# Artificial Neural Networks in the Oil and Gas Industry: Bibliometric Analysis (2020-2024)

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*Abstract* — In the oil and gas industry, applying prediction and estimation methodologies such as Artificial Neural Networks has represented a valuable tool in the whole petroleum system. The review's objective was to analyze, from a bibliometric perspective, the scientific production of the last five years on the use of Artificial Neural Networks in this industry. The Scopus database was used to filter the information by time, subject, type of documents, and origin. A search equation was used with the keywords artificial neural network and oil and gas industry. The information was processed using LibreOffice Clac, JASP, and VOSviewer software. A total of 267 documents were obtained, with 59.9% original scientific articles, 56.0% published in scientific journals, China as the country with the highest production, the main authors were from Saudi Arabia, 69.8% of the research was in the Energy sub-area, 67.1% of the research was affiliated to oil companies and the application areas were, in addition to the traditional exploration, drilling, production and reservoir, flow analysis, artificial lift, emissions, anomaly detection, automation, corrosion, and carbon dioxide detection. It is concluded that in the last five years, research on the use of ANNs in the oil and gas industry has deepened, especially in production prediction, reserves, and reservoir studies.

*Keywords:* Artificial Intelligence; Artificial Neural Networks; Petroleum Operations; Predictions; Natural Gas; Bibliometrics.

*Resumen* — En la industria del petróleo y gas la aplicación de metodologías de predicción y estimación como las Redes Neuronales Artificiales ha representado una herramienta valiosa en todo el sistema petrolero. El objetivo de la revisión fue analizar, desde la perspectiva bibliométrica, la producción científica de los últimos cinco años sobre el uso de las Redes Neuronales Artificiales en esta industria. Se utilizó la base de datos de Scopus, filtrando la información por tiempo, temática, tipo de documentos y origen. Se utilizó una ecuación de búsqueda con palabras clave artificial neural network y oil and gas industry. La información se procesó mediante los softwares LibreOffice Clac, JASP y VOSviewer. Se obtuvo un total de 267 documentos, de los cuales el 59,9% correspondió a artículos científicos originales y el 56,0% fueron publicados en revistas científicas. China se posicionó como el país con mayor producción, mientras que los principales autores procedieron de Arabia Saudita. El 69,8% de las investigaciones se enfo-

caron en la subárea de Energía, y el 67,1% estuvieron afiliadas a empresas petroleras. Las áreas de aplicación incluyeron, además de las tradicionales (exploración, perforación, producción y yacimientos), el análisis de flujo, levantamiento artificial, emisiones, detección de anomalías, automatización, corrosión y detección de dióxido de carbono. Se concluye que, en los últimos cinco años, se ha profundizado la investigación sobre el uso de las RNA (redes neuronales artificiales) en la industria del petróleo y gas, especialmente en temas como la predicción de producción, reservas y estudios de yacimientos.

*Palabras clave:* Inteligencia Artificial; Redes Neuronales Artificiales; Operaciones petroleras; Predicciones; Gas Natural; Bibliometría.

## I. INTRODUCTION

**T**ECHNOLOGICAL evolution has penetrated all levels of humanity's daily activities, and the oil and gas industry is no exception, especially the oil and gas industry, which is considered the main industry in the world energy market, due to the importance of hydrocarbons as a primary energy source [1].

Artificial Intelligence (AI) has been progressively used in industry as a means to optimize operations, increase productive capacity, and control pollutant emissions, ensuring product quality, in what has been called Industry 4.0 [2]. This is a fact also in the oil and gas industry, where the inclusion of AI tools such as Machine learning and Artificial Neural Networks (ANN) have proven useful in predicting the behavior of key parameters in processes and optimizing operations [3], [4].

Although review papers have been developed on the evolution of the use of AI in the oil and gas industry and how it has impacted all areas that compose it [5], these have focused on the technology in a general way, i.e., the use of any of the available AI tools or techniques. In the specific case of the use of ANN, research papers have been presented focused on solving operational problems and predicting conditions at different stages of the petroleum system [6], but there have been few reviews leading to an understanding of the evolution and importance given to ANNs in this industry, limited to reviews in specific areas such as in exploration [7], petrophysical properties [8], or reservoir characterization [9]. Some reviews have been more general in using ANNs [10].

