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ADVANCES IN WATER QUALITY ASSESSMENT USING FUZZY APPROACH: RECENT TRENDS OF THEORY AND APPLICATIONS

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Abstract:

Due to the rapid growth of economic development and population, the demand for water consumption and the levels of polluted water in Malaysia have constantly increased and are considered crucial issues in Malaysia. Urbanization has steadily produced great amounts of human wastes, such as domestic and industrial wastes which inevitably end up in the water bodies. The World Health Organization claimed that approximately 2.2 million people die annually from such illnesses caused by ingesting bacteria, viruses, protozoans, and other pathogenic microbes in untreated or poorly treated waters or wastewater. This paper intends to provide insight into the publication trends on water quality assessment using fuzzy approaches from 2015 to 2023. This study conducted a bibliometric analysis of 404 scholarly works on water quality assessment as recorded in the Scopus database in September 2023. The data was analysed using a variety of software which are VOSviewer, Harzing's Publish and Perish, and Microsoft Excel. This paper highlights important contributions, publications, statistics, and current trends of theory and applications in the field. The finding also addresses essential information on present and future developments and critical information for increasing the inclusivity and global reach of water quality assessment which need further attention from the fuzzy research community.

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Keywords:

Water Quality, Water Quality Index, Factor Analysis, Fuzzy Mathematics, Fuzzy Decision Making, Water Quality Evaluation, Water Quality Assessments

Introduction

Water is without a doubt the most important natural resource on the earth, essential for all aspects of daily life as well as for industrialization, urbanization, and the growth of the world economy. The volume of water consumed worldwide each year totals 2 billion cubic meters (Maxwell and Yates, 2011). The world's population is predicted to reach 8.5 billion people by the year 2030 (UN News Centre, 2015), and an adequate supply of high-quality water is essential for both our survival and the growth of our economy. By 2050, 685 million of the population from more than 570 cities will face an increased decline in clean and fresh water of at least 10% (United Nations, 2020). The water shortage and water crisis are not caused by having too little water, but probably by unsustainable management of water resources and assessment. Several research in the past have been focused continuously on water quality assessment. There are a few factors that contribute to the poor water quality index. Some researchers concluded that in developing nations, inadequate resource management and policy shortcomings are key factors contributing to the degradation of water quality levels (Abdullahi et al. 2023, Mohamed et al. 2022, Fentahun et al., 2023). Besides, the decline in water quality levels can also be attributed to rapid population growth and extensive human activities in agriculture, industry, and urbanization. (Zhao et al., 2022; Goi, 2020]. In addition, natural circumstances such as volcanic eruptions and the rainy season as factors that lead to increased precipitation, thereby contributing to a decline in water quality (Ding et al., Hu et al. 2022).

Water quality level can be determined by various parameters such as pH level (Abdullahi et al. 2023, Feisal et al.), biochemical oxygen demand [Rak et al. 2022, Loi et al. 2022], inorganic pollutants indicators such as ammonia nitrogen (NH3–N), total phosphorus (TP), total nitrogen (TN), fluoride, chloride (Itoh et al. 2023, Ding et al., Fonseca et al, 2022), and metal pollutants (Hu et al. 2022). These parameters represent vital indicators employed in the evaluation of the water quality index (WQI), utilizing diverse methods such as statistical analysis which is the multivariate analysis and linear regression analysis (Rak et al. 2022, Loi et al. 2022, Itoh et al. 2023). Next, machine learning techniques by probabilistic-fuzzy, neural network, and analytic hierarchy process (AHP) (Singh, Majumder & Vidyarthi, 2023, Hu et al. 2022, Fonseca et al, 2022, Ding et al., Zhao et al. 2022, Abdullahi et al. 2023).

