and the evolution of research topics over time, providing a comprehensive perspective on the development of Steel Corrosion Analysis by EIS over a 24-year period.

Density Visualization of analyses of Steel Corrosion by EIS keyword

This density visualization represents the distribution of research activity in the field of steel corrosion analysis by electrochemical impedance spectroscopy (EIS). Areas with more intense colours indicate a higher concentration of publications and research, reflecting the most active and widely studied domains. Researchers' names, such as hammouti, b, ramezanzadeh, Bahram and quraishi, m.a. appearing in these dense regions, suggest that they are key figures and major contributors to this field.

The distribution of names and colours helps identify the most influential researchers and the most explored research topics in steel corrosion analysis by EIS. Less dense areas indicate understudied aspects or emerging fields within this research domain (**Figure 7**).

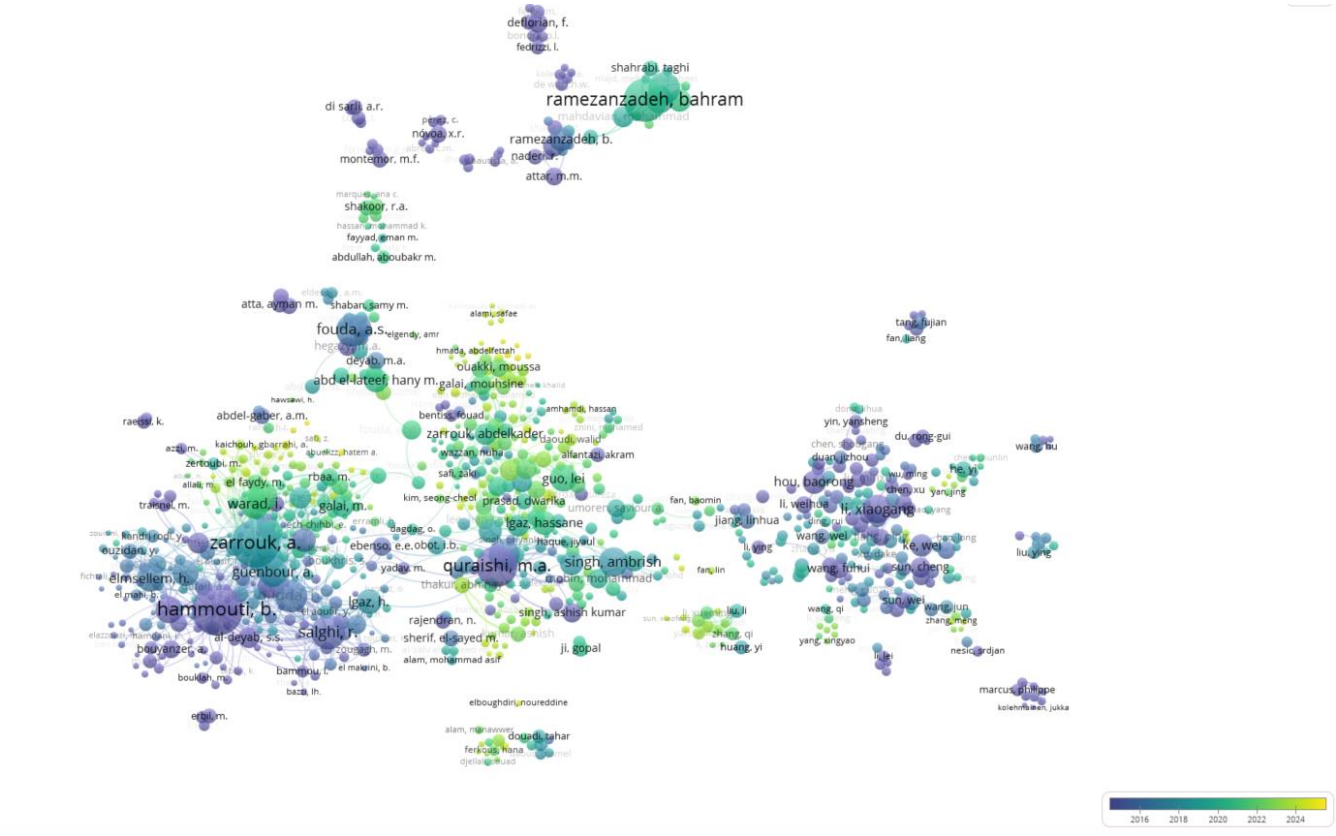

Figure 6. Overlay Visualization of analyses of Steel Corrosion by EIS keyword

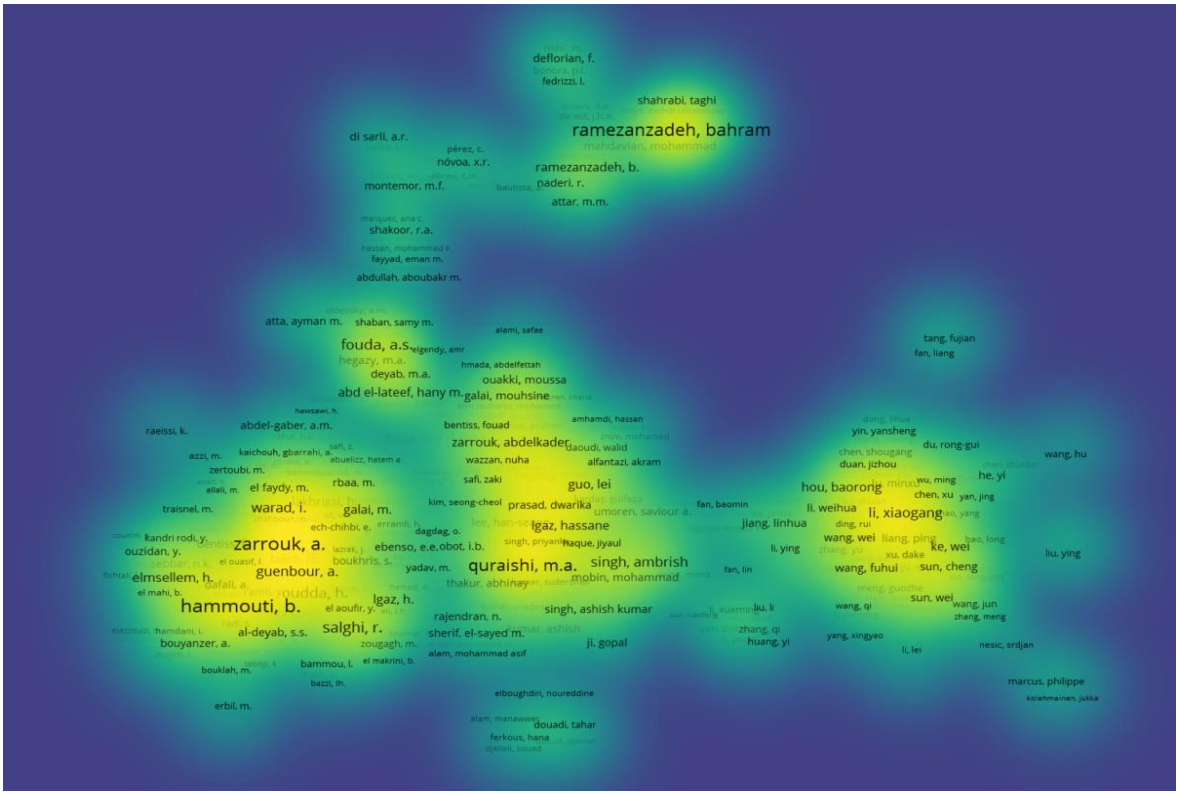

Figure 7. Density Visualization of analyses of Steel Corrosion by EIS keyword

Conclusion

The VOSviewer software was used for the bibliometric analysis. The research focused on articles in the thematic area between 2000 and 2024, specifically targeting the most influential authors, citation counts, countries, and fields. This rigorous research yielded 11,000 relevant published articles with professor Hammouti, Zarrouk, Quraishi, Ramezanzadeh, and Salghi considered as the five most published authors. Further analysis was conducted using VOSviewer, which generated three distinct visualizations: network visualization, overlay visualization, and density visualization. The analysis revealed a consistent upward trend in publications related to steel corrosion using EIS from 2000 to 2024. This research is expected to serve as a valuable reference point for researchers, helping them to conduct future studies and select promising research topics in the field of steel corrosion using EIS

Disclosure statement: *Conflict of Interest:* The authors declare that there are no conflicts of interest.
Compliance with Ethical Standards: This article does not contain any studies involving human or animal subjects.

