Malaysian Journal Of Civil Engineering

Full Paper

THE IMPACT OF CLIMATE CHANGE ON WATER QUALITY: A BIBLIOMETRIC REVIEW (2010-2024)

Josilva M Muniandy

Department of Water and Environmental Engineering, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

Article history
Received
09 October 2024
Received in revised form
8 January 2025
Accepted
20 January 2025
Published online
31 March 2025

*Corresponding author
josilva@utm.my

Graphical abstract

Abstract

This bibliometric analysis provides a detailed overview of global research on the impact of climate change on water quality from 2010 to 2024. With increasing concerns about how climate change exacerbates water pollution, this study highlights key research trends, influential authors, leading institutions, and significant research areas in the field. By using advanced bibliometric techniques such as co-authorship analysis, citation analysis, and trend topic analysis, the study systematically explores the evolution of research linking climate change with water quality. It sheds light on the research focus areas, such as the effects of extreme weather events, temperature shifts, and altered hydrological cycles on freshwater ecosystems. Furthermore, this study identifies emerging contaminants and technological innovations related to climate-induced water quality changes. The results provide a comprehensive understanding of the current state of climate change's impact on water quality and offer guidance for future research efforts aimed at mitigating its detrimental effects on water resources and public health. This work contributes to forming strategies that help address challenges posed by changing climatic conditions and their effects on water systems globally.

Keywords: climate change, water quality, bibliometric analysis, trend

Abstrak

Analisis bibliometrik ini memberikan gambaran keseluruhan terperinci mengenai penyelidikan global tentang kesan perubahan iklim terhadap kualiti air dari tahun 2010 hingga 2023. Dengan peningkatan kebimbangan tentang bagaimana perubahan iklim memburukkan lagi pencemaran air, kajian ini menyerlahkan trend penyelidikan utama, pengarang berpengaruh, institusi terkemuka dan penting. bidang penyelidikan di lapangan. Dengan menggunakan teknik bibliometrik lanjutan seperti analisis pengarang bersama, analisis petikan dan analisis topik trend, kajian ini meneroka secara sistematik evolusi penyelidikan yang menghubungkan perubahan iklim dengan kualiti air. Ia memberi penerangan tentang bidang tumpuan penyelidikan, seperti kesan peristiwa cuaca ekstrem, peralihan suhu, dan kitaran hidrologi yang diubah pada ekosistem air tawar. Tambahan pula, kajian ini mengenal pasti bahan cemar yang muncul dan inovasi teknologi yang berkaitan dengan perubahan kualiti air yang disebabkan oleh iklim. Hasilnya memberikan pemahaman yang komprehensif tentang keadaan semasa kesan perubahan iklim terhadap kualiti air dan menawarkan panduan untuk usaha penyelidikan masa depan yang bertujuan untuk mengurangkan kesan buruknya terhadap sumber air dan kesihatan awam. Kerja ini menyumbang kepada pembentukan strategi yang membantu menangani cabaran yang ditimbulkan oleh perubahan keadaan iklim dan kesannya terhadap sistem air secara global.

Kata Kunci: perubahan iklim, kualiti air, analisis biometrik, aliran

1.0 INTRODUCTION

Climate change has emerged as one of the most pressing global concerns of the twenty-first century, with profound implications for water resources and ecosystems worldwide (Dixit et al., 2022). Rising temperatures, shifting precipitation patterns, and the increasing frequency of extreme weather events have heightened concerns about water quality, intensifying existing challenges and introducing new risks (Whitehead et al., 2009). These climatic shifts can significantly alter the physical, chemical, and biological characteristics of water bodies, exacerbating pollution issues and threatening freshwater ecosystems and public health (Barbieri et al., 2023). Key concerns include increased stormwater runoff, flooding, and droughts, which affect the transport and concentration of pollutants such as nutrients, heavy metals, pathogens, and emerging contaminants like microplastics and pharmaceuticals (Johnson et al., 2022). These issues necessitate urgent attention to safeguard ecosystem services and human well-being.