Within the studies dedicated to the analysis of scientific production in a specific subject, bibliometrics is a popular and rigorous method for exploring and analyzing large volumes of scientific data, which allows for unraveling the evolutionary

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nuances of the subject, while giving a clear idea about the emerging areas in the same [11]. Thus, the use of bibliometric studies makes it possible to identify emerging trends in the production of scientific papers and the most important publication media, collaboration patterns, and research components, as well as to explore the intellectual structure of a specific field in the existing literature at a global level [12].

In the case of bibliometric studies referring to the use of AI, research in various areas of knowledge stands out, such as in health care [13], environmental operations [14], marketing [15], supply chains [16], among others. In the oil and gas industry, bibliometric analysis in sustainable production [17], in machine learning methods [18], and in general, the use of AI in petroleum engineering [19], and on trends and patterns of AI in the oil and gas industry [20].

Since few bibliometric studies have been visualized on the use of AI in the oil and gas industry and less on the specific use of ANNs, the present research was proposed to analyze the scientific production of the application of ANNs in this industry in the last five years, using the Scopus database as a reference, to quantitatively analyze the main characteristics of the research published on the subject, in order to evaluate and understand the main trends in the use of ANNs in the oil and gas industry, contributing to the global knowledge on this important subject for the industry.

## II. METHODOLOGY

### A. Information source

For the development of the bibliometric analysis, the Scopus database was used, which is considered one of the most exhaustive in the field of scientific publication. For this purpose, the official web page of the indexer and the database available for the year 2024 were consulted. For the extraction of the data, the selection criteria were established as articles between 2020 and 2024, as thematic sub-areas: Energy, Engineering, Chemical Engineering, Chemical, Material Science, and Environmental Science. The document type was filtered by Article, Conference Paper, Review, and Conference Review. The type of publication was established as Journal and Proceeding. Since it was impossible to obtain documents written in Spanish, the search was limited to documents in English. The above generated the following equation as a search engine:

(TITLE-ABS-KEY(oil AND gas AND industry AND artificial AND neural AND networks) AND PUBYEAR > 2019 AND PUBYEAR < 2025 AND (LIMIT-TO (SUBJAREA,"ENER") OR LIMIT-TO (SUBJAREA,"ENGI") OR LIMIT-TO (SUBJAREA,"CENG") OR LIMIT-TO (SUBJAREA,"MATE") OR LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA, "CHEM")) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"cp") OR LIMIT-TO (DOCTYPE,"cr") OR LIMIT-TO (DOCTYPE,"re") OR LIMIT-TO (DOCTYPE,"ch")) AND (LIMIT-TO (SRCTYPE,"j") OR LIMIT-TO (SRCTYPE,"p")) AND (LIMIT-TO (LANGUAGE,"English")))

A total of 267 documents were obtained that met the selection criteria according to the filtering performed.

### B. Indicators extracted

The obtained documents contained relevant information for the bibliometric analysis, such as the country of origin of the research, authors, institutional affiliation, sub-area, year of publication, type of document, keywords used, and the specific process where ANNs were used in the oil and gas industry.

### C. Information analysis

The information was analyzed using the analysis tool provided by Scopus to obtain the totals of the indicators and the database downloaded for subsequent descriptive processing using the statistical software JASP v. 0.19.1 and the graphs of results using the office software LibreOffice Calc v. 24.2.6. 24.2.6. For the analysis of co-occurrence of authors, countries, keywords, and affiliations, the bibliometric software VOSviewer was used, which displays the information in maps that were then interpreted according to the objective of the study and the indicators analyzed.