References

Alharthi R. H. E., Nor Zafir Md S., Mazilah A., Adnan A., Faisal F., Roshazlizawati M. N. (2023), Research trends, developments, and future perspectives in brand attitude: A bibliometric analysis utilizing the Scopus database (1944–2021), *Heliyon*, 9(1), e12765, ISSN 2405-8440, https://doi.org/10.1016/j.heliyon.2022.e12765

Ali F., Khusro S. (2021), Content and link-structure perspective of ranking webpages: A review, *Computer Science Review*, 40, 100397, ISSN 1574-0137, https://doi.org/10.1016/j.cosrev.2021.100397

Aljourani J., Raeissi K., Golozar M.A. (2009), Benzimidazole and its derivatives as corrosion inhibitors for mild steel in 1M HCl solution, *Corrosion Science*, 51(8), 1836-1843, ISSN 0010-938X, https://doi.org/10.1016/j.corsci.2009.05.011

Aouniti A., Khaled K.F., Hammouti B. (2013), Correlation Between Inhibition Efficiency and Chemical Structure of Some Amino Acids on the Corrosion of Armco Iron in Molar HCl, *Int. J. Electrochem. Sci.*, 8(4), 5925-5943

Aouniti A., Arrousse N., El-Hajjaji F., Salghi R., *et al*. (2017), Amino acid compounds as eco-friendly corrosion inhibitor in acidic media- Review, *Arab. J. Chem. Environ. Res.* 04, 18-30

Arrousse N., Salim R., Abdellaoui A., ElHajjaji F., *et al*. (2021), Synthesis, characterization, and evaluation of xanthene derivative as highly effective, nontoxic corrosion inhibitor for mild steel immersed in 1 M HCl solution, *Journal of the Taiwan Institute of Chemical Engineers*, 120, 344-359, https://doi.org/10.1016/j.jtice.2021.03.026

Barouni K., Kassale A., Albourine A., Jbara O., Hammouti B., Bazzi L. (2014), Aminoacids as corrosion inhibitors for copper in nitric acid medium: Experimental and theoretical study, *J. Mater. Environ. Sci.* 5 (2), 456-463

Belli, S., Mugnaini, R., Baltà, J. et al. (2020). Coronavirus mapping in scientific publications: When science advances rapidly and collectively, is access to this knowledge open to society? *Scientometrics* 124, 2661–2685, https://doi.org/10.1007/s11192-020-03590-7

Beniken M., Salim R., Ech-Chihbi, E. Sfaira M., *et al.* (2022), Adsorption behavior and corrosion inhibition mechanism of a polyacrylamide on C–steel in 0.5 M H_2SO_4: Electrochemical assessments and molecular dynamic simulation, *Journal of Molecular Liquids*, 348, 118022, https://doi.org/10.1016/j.molliq.2021.118022

Bouklah M. (2022). Dynamiques des systèmes - Impédances électrochimiques (System dynamics - Electrochemical impedances), *J. Appl. Sci. Envir. Stud.* 5(4), 219

Chetouani A., Medjahed K., Sid-Lakhdar K.E., et al. (2004), Poly(4-vinylpyridine poly(3-oxide ethylene) tosyle) an excellent inhibitor for iron in sulphuric acid medium at 80°C. *Corros. Sci.*, 46, 2421-2430.

Chowdhury M. (2016). Emphasizing morals, values, ethics, and character education in science education and science teaching, *The Malaysian Online Journal of Educational Science*, 4(2), 1-16

Čipková, E., Karolčík, Š., & Scholzová, L. (2019). Are secondary school graduates prepared for the studies of natural sciences? – evaluation and analysis of the result of scientific literacy levels achieved by secondary school graduates. *Research in Science & Technological Education*, 38(2), 146–167. https://doi.org/10.1080/02635143.2019.1599846

Colonia, S. C., Fuster-Guillén, D., Castro, A. S., Leyva, H. W. M., Ramírez, T. V. C. (2021). Scientific literacy: a key part of school contexts. *Revista Tempos e Espaços em Educação*, 14(33), e15611. http://dx.doi.org/10.20952/revtee.v14i33.15611

Díaz, N., Caparrós, E. y Sierra, E. (2019). Las controversias sociocientíficas como herramienta didáctica para el desarrollo de la alfabetización científica. *International Journal of Educational Research and Innovation (IJERI)*, 12, 261-281.