Since 2010, there has been a notable increase in research examining the interplay between climate change and water quality. This growing body of work reflects heightened awareness of the risks posed by climate-induced water pollution and the urgent need for adaptive strategies. Spanning diverse disciplines such as hydrology, environmental science, engineering, and public health, these studies investigate the complex interactions between climate variables, land use changes, and human activities across different geographical and climatic contexts. However, understanding the full scope of climate change impacts on water quality remains a formidable challenge due to the intricate, site-specific nature of these interactions. Additionally, research efforts remain fragmented, with regional disparities in focus and a lack of cohesive understanding of the complexities involved.

The primary objective of this study is to conduct a comprehensive bibliometric analysis of research on the impact of climate change on water quality published between 2010 and 2024. By systematically reviewing the academic literature, this analysis seeks to identify key trends, influential researchers and institutions, and emerging research areas. The study will employ bibliometric techniques, including co-authorship networks, citation analysis, and topic trend analysis, to uncover how research priorities have evolved over the past decade. These findings aim to inform future research agendas, foster international collaboration, and guide the development of innovative, climate-resilient strategies to mitigate the adverse effects of climate change on water quality.

The scope of this study encompasses research exploring the effects of climate change on freshwater systems, including alterations in precipitation patterns, temperature fluctuations, and extreme weather events. It examines various water quality parameters, such as nutrient loading, sediment transport, heavy metal contamination, and the presence of emerging pollutants like microplastics and pharmaceuticals. The analysis includes diverse scientific publications, such as peer-reviewed journal articles, conference proceedings, and other relevant scholarly sources. By synthesizing this body of work, the study aims to bridge gaps in understanding, highlight global and regional research disparities, and provide actionable insights for developing adaptive water quality management strategies.

Through this bibliometric analysis, the study will contribute to shaping future research directions and addressing the escalating water quality challenges posed by a changing climate, particularly in vulnerable regions with limited capacity to adapt. The outcomes will support efforts to ensure the sustainability of freshwater resources and the resilience of ecosystems and communities worldwide.

2.0 METHODOLOGY

This study uses a bibliometric technique to assess the global literature on the influence of climate change on water quality between 2010 and 2024. The methodology involves several systematic steps to ensure comprehensive data collection, accurate processing, and insightful analysis:

1. Data Collection: A systematic search of the Scopus databases will be conducted to gather relevant academic publications. The search will focus on the keywords “climate change,” “water quality,” “pollution,” and related terms. The inclusion criteria will be studies published between 2010 and 2024, covering peer-reviewed journal articles, conference papers, and review articles.
2. Data Preprocessing: The collected data will be preprocessed to ensure accuracy and consistency. This includes deduplication, removal of irrelevant publications, and verification of metadata such as authors, institutions, keywords, and publication years. All data will be checked for completeness before analysis.
3. Bibliometric Analysis: The preprocessed data will be analyzed using bibliometric techniques, including:
    - Co-authorship analysis to identify collaborative networks among researchers and institutions.
    - Citation analysis to determine the most influential papers and authors within the field.
    - Keyword analysis to uncover emerging research trends, hot topics, and thematic shifts related to climate change impacts on water quality.
4. Interpretation: The visualized data will be interpreted to assess the evolution of climate change and water quality research, with a focus on identifying key authors, institutions, and thematic areas. Particular attention will be paid to regional research patterns and interdisciplinary collaborations.
5. Discussion: The study’s findings will be discussed about the implications for policy development, research prioritization, and the design of adaptive water quality management strategies in response to climate change. The gaps identified through this analysis will provide a roadmap for future research directions.

By employing this rigorous bibliometric methodology, the study aims to provide a detailed understanding of global research trends in climate change and water quality (Gao et al., 2023). The use of tools such as R Studio will allow for deep exploration of research patterns and collaborative networks,

facilitating evidence-based decision-making for future water management strategies (Bhat et al., 2023).