## III. RESULTS AND DISCUSSION

### A. Documents by publication year

The distribution of the documents retrieved according to the year of publication showed a fairly homogeneous trend (Figure 1), with 2021 being the year in which most research was published with 60, representing 22.5%. In second place, 56 documents were published in 2023, 21.0%. In 2020 and 2022, an equal number of documents were published (52), representing 19.5% in both years and 2024 (47), corresponding to 17.6%.
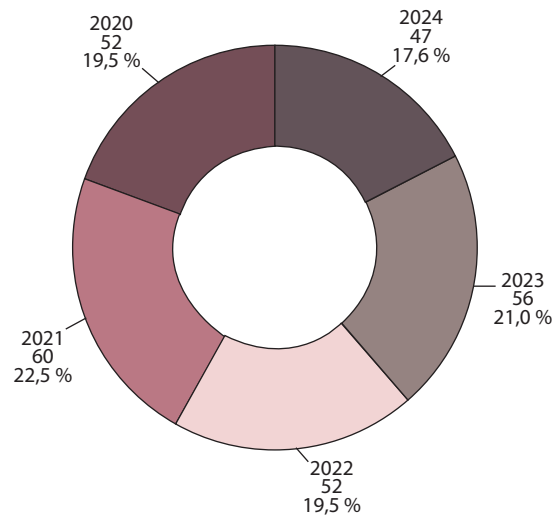


**Fig. 1.** Distribution of documents published by year.

The growth of AI and its use in industry has evolved in recent years, in the conception of the so-called Industry 4.0, which has created an unprecedented technological revolution in all production processes [21]. Being ANNs one of the most widely used AI tools, it was to be expected a fairly homogeneous document production in the last 5 years, as observed in

reviews by different authors in specific areas such as process optimization [22], in solid waste treatment [23], in building construction [24], in refrigeration systems [25], among others. This shows the importance of this topic in recent years and supports the trend observed in the use of ANWR in the oil and gas industry.

## B. Documents by publication type

Regarding the type of document published (Figure 2), the largest number were original articles in scientific journals (59.9%), with a significant percentage of articles presented at conferences (35.6%). The minority were review papers published in scientific journals and articles presented at conferences (4.4% between the two).
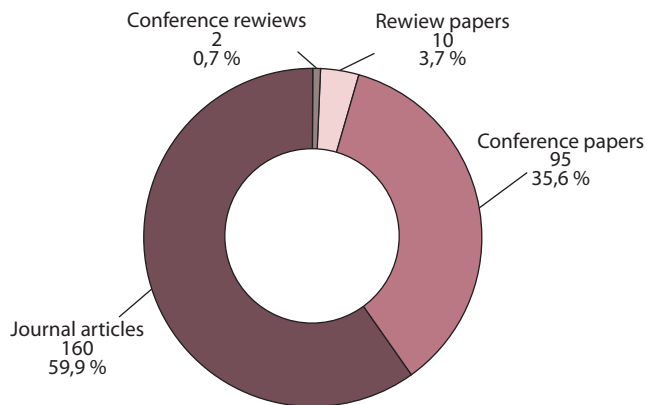


**Fig. 2.** Distribution of documents published by type.

The publication of research results is a crucial step in scientific development and, in general, the most suitable media for this purpose are scientific journals; therefore, it is to be expected that a majority of the documents retrieved regarding the use of ANNs in the oil and gas industry come from this source. In this regard, the publication of research results in high impact scientific journals is fundamental for the development of engineering and technology, which is in agreement with what has been obtained [26]. On the other hand, the fact that the rise of Information and Communication Technologies (ICT) has been an incentive for the tendency to publish in scientific journals, due to the accessibility that these technologies have given to authors to place their articles, in addition to the access to a greater amount of information [27].

In engineering, scientific congresses have always been taken very seriously as a means for the dissemination of knowledge and research results, in the form of papers and conferences [28]. For this reason, articles published in congresses and conferences tend to be the second most important for the subject studied. Scientific conferences are of utmost importance, not only in the dissemination of information and research results, but also as social events, for the exchange of information and experience directly [29], this makes the results obtained in terms of the number of papers published in conferences justified.