Dragos V. & Mih V. (2015), Scientific Literacy in School, *Procedia - Social and Behavioral Sciences*, 209, 167 – 172, https://doi.org/10.1016/j.sbspro.2015.11.273

Elmsellem H., El Ouadi Y., Mokhtari M., Bendaif H., *et al.* (2019), A natural antioxidant and an environmentally friendly inhibitor of mild steel corrosion: a commercial oil of basil (ocimum basilicum l.), *Journal of Chemical Technology and Metallurgy*, 54, 4, 742-749

Elmsellem H., Youssouf M. H., Aouniti A., *et al*. (2014), Adsorption and inhibition effect of curcumin on mild steel corrosion in hydrochloric acid, *Russian J. Appl. Chem.*, 87 (6), 744-753, https://doi.org/10.1134/S1070427214060147

Ettahiri W., Mohamed Adardour M., Ech-chihbi E., *et al.* (2024), Regio- and chemoselective synthesis of new isoxazolyl-linked benzimidazolones via 1,3-dipolar cycloaddition: Characterization, corrosion studies, density functional theory, and Monte Carlo simulations, *Fuel*, 371, Part B, 132058, ISSN 0016-2361, https://doi.org/10.1016/j.fuel.2024.132058

Ghazoui A., Zarrouk A., Bencaht N., Salghi R., *et al*. (2014), New possibility of mild steel corrosion inhibition by organic heterocyclic compound, *J. Chem. Pharmac. Res.*, 6 N°2, 704-712

Guendouz A., Ettahiri W., Adardour M., Lazrak J., *et al.* (2024), New Benzimidazole Derivatives as Efficient Organic Inhibitors of mild steel Corrosion in Hydrochloric Acid Medium: Electrochemical, SEM/EDX, MC, and DFT Studies, *Journal of Molecular Structure*, 2024, 139901, ISSN 0022-2860, https://doi.org/10.1016/j.molstruc.2024.139901

Guerrero G., & Sjöström J. (2024). Critical scientific and environmental literacies: a systematic and critical review. *Studies in Science Education*, 61(1), 41–87. https://doi.org/10.1080/03057267.2024.2344988

Hallemans N., Howey D., Battistel A., Saniee N. F., *et al*. (2023), Electrochemical impedance spectroscopy beyond linearity and stationarity—A critical review, *Electrochimica Acta*, 466, 142939, ISSN 0013-4686, https://doi.org/10.1016/j.electacta.2023.142939

Hammouti B. (2010), Comparative bibliometric study of the scientific production in Maghreb countries (Algeria, Morocco and Tunisia) North Africa 1996-2009, *J. Mater. Environ. Sci.* 1(2),70-77.

Hbika A., Bouyanzer A., Jalal M., setti N. *et al.* (2023), The Inhibiting Effect of Aqueous Extracts of Artemisia Absinthium L. (Wormwood) on the Corrosion of Mild Steel in HCl 1 M, *Analytical & Bioanalytical Electrochemistry*, 15(1), 17-35; https://doi.org/10.22034/abec.2023.701392

José de Oliveira O., Francisco da Silva F., Juliani F., César Ferreira Motta B. L., Vieira Nunhes T. (2019). Bibliometric Method for Mapping the State-of-the-Art and Identifying Research Gaps and Trends in Literature: An Essential Instrument to Support the Development of Scientific Projects [Internet]. *Scientometrics Recent Advances. IntechOpen;* Available from: http://dx.doi.org/10.5772/intechopen.85856

Jufrida, J., Basuki, F., Kurniawan, W., Pangestu, M. y Fitaloka, O. (2019). Scientific literacy and science learning achievement at junior high school. *International Journal of Evaluation and Research in Education (IJERE)*, 8(4), 630. https://doi.org/10.11591/ijere.v8i4.20312