3.0 RESULTS AND DISCUSSIONS

3.1 Publications

From January 2010 to September 2024, a total of 1104 papers were published (903 journal articles, 126 proceedings and 76 review papers). From 2010 to 2024, the number of publications on climate change and water quality research showed a general upward trend (Figure 1a). The number of publications (N) increased from 42 in 2010 to 104 in 2024, indicating growing interest and contributions in this field. Notably, after a steady rise through the 2010s, there was a significant jump in 2021, with 130 publications, which could be attributed to increasing concerns over climate change's impact on water quality, possibly fueled by recent global environmental challenges and climate initiatives. The most notable increases in publication numbers occurred between 2014 and 2015 (from 55 to 61), and 2020 to 2021 (from 75 to 130). This surge reflects heightened research activities in response to the escalating awareness of water-related climate challenges. However, in 2023 and 2024, a slight decrease in publications was observed, with 130 in 2023 and 104 in 2024. This could be due to various factors such as shifts in research focus, funding dynamics, or the conclusion of major projects initiated in earlier years. Those 1104 articles contained a total of 4641 authors, and only 55 of those pieces had just one author. The average number of authors per piece was 5.17.

years have been cited more frequently on an annual basis. The peak in citation activity occurred for papers published in 2015 (5.96), followed closely by 2018 (4.96), 2019 (4.76), and 2021 (4.36). This steady growth indicates that research from this period remains highly relevant and continues to shape the scientific discourse on climate change and water quality. However, in the most recent years (2022-2024), the average citations per year show a sharp decline, with 3.12 in 2022, 2.29 in 2023, and 0.74 in 2024. This is a natural outcome as these more recent publications have had limited time to accumulate citations.

The variable "Average citations per year" in Figure 1b represents the number of citations received per year for publications published within a certain year. The Mean Citations per Year shows a general upward trend from 2010 (2.09) to 2021 (4.36), suggesting that publications in recent

The authors of scholarly papers on the impact of climate change on water quality pollution are included in Figure 2a. The most pertinent authors are included in the provided data, along with how frequently they occur as authors in the dataset. It seems that a number of writers have made substantial contributions to the study of climate change and water quality, including Whitehead PG (14), Li Y, Liu Y, Na Na, Soulsby C, Wang L, Zhang Y (11 each). Further examination of their individual contributions, publication quality, citations obtained, and involvement in changing the area of climate and water quality research would provide a more complete picture of their significance. The compilation in Figure 2b denotes a collection of references that have been cited globally. The papers cover a broad spectrum of topics, including hydrology, geophysics, bio geosciences, irrigation, and environmental science, suggesting that climate change impacts on water quality are being addressed from multiple scientific perspectives. The paper by Abbaspour KC in 2015 from the "Journal of Hydrology" (DOI: 10.1016/j.jhydrol.2015.03.027) has the highest total citations of 1213. This paper stands out as the most cited research within the dataset, with an impressive 1,213 citations and an average citation rate of 121.30 per year. Its high citation frequency, coupled with a normalized citation score of 20.36, indicates that it is not only a widely read article but also one that significantly influences subsequent research in the field. The high impact of this paper could be attributed to the dealing with key aspects of water resources in the context of climate change. Similarly, Fletcher (2013) and Mosley (2015) have produced high-impact works, addressing critical issues related to water resource management and earth science.