## C. Documents by sub-areas

In the analysis of the sub-areas (Figure 3), 69.8% of the documents retrieved correspond to Energy and Engineering (Miscellaneous), with a homogeneous contribution from the other sub-areas taken as filtering parameters. Chemical Engineering was the third most important (9.7%), followed by Environmental Sciences, Chemistry, and Materials Sciences with 7.8%, 6.8%, and 6.0%, respectively.
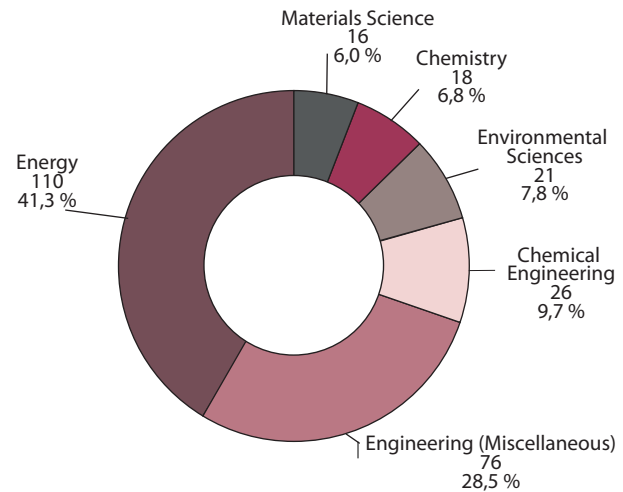


**Fig. 3.** Distribution of published documents by sub-area.

As the oil and gas industry is the most important industry among those belonging to the energy area, it is logical to observe that this sub-area of research is the one that contributes the largest number of published papers. The oil and gas industry supplies 70% of the world's energy needs [30] so, understandably, publications are preferentially directed towards this area. In this same context, that the oil and gas industry has been influenced by global trends towards renewable and low-carbon energy sources, however, it has been adjusting to changes, especially in terms of technology to adapt to the market, environmental and social trends within the framework of the energy transition, which is not yet fully developed, so oil and gas are still the main energy sources and will be for many years to come [31].

## D. Documents by country of origin

The countries with the highest research production for using ANNs in the oil and gas industry are China, the United States of America, Saudi Arabia, Iran, Brazil, India, Canada, Malaysia, Russia, Germany, and Nigeria (Figure 4). These 11 countries account for 61.8% of all published papers. Rounding out the list are another 50 countries accounting for 38.2%. The most productive were China with 39 papers, the United States of America with 35 papers, and Saudi Arabia with 34 papers.
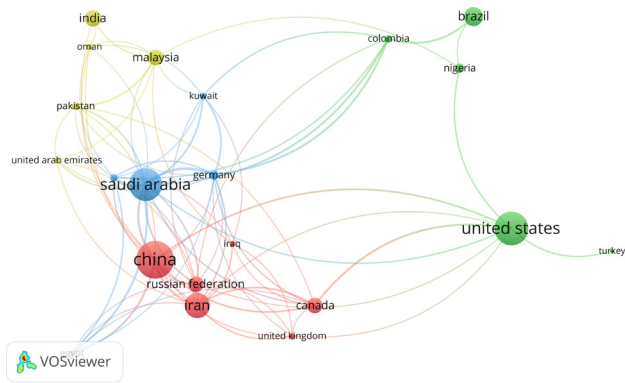
**Fig. 4.** Map of occurrence of country of origin of the documents.

According to the Scimago Journals & Country Rank, the countries with the highest global scientific production are the United States of America and China, which is consistent with what was obtained and corroborates that these two countries are also the ones with the highest production in the subject under study. In the oil and technology areas, China represents a country with significant progress in recent years, as corroborated by the studies indicating that Chinese research in the oil and gas industry is focused on enhanced oil recovery with the use of state-of-the-art technology and intelligent systems [32], which is consistent with their greater number of papers in the use of ANN. Likewise, it has been noted that China is using AI in all phases of oil exploration and exploitation, so a considerable amount of research where ANNs have been used as AI tools is to be expected [33].

Regarding the United States of America, the use of AI in the oil and gas industry is also widespread with studies deriving from research in areas such as reservoir analysis and especially the prediction of saturation pressures [34]. Although Saudi Arabia is not among the top producers of scientific papers globally, being one of the largest oil producers in the world, a significant share of papers on the subject under study was to be expected. International collaboration in research has led to its development in Saudi Arabia [35], while it is also credited with increasing in production to the effectiveness of government regulations and financial incentive plans to increase the number of articles published in various scientific fields [36], which has led to an increase in scientific production in an area of knowledge as important for this country as the oil industry.