In Malaysia, several research studies have been conducted to investigate and measure water quality levels (Feisal et al., 2023; Itoh et al., 2023; Loi et al., 2022; Rak et al., 2022; and Goi, 2020). The areas studied include the Muda River, Juru River, Pahang River, Pergau Lake, Selangor River basin, Langat River basin, and Klang River basin. Despite the advantages portrayed in previous studies, there are limitations in the evaluation and assessment of risk factors. Nevertheless, no single parameter has been identified as the primary contributor to water quality assessment in Malaysia. Statistical analysis is mainly employed to assess the quality of rivers in Malaysia. There have been few attempts to integrate the various methodologies used in the literature in this field. However, previous research has primarily focused on statistical analysis and empirical findings, indicating a need for a comprehensive

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understanding of the main factors influencing water quality. Therefore, it is highly recommended that researchers consider evaluations and investigations of publications on water quality assessment using a fuzzy approach as one of the potential tools for evaluating the factors affecting water quality assessment. Moreover, critical summaries from existing studies could effectively aid future endeavors.

From this bibliometric analysis, an excellent and detailed analysis data of research allows the readers to identify the directions of knowledge gaps, the assessment of the quality of research, and the discovery of new developments in each field (Chistov et al., 2021). The bibliometric analysis provides a comprehensive overview of the most influential authors, journals, countries, and keywords in a particular research field (Ding et al., 2023; Sahabuddin et al., 2023). Using the science mapping approach, this study illustrates the framework of water quality assessment which is published in journals and conference proceedings indexed in Scopus from 2015 to 2023. Specifically, this study seeks to answer the following questions:

1) To identify the main research topics and focus on water quality assessment using a fuzzy method.
2) To identify gaps in knowledge in predicting water quality assessment using fuzzy methods.
3) To identify the future direction for predicting water quality assessment using a fuzzy method.

The direction of this study aims to contribute to the review in two focuses. The first focus is to present the research trends and applications of water quality assessment through bibliometric analysis. Second, to summarise specific knowledge for relevant fuzzy theoretical research. The fuzzy concepts and theories have successfully been known to deal with both qualitative and quantitative measurement especially when involving linguistic terms mimicking human thoughts (Chimatapu, 2018), and have been adopted in various applications in environmental issues such as water supply (Lei et al., 2024; Nguyen et al., 2023), weather forecasting (Chen et al., 2015), earthquake prediction (Zheng et al., 2015) just to name a few. Thus, it is hoped that this study will help to provide future researchers with one concrete analysis regarding this field. This paper is organised as follows: Section 2 briefly describes the data sources and methods. Section 3 explores the direct results and conclusions of the findings. Section 5 mentions the main conclusions of this paper, and finally, the references are shown.

Methods

In this paper, the Scopus database was used to collect the data, as it is one of the largest multidisciplinary databases of peer-reviewed academic literature. Scopus manages to identify relevant and authoritative research, experts, and reliable data, metrics, and analytical tools. In addition, Scopus also includes nearly 10,741 active titles and inactive titles.

The search query “water quality factors” was applied to the article title within the Scopus database on September 25, 2023. To obtain the most relevant articles related to the scope of the study, the search was limited to using a fuzzy method and only included documents from 2015 until 2023 (8 years). Next, several online refinements were conducted. For instance, the language was limited to the English language, and the subject areas only included environmental sciences, agriculture and biological sciences, earth and planetary sciences, social sciences, biochemistry, genetics and molecular biology, engineering, energy, computer sciences, and decision sciences. In addition, the document type is limited to articles, conference

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papers, reviews, and book chapters. The keywords that are not related to fuzzy methods or water quality factors were also excluded. Lastly, manual filtration was conducted to exclude irrelevant articles. Table 1 shows the details of the queries for data collection.

As part of the data sets, the data was exported in CSV and RIS formats. To analyze the collected documents, several tools were used, including Microsoft Excel, VOSviewer, and Harzing's Publish and Perish software.