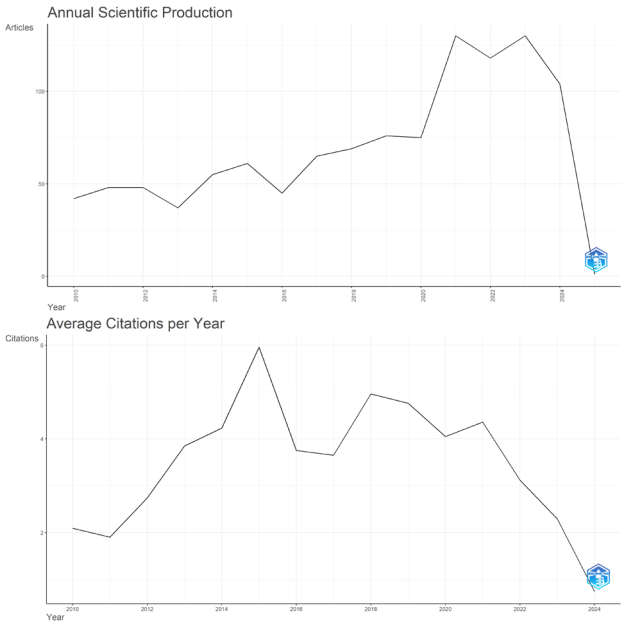

Figure 1: Publication details from 2010 to 2024 (a) Annual Scientific production and (b) Average citations per year

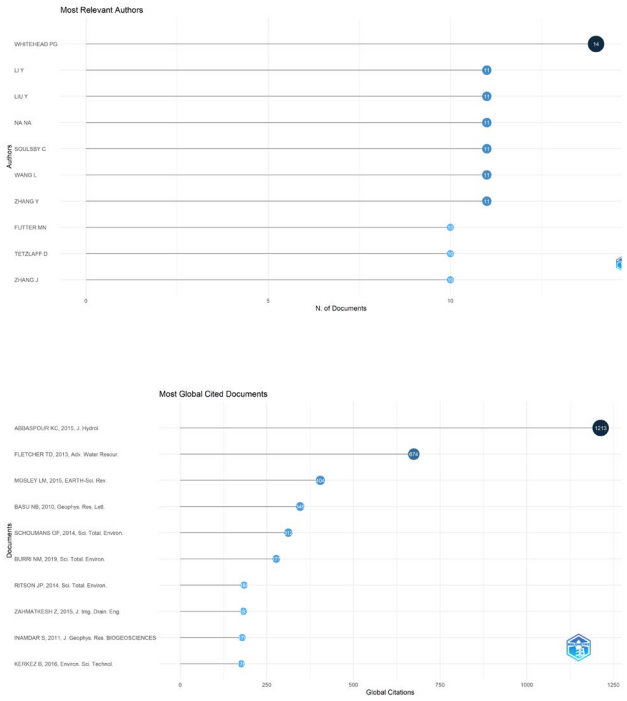

Figure 2: (a) Most relevant authors and (b) Most globally cited documents

3.2 Factorial Analysis

In the social sciences, psychology, and data mining, factororial analysis—also known as factor analysis—is a statistical technique for finding patterns and reducing data. It is used to break down complex data into more manageable chunks and uncover hidden connections between a large number of variables (Watkins, 2021). From the data provided in Figure 3, it presents the findings from a factorial analysis of key terms related to climate change and water quality research, based on their dimensional positions (Dim1 and Dim2). The data cluster indicates that all the terms belong to a single cluster, demonstrating their strong interconnection in the context of water-related studies. The analysis reveals the relationships between these terms in two main dimensions, Dim1 and Dim2, which are interpreted based on their relative distances and positions. The words are positioned within a two-dimensional space, and their coordinates indicate relationships in terms of shared thematic importance. Dim1 appears to reflect a gradient from general water and climate change topics (closer to zero) to more specific and detailed research terms (further from zero), while Dim2 captures relationships between monitoring or controlled studies and broader environmental processes. All terms are grouped within a single cluster, meaning they are tightly related in the context of climate change and water quality research. This reinforces the interconnectedness of the themes, with central terms like "water quality," "climate change," and "runoff" forming the backbone of the field, while peripheral terms such as "eutrophication," "agriculture," and "river pollution" represent specific applications or case studies within the broader scope. The factorial analysis highlights the central role of water quality, climate change, and runoff in the body of research, while also pointing to the importance of nutrient management, hydrology, and environmental monitoring. This interconnected framework reflects a holistic approach to understanding and mitigating the impacts of climate change on water systems. The clustering of all terms into a single group further emphasizes the interdependence of these factors, showing that studies in this field are highly integrated and focused on addressing the global challenge of sustaining water quality in the face of climate change.