### E. Documents by authors

When analyzing the scientific production in the use of ANN in the oil and gas industry according to the main authors (Figure 5), it was observed that the author with the highest number of published papers is Eftekhari-Zadeh, Ehsan with 32, representing 12.0% of the papers, followed by Mayet, Abdulilah Mohammad and Hanus, Robert with 19 papers (7.1%) each, and in third place Salama, Ahmed S. with 12 authorships (4.5%). A total of 1073 authors were counted. In terms of citations,

Nazemi, Ehsan with 219, Hanus, Robert with 159, Lui, Wei with 148, and Eftekhari-Zadeh, Ehsan with 122.
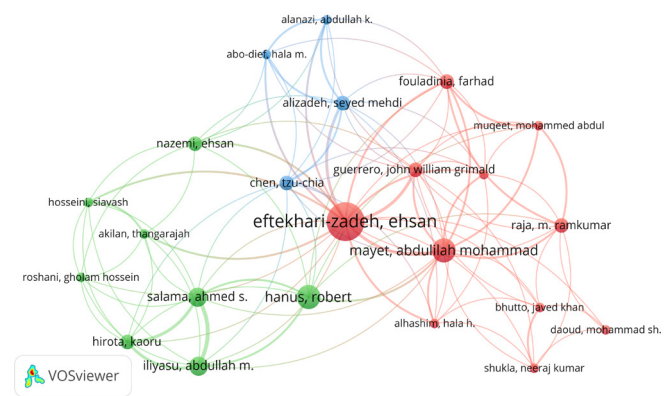


**Fig. 5.** Map of co-occurrence of authors.

It was observed that the author with the highest number of publications, Eftekhari-Zadeh, Ehsan, is affiliated with the Friedrich Schiller University Jena in Germany, which contributes significantly to the fact that this country is among the most productive in the subject studied. On the other hand, Mayet, Abdulilah Mohammad is a researcher attached to the King Khalid University of Saudi Arabia, and Hanus, Robert belongs to the Rzeszow University of Technology in Poland. From the above, it can be seen that only one of the three major producers of scientific papers related to the use of ANNs in the oil and gas industry belongs to one of the top research producing countries, with a low participation of authors from China and the United States of America, which is not consistent with the record of the top producing countries. From China, Chen, Tzu-Chia is identified with only three papers.

In the case of China, there is a large dispersion of authors with few papers, mostly in projects that were carried out in international collaboration, something that has led to the generation of a large number of scientific papers by this country [37], [38]. This trend seems to favor the number of papers published by the country, but not the amount of individual production, as corroborated in the present research.

### F. Documents by affiliation

The institutional affiliation of the documents published on the subject studied was dominated by the King Fahd University of Petroleum and Minerals and the Saudi Arabian Oil Company, both institutions located in Saudi Arabia, with 13 documents, representing 4.9% each (Figure 6). Other institutions appearing among those with the highest number of papers are Universiti Teknologi PETRONAS of Malaysia with 10 papers (3.7%), Friedrich-Schiller-Universität Jena of Germany with 8 papers (3.0%) and Politechnika Rzeszowska im. Ignacego Łukasiewicza of Poland with 7 papers (2.6%). The list is completed by 364 other institutions, where oil companies account for 67.1% of the research on the use of ANNs and the remaining 32.9% corresponds to universities (28.8%), Institutes of Higher Education (3.0%) and Schools of Higher Education (1.1%).
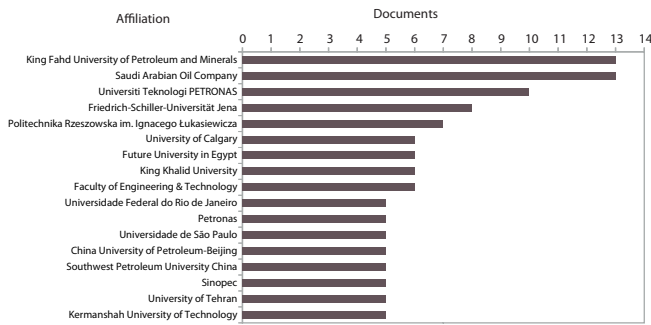
**Fig. 6.** Affiliations of retrieved documents.



**Fig. 7.** Origin of retrieved documents.

The presence of Saudi Arabian institutions as those with the highest production is due to their dependence on oil exploitation, which has led to the generation of a considerable amount of research in this area, in addition to the use of AI technologies, which leads this industry to focus on its research. This also adds to the increase in research incentives, not only at the governmental level but also at the industrial level, so it can be seen that the first two institutions are a university and an oil company [36].