Jüttner K. (1990), Electrochemical impedance spectroscopy (EIS) of corrosion processes on inhomogeneous surfaces, *Electrochimica Acta*, 35(10), 1501-1508, https://doi.org/10.1016/0013-4686(90)80004-8

Langlais, P-C. (2023), Bibliometrics, Petite encyclopédie de la science ouverte / *Small encyclopedia of Open Science*, published on 1 November 2023. https://doi.org/10.52949/73

Laugksch R. C. (2000). Scientific Literacy: A Conceptual Overview. *Science Education*, 84, 71-94

Lrhoul H., Turki H., Hammouti B. (2023), Benammar O., Internationalization of the Moroccan Journal of Chemistry: A bibliometric study, *Heliyon*, 9(5), e15857, ISSN 2405-8440, https://doi.org/10.1016/j.heliyon.2023.e15857

Lyu, P., Liu, X., & Yao, T. (2023). A bibliometric analysis of literature on bibliometrics in recent half-century. *Journal of Information Science*, 0(0). https://doi.org/10.1177/01655515231191233

Mejia C, Wu M, Zhang Y and Kajikawa Y (2021) Exploring Topics in Bibliometric Research Through Citation Networks and Semantic Analysis. *Front. Res. Metr. Anal.* 6:742311. doi: 10.3389/frma.2021.742311

Nahlé A., Salim R., Hajjaji F., Ech-Chihbi E., Titi A, Messali M., Kaya S. (2022). Experimental and theoretical approach for novel imidazolium ionic liquids as Smart Corrosion inhibitors for mild steel in 1.0 M hydrochloric acid, *Arabian Journal of Chemistry*, 15 (8), 103967

N'diaye A.D., Hammouti B., Nandiyanto A. B. D., Al Husaeni D. F. (2022), A review of biomaterial as an adsorbent: From the bibliometric literature review, the definition of dyes and adsorbent, the adsorption phenomena and isotherm models, factors affecting the adsorption process, to the use of Typha species waste as a low-cost adsorbent, *Communications in Science and Technology*, 7 No.1, 140-153

Petrovich, E. (2022). Bibliometrics in Press. Representations and uses of bibliometric indicators in the Italian daily newspapers. *Scientometrics* 127, 2195–2233, https://doi.org/10.1007/s11192-022-04341-6

Rudolph J. L. (2024) Scientific literacy: Its real origin story and functional role in American education, *Journal of Research in Science Teaching*, 61, 519–532, https://doi.org/10.1002/tea.21890

Rusilowati A., Nugroho S. E., Susilowati E. S. M., Mustika T., Harfiyani N. and Prabowo H. T. (2018) The development of scientific literacy assessment to measure student's scientific literacy

skills in energy theme, *IOP Conf. Series: Journal of Physics: Conf. Series* 983, 012046 https://doi.org/10.1088/1742-6596/983/1/012046

Salim R., Elaatiaoui A., Benchat N., Ech-Chihbi E., *et al*. (2017). Corrosion behavior of a smart inhibitor in hydrochloric acid molar: experimental and theoretical studies, *J. Mater. Environ. Sci.,* 8 (10), 3747-3758

Solmaz, R., Kardaş, G., Çulha, M., Yazici B., Erbil M. (2008) Investigation of adsorption and inhibitive effect of 2-mercaptothiazoline on corrosion of mild steel in hydrochloric acid media, *Electrochimica Acta*, 53(20), 5941-5952, https://doi.org/10.1016/j.electacta.2008.03.055

Steele, C. (2014). Scholarly Communication, Scholarly Publishing and University Libraries. Plus Ça Change? Australian Academic & Research Libraries, 45(4), 241–261. https://doi.org/10.1080/00048623.2014.950042

Taşkın Z., Akça S. (1016), Mapping and Bibliometric Analysis of American Historical Review Citations and Its Contribution to the Field of History, *Journal of Information & Knowledge Management*, 15, 04

Tasquier G., Knain E. and Jornet A. (2022) Scientific Literacies for Change Making: Equipping the Young to Tackle Current Societal Challenges. *Front. Educ.* 7, 689329. doi: 10.3389/feduc.2022.689329