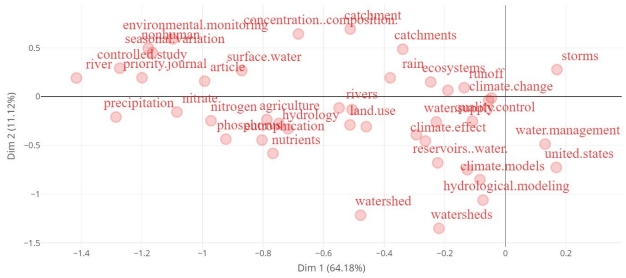

Figure 3 Factorial analysis

3.3 Collaboration Network

A graphical representation of the interactions and collaborations between people, groups, or entities based on their shared contributions to a particular topic, project, or body of work is called a collaboration network, sometimes referred to as a co-authorship network (Lei et al., 2021). Collaboration networks are frequently used in academic and scientific settings to illustrate how researchers, writers, or institutions collaborate on publications, papers, or projects. Analyzing these networks allows academics to better understand the collaborative dynamics, knowledge transfer, and influence within a given research landscape. It also visualizes how individuals and companies collaborate to promote knowledge and innovation in a specific subject. From Figure 4, Nodes refer to the specific researchers or individuals who are actively involved in the collaboration network. Cluster membership refers to each node's membership in a cluster. In the current situation, the researchers are assigned to the same cluster (Cluster 1) based on their collaborative behavior. Betweenness centrality is a statistic that measures the degree to which a node is located on the shortest paths connecting other nodes in a network. Nodes with high betweenness centrality are typically used to connect various components of a network. The closeness centrality metric measures how well a node relates to all other nodes in a network. Strong connection and effective information dissemination are features of nodes with a high degree of proximity centrality. A highly organized and clustered research community is revealed by the collaboration network, with important nodes promoting information sharing among various organizations. Researchers like Li J and Whitehead PG serve as central hubs within their respective clusters, playing pivotal roles in bridging diverse research topics and promoting interdisciplinary collaboration. Clusters 2 and 4 are particularly notable for their dense connections and influential researchers, likely signifying more active areas of research related to climate change, hydrology, and water management. In contrast, Clusters 5 through 7 reflect smaller or more specialized research groups with lower centrality values, suggesting that while they contribute to the broader network, their research focus might be more niche. This

structural diversity enhances the overall robustness of the network, allowing for both broad interdisciplinary collaborations and deep, specialized investigations into specific environmental and water-related issues.

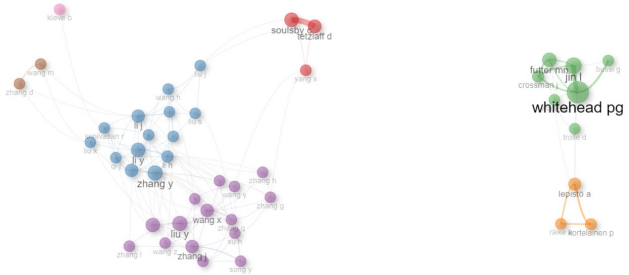

Figure 4 Collaboration Network

3.4 Thematic Map

A thematic map is one that shows spatial patterns or links between distinct geographic locations based on a particular theme or issue. The essential feature of thematic maps is that they use colors, symbols, or other visual components to reflect the data being displayed, allowing users to rapidly absorb the information offered. The thematic map in Figure 5 identified three main thematic clusters in the field of runoff water quality research, centered around the key topics of water management, water quality, and rain. These clusters represent the dominant areas of research focus, as illustrated by the high frequency of keyword occurrences, centrality metrics, and interrelations among various sub-topics. The prominence of water management-related terms, particularly those connected to climate models and watershed management, demonstrates the field's focus on developing resilient water management strategies in the face of climate change. The integration of terms such as "groundwater" and "urbanization" suggests that researchers are increasingly considering the interactions between human activity, land use, and water resources. This highlights the need for holistic management approaches that address the multifaceted challenges of water conservation, flood management, and sustainable urban planning.