Again, it is striking that the institutions of the most productive countries (China and the United States of America) do not appear among those with the highest production, where the best placed is China, University of Petroleum-Beijing with 5 documents, and for the United States of America, The University of Texas at Austin with 3 documents. This presents a similar panorama to what happened in the case of the authors.

Due to the importance of the subject matter for the industry and its greater financing power, it can be seen that most of the research is carried out within the industry. Despite this reality, no evidence in previous research corroborates what has been observed, or that has focused on this aspect, which leaves an open gap in this direction. University-industry collaboration has been highlighted, which may explain what has been observed [39], [40], [41], [42]. Since a significant percentage of cases, research carried out within the framework of this collaboration can be found, which leads to significant participation of companies as affiliation in the retrieved documents.

### G. Documents by origin

Regarding the origin from which the documents referring to the use of ANNs in the oil and gas industry were extracted, 25 main sources were counted, including scientific journals, congresses, and conferences (Figure 7). In the Journal of Petroleum Science and Engineering, 13 papers were published (4.9%), in Geoenergy Science and Engineering and Society of Petroleum Engineers-SPE Nigeria Annual International Conference, 10 papers were published, that is, 3.7% in each one. Completing the top sources was the journal Energies with 9 papers (3.4%).
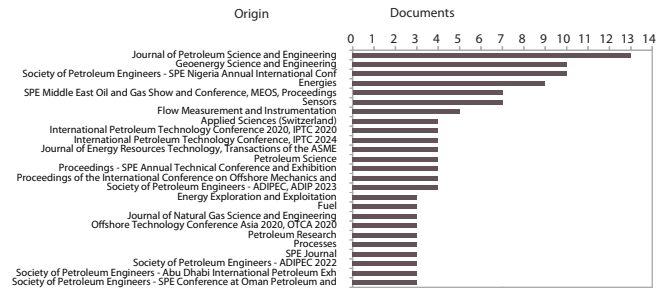
Scientific journals accounted for 56.0% of the origin of the documents, with the Society of Petroleum Engineers (SPE) conferences responsible for 24.0% of the publications, the remaining 20.0% being obtained from other sources.

The above corroborates what was obtained regarding that most of the documents come from scientific journals, without subtracting the importance of conferences and congresses that represent 44.0% because even though the scientific dissemination media par excellence is the indexed scientific journal, in engineering the presentation of research in congresses and conferences, and its subsequent publication as part of the proceedings of the same, is a common practice that contributes to the dissemination and exchange of knowledge [43], [44], [45].

### H. Keyword co-occurrence

The keyword co-occurrence allowed not only to identification of the words and phrases most used in published research on the subject under study but also the processes and operations of the oil and gas industry where ANNs have been applied as a tool for their improvement and optimization. Figure 8 shows the co-occurrence map of the keywords, where it is evident that the most used were Artificial Neural Networks, Machine Learning, Random Forest, and Convolutional Neural Networks.
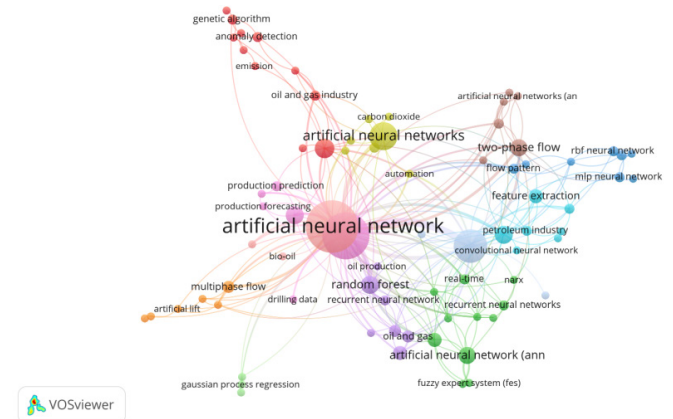


**Fig. 8.** Keyword co-occurrence distribution map.

Among the processes and operations where ANNs have been used, production operations, multiphase flow, artificial lift, drilling, two-phase flow, extraction, flow patterns, production prediction, emissions, anomaly detection, automation, and carbon dioxide detection were identified.