Table 1: Final Query Used for Data Collection

No.	Search Query	Results
1.	**Final query**: (TITLE-ABS-KEY (water AND quality AND index AND factor) AND PUBYEAR > 2014 AND PUBYEAR < 2024) AND (fuzzy) AND (LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "AGRI") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "MULT") OR LIMIT-TO (SUBJAREA , "MATH")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "ch")) AND (LIMIT-TO (EXACTKEYWORD , "Water Quality") OR LIMIT-TO (EXACTKEYWORD , "Water Quality Indexes") OR LIMIT-TO (EXACTKEYWORD , "Water Quality Index") OR LIMIT-TO (EXACTKEYWORD , "Factor Analysis") OR LIMIT-TO (EXACTKEYWORD , "Fuzzy Mathematics") OR LIMIT-TO (EXACTKEYWORD , "Water Quality Assessments") OR LIMIT-TO (EXACTKEYWORD , "Water Quality Assessment") OR LIMIT-TO (EXACTKEYWORD , "Water Quality Evaluation") OR LIMIT-TO (EXACTKEYWORD , "Decision Making")) AND (LIMIT-TO (LANGUAGE , "English"))	481
2.	Keywords limited to water quality, water quality index, water quality indexes, factor analysis, fuzzy mathematics, decision making, water quality evaluation, water quality assessments, and water quality assessment.	481
3.	Manual filtration to exclude irrelevant articles.	404

Results and Discussions

This section describes a summary of the research on water quality evaluation using a fuzzy method, some general statistics of the data sets are presented. The following criteria were used to evaluate every article that matched the search query: titles and abstract analysis, authorship, most active institutions, citation analyses, research productivity, subject area, most active source title, keywords, and distribution of publications by country.

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Document and Source Types

The selection of document types refers to the originality of the documents, such as conference proceedings, journal articles, or book series, whereas source types refer to the type of source documents, whether journal, conference paper, book chapter, book, or trade publication (Sweileh et al., 2017). We can see from Table 2 that most documents found are articles, with 91.83%, followed by conference papers, reviews, and book chapters with 4.95%, 1.73%, and 1.49%, respectively. As shown in Table 3, the documents are classified into four different source types, with journals representing the most with 378 documents (93.56%), followed by conference proceedings with 19 documents (4.7%) of the total publications.

Table 2: Document Type

Document Type	Total Publication (TP)	Percentage (%)
Article	371	91.83
Conference Paper	20	4.95
Review	7	1.73
Book Chapter	6	1.49
Total	**361**	**100.00**

Table 3: Source Type

Source Type	Total Publication (TP)	Percentage (%)
Journal	378	93.56
Conference Proceeding	19	4.70
Book	4	0.99
Book Series	3	0.743
Total	**361**	**100.00**

Year of Publications - Evolution of Published Studies

The evolution of published studies discovered by examining documents by year of publication allows the researcher to see the pattern and popularity of the research subject over time (Ahmi and Mohamad, 2019). The overall quantity of publications has experienced a swift rise from 2022 to the present. With only one publication, the field of water quality index factors using fuzzy methods began in 1988. Until now, the number of publications has increased significantly.

Table 4: Year of Publications

Year	TP	NCP	TC	C/P	C/CP	*h*	*g*
2015	23	23	931	40.48	40.48	17	23
2016	26	23	1197	46.04	52.04	16	26
2017	22	21	765	34.77	36.43	14	22
2018	35	34	750	21.43	22.06	16	27
2019	26	26	787	30.27	30.27	15	26
2020	37	36	713	19.27	19.81	14	26
2021	64	50	632	9.88	12.64	15	22
2022	100	78	567	5.67	7.27	13	18
2023	71	28	66	0.93	2.36	4	5
Total	**361**						

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Notes: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; and g=g-index.