The water quality cluster reflects the growing concern around nutrient pollution, particularly from agricultural sources. The high occurrence of terms such as "phosphorus" and "nitrogen" points to an ongoing interest in understanding the impacts of nutrient runoff on water ecosystems, including issues like eutrophication and river pollution. This underscores the importance of integrated catchment management strategies that address both water quantity and quality issues, with a particular focus on reducing nutrient loading from agricultural activities. The rain-related cluster highlights the increasing attention to urban water management, especially in the context of stormwater runoff and flooding. The presence of terms like "stormwater," "sewage," and "flooding" suggests that urban water pollution and flood risk management are critical areas of concern. As urban areas expand, the management of stormwater and the mitigation of water pollution from urban runoff will remain central to ensuring water security and minimizing the environmental impacts of urban development.

A major thematic cluster in recent years is the link between climate change and water quality. Terms such as climate effect (117 occurrences), climate change scenarios (41 occurrences), and winter (35 occurrences) illustrate the growing recognition of how changing precipitation patterns, temperature fluctuations, and seasonal variations impact runoff water quality.

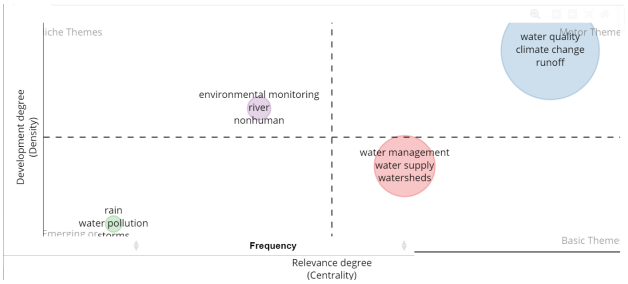

Figure 5 Thematic map

3.5 Trend Topic

A graphic depiction of the trend topic analysis that sheds light on the temporal distribution of particular phrases in the subject of water quality and climate change research is shown in Figure 6. Between 2010 and 2014, the focus of runoff water quality research was centered on foundational themes such as management, hydraulics, and concentration (process), with significant contributions made between 2010 and 2011. Additionally, artificial neural networks (7 occurrences) began appearing in 2011, indicating an early adoption of advanced computational tools in hydrological research. However, the median year of 2020 suggests that this area has only recently gained traction, likely due to advances in machine learning and artificial intelligence.

From 2020 onward, research has delved deeper into more specific pollutants and ecological impacts. This shift is likely driven by increased recognition of agricultural runoff as a major contributor to water quality degradation, resulting in harmful algal blooms and hypoxic conditions in water bodies.

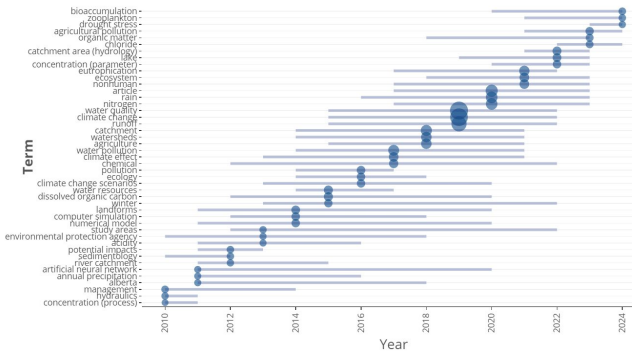

Figure 6 Trend topics

4.0 CONCLUSIONS

The bibliometric analysis of climate change effect on water quality from 2010 to 2023 reveals significant evolution in the field. Early research focused on fundamental hydrological processes, including management, hydraulics, and sedimentology, as well as basic water quality concerns. However, as environmental challenges have become more complex, research has progressively shifted towards understanding the impacts of climate change, pollutants, and the role of catchment systems. The increasing frequency of topics like water quality, climate change, agriculture, and runoff reflects growing concerns over both anthropogenic and natural influences on water systems.