Reference [9] indicated that ANNs has been applied in all phases of the oil industry (exploration, drilling, production, and reservoir studies) showing reasonable effectiveness, which is consistent with what was obtained in the present bibliometric analysis. Other research also highlighted the use of ANNs in different areas of the oil and gas industry, such as the study of oil production forecast rate through ANNs [46]. ANNs were also applied in well log analysis and demonstrated their flexibility and applicability in contrast to traditional methods [47]. The applicability of ANNs for penetration rate prediction in drilling operations was also highlighted [48].

The results indicate, in the last five years, a trend towards the use of ANNs in traditional areas such as drilling [49], [50], [51] and oil and gas production [52], [53], [54]. However, it has diversified its use in other areas such as pollutant gas emissions [55], [56], corrosion [57], [58], and flow patterns [59]. This trend of the oil industry to apply AI tools such as ANNs in all its processes and to diversify their use is consistent with previous research where it has been noted that, AI tools are driving the optimization of industrial processes and driving innovation in different areas of the industries [60]. Has also demonstrated the applicability of ANNs in the prediction of the corrosive tendency of natural gas [5], which is consistent with the trend observed in this area of knowledge.

## V. CONCLUSION

The scientific output on the use of ANNs in the oil and gas industry has been relatively stable in terms of papers published per year, ranging from 47 papers (2024) to 60 papers (2021). This is evidence that the research and production of scientific papers on the subject during the period under study shows an importance that is maintained over time, and demonstrates the importance given to ANNs in the oil and gas field worldwide.

Even though scientific journals continue to be the ideal media for the dissemination of research results, it was found that presentations at indexed congresses and conferences represent an important percentage in the publication of full-text scientific papers, which shows the relevance that engineers and oil companies give to these events for the dissemination of knowledge.

In terms of knowledge sub-areas, the papers published in Energy and Engineering stood out, with a minority participation from other fields such as Chemical Engineering, Environmental Sciences, Chemistry and Materials Sciences. This suggests that research has been generated mainly from the perspective of researchers associated with the oil and gas industry, with topics focused on energy efficiency and improving engineering operations.

The countries with the highest oil production are the ones that are generating the greatest amount of research in the use of ANNs, due to the importance they give to innovation in their operations and process optimization, which also leads to a significant participation of industries as producers of scientific documents, displacing universities in their role of knowledge production and research.

Researchers from Arab and Asian countries have devoted the most effort to studying the applicability of ANNs in oil and gas operations. This is evidenced by the greater number of authors from countries in these two regions, with the most prolific author being Ehsan Eftekhari-Zadeh, who produced 12.0% of the papers.

The King Fahd University of Petroleum and Minerals and the Saudi Arabian Oil Company, both institutions located in Saudi Arabia with 13 documents each, were the institutions with the highest number of appearances as institutional affiliations of the authors. This shows the importance given to the study of the use of NAR in oil and gas operations in Saudi Arabia as an oil producing country. Other institutions that appear as important generators of documents on the subject analyzed were the Universiti Teknologi PETRONAS of Malaysia, Friedrich-Schiller-Universität Jena of Germany and Politechnika Rzeszowska im. Ignacego Łukasiewicza from Poland, which shows that this subject is not only developed in Arab countries, but there is also a significant production in Europe.

Most of the papers were published in scientific journals, the most important being the Journal of Petroleum Science and Engineering. There were also publications in conferences, especially those of the Society of Petroleum Engineers (SPE). The results indicate that scientific journals in the field of petroleum science and engineering are considered to be the ideal media for the diffusion of research on the subject studied, but importance was also given to SPE conferences as a means of diffusion due to the relevance of this organization in the world petroleum field.

According to the keyword co-occurrence analysis, the use of ANNs in the oil and gas industry has focused on basic exploration, production and reservoir operations; however, there is a trend toward other areas that affect the petroleum system, such as the study of flow patterns, the prediction of pollutant emissions to the environment, especially carbon dioxide, the detection of operational problems, corrosion and the automation of operations.

Given that the bibliometric analysis was limited to the last five years and only to documents published in Scopus, it is recommended to extend the study period and use other databases such as SciELO or DOAJ where documents published in Spanish can be found, which can generate a broader panorama of scientific production in this area, especially by including research by Latin American authors from oil and gas producing countries.

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