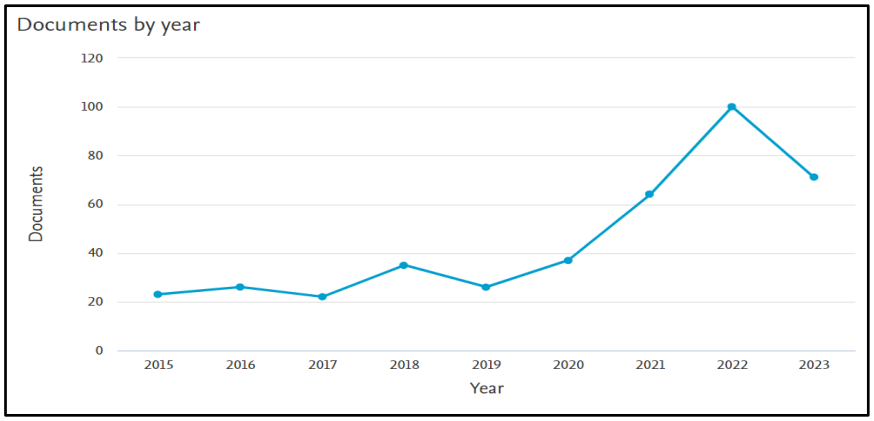

Figure 1: Document by Year

Subject Area

Table 5 shows the top 20 subject areas in water quality assessment using a fuzzy approach. Environmental science has the highest number of publications, with 375 (44.27%), since water quality is an environmental topic. Agriculture and Biological Sciences contributed 11.45% of the total publications, followed by Earth and Planetary Sciences with 8.62%, Social Sciences with 7.56%, and Biochemistry, Genetics, and Molecular Biology with 5.43%.

Table 5: Subject Area

Subject Area	Total Publications (TP)	Percentage (%)
Environmental Science	375	44.27
Agricultural and Biological Sciences	97	11.45
Earth and Planetary Sciences	73	8.62
Social Sciences	64	7.56
Biochemistry, Genetics and Molecular Biology	46	5.43
Engineering	45	5.31
Energy	33	3.90
Computer Science	20	2.36
Decision Sciences	18	2.13
Medicine	17	2.01
Business, Management and Accounting	9	1.06
Chemical Engineering	9	1.06
Physics and Astronomy	8	0.94
Chemistry	7	0.83
Pharmacology, Toxicology and Pharmaceutics	7	0.83
Materials Science	6	0.71
Multidisciplinary	6	0.71
Mathematics	5	0.59
Economics, Econometrics and Finance	2	0.24

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Most Active Source Titles

Table 6 presents the most active source title, we found that Water (Switzerland) was the most active source title, followed by Environmental Science and Pollution Research and Lecture Notes in Bioinformatics, Computational Economics, Knowledge-Based Systems, and Environmental Monitoring and Assessment.

Table 6: Most Active Source Title

Source Title	TP	Publisher	Cite Score	SJR 2022	SNIP 2022
Water (Switzerland)	38	MDPI	5.5	0.723	1.063
Environmental Science and Pollution Research	28	Springer Science and Business Media Deutschland GmbH	7.9	0.944	1.214
Environmental Monitoring and Assessment	24	Springer Science and Business Media Deutschland GmbH	5.2	0.626	0.906
Science of the Total Environment	23	Elsevier B.V.	16.8	1.946	2.026
Environmental Earth Sciences	21	Springer Science and Business Media Deutschland GmbH	5.2	0.599	0.931
Ecological Indicators	12	Elsevier B.V.	10.3	1.396	1.665
IOP Conference Series: Earth and Environmental Science	11	IOP Publishing	0.8	0.197	0.255
International Journal of Environmental Research and Public Health	10	MDPI	5.4	0.828	1.28
Groundwater for Sustainable Development	9	Elsevier B.V.	10.4	1.08	1.646
Journal of Hydrology	9	Elsevier B.V.	10.4	1.67	1.731
Arabian Journal of Geosciences	8	Springer Science and Business Media Deutschland GmbH	N/A	0.232	0.777

Keywords Analysis

The author's keywords were mapped using VOSviewer, a software programme for creating and visualizing bibliometric networks. A network visualization of the author's keywords is shown in Figure 2, where the relationships between the keywords are represented using colour, square size, text size, and connecting line thickness. For example, keywords of the same colour were often placed together. For instance, the study's groundwater quality, groundwater sample,

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groundwater chemistry, weathering, agricultural activities, and human consumption all exhibit similar colours (green), suggesting a relationship and frequent co-occurrence of these terms.

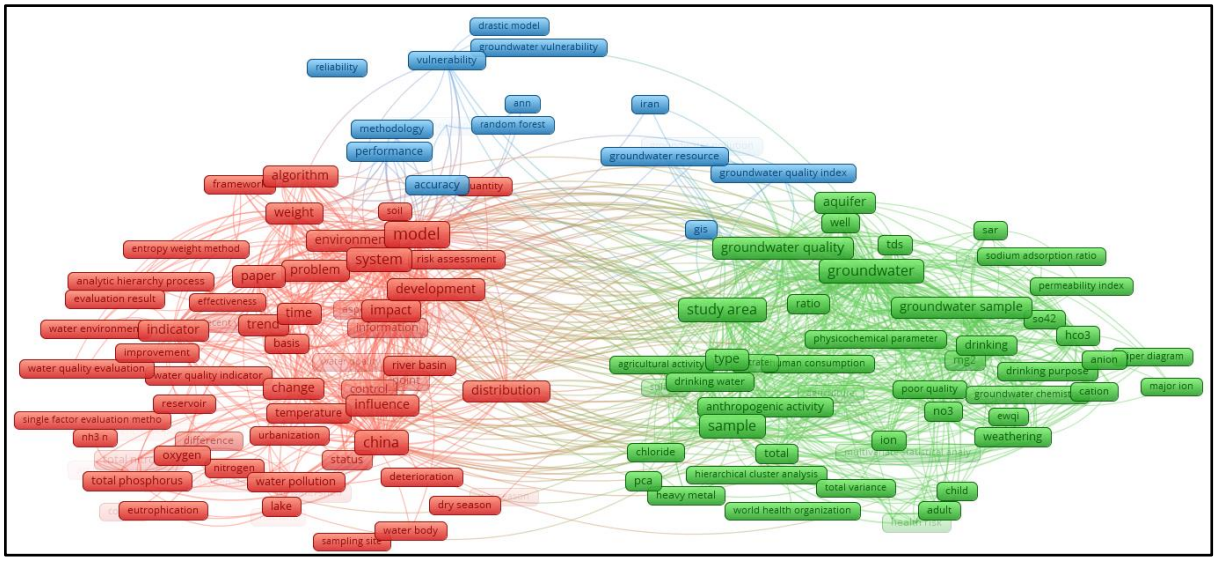

Figure 2: Network visualization map of the author keywords

The study's top keywords are displayed in Table 7. Among the most frequently encountered author keywords were water quality, quality control, groundwater, environmental monitoring, and water pollution.

Table 7: Top Keywords

Author Keywords	Total Publications (TP)	Percentage (%)
Water Quality	367	19.03
Quality Control	149	7.72
China	144	7.47
Groundwater	129	6.69
Article	105	5.44
Environmental Monitoring	99	5.13
Rivers	93	4.82
Water Pollution	82	4.25
Water Quality Indexes	78	4.04
Water Management	77	3.99
Water Supply	71	3.68
River Pollution	67	3.47
Water Quality Index	65	3.37
Risk Assessment	62	3.21
Groundwater Resources	61	3.16
Principal Component Analysis	61	3.16
Water Pollutant	56	2.90
Hydrochemistry	55	2.85
Potable Water	55	2.85
Drinking Water	53	2.75

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Geographical Distribution of Publications

Table 8 reports the top 5 countries with the highest number of published studies in the water quality assessment literature. China is at the top, achieving 206 counts (37.39%), followed by India 69 (12.52%), Iran 28 (5.08%), and the United States 20 (3.63%). Nevertheless, the study found that Malaysia placed sixth with 13 (2.36%) that were published regarding the issue stated.

Table 8: Top 20 Countries Contributed to the Publications

Country	Total Publications (TP)	Percentage (%)
China	206	37.39
India	69	12.52
Iran	28	5.08
United States	20	3.63
South Korea	14	2.54
Malaysia	**13**	**2.36**
Saudi Arabia	13	2.36
Turkey	12	2.18
Australia	11	2.00
Bangladesh	10	1.81
Nigeria