Recent years have seen a surge in studies on nutrient pollution, particularly focusing on nitrogen and eutrophication, driven by the impact of agricultural runoff. Advanced numerical models and computer simulations have become integral to managing water quality under changing environmental conditions, while topics like bioaccumulation and drought stress highlight emerging areas of concern for future research.

Overall, the trends demonstrate a clear shift from basic water quality monitoring to addressing the multifaceted challenges posed by climate change, pollution, and land use. This evolution signals the need for continuous innovation in both research methodologies and policy approaches to effectively manage and protect water resources, ensuring sustainability for ecosystems and human populations alike. Future research should prioritize integrated watershed management, address agricultural pollution, and further explore the resilience of water systems to climate extremes such as drought.

Acknowledgements

I would like to offer our heartfelt gratitude to all those from Universiti Teknologi Malaysia (UTM) who participated to the completion of this research paper. While this effort did not get particular financing, it was made feasible via the help and cooperation of various individuals, mainly academic personnel from Faculty of Civil Engineering, UTM who generously offered their expertise, time, and resources.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper

References

[1] Whitehead, P. G., Wilby, R. L., Battarbee, R. W., Kernan, M., & Wade, A. J. 2009. A review of the potential impacts of climate change on surface water quality. *Hydrological Sciences Journal,* 54(1): 101-123.

[2] Johnson, T., Butcher, J., Santell, S., Schwartz, S., Julius, S., & LeDuc, S. 2022. A review of climate change effects on practices for mitigating water quality impacts. *Journal of Water and Climate Change,* 13(4): 1684-1705.

[3] Gao, J., Zhu, S., Li, D., Jiang, H., Deng, G., Wen, Y., & Cao, Y. 2023. Bibliometric analysis of climate change and water quality. Hydrobiologia, 850(16): 3441-3459.

[4] Bhat, W. A., Khan, N. L., Manzoor, A., Dada, Z. A., & Qureshi, R. A. 2023. How to Conduct Bibliometric Analysis Using R-Studio: A Practical Guide. *European Economic Letters (EEL),* 13(3): 681-700.

[5] Watkins, M. W. 2021. A step-by-step guide to exploratory factor analysis with SPSS. Routledge.

[6] Lei, P., Shrestha, R. K., Zhu, B., Han, S., Yang, H., Tan, S., & Xie, D. 2021. A bibliometric analysis on nonpoint source pollution: current status, development, and future. *International Journal of Environmental Research and Public Health*, 18(15): 7723.

[7] Barbieri, M., Barberio, M. D., Banzato, F., Billi, A., Boschetti, T., Franchini, S., & Petitta, M. 2023. Climate change and its effect on groundwater quality. *Environmental Geochemistry and Health,* 45(4): 1133-1144.

[8] Dixit, A., Madhav, S., Mishra, R., Srivastav, A. L., & Garg, P. 2022. Impact of climate change on water resources, challenges and mitigation strategies to achieve sustainable development goals. *Arabian Journal of Geosciences*, 15(14): 1296.

[9] Abbaspour, K. C., Rouholahnejad, E., Vaghefi, S. R. I. N. I. V. A. S. A. N. B., Srinivasan, R., Yang, H., & Kløve, B. 2015. A continental-scale hydrology and water quality model for Europe: Calibration and uncertainty of a high-resolution large-scale SWAT model. *Journal Of Hydrology,* 524: 733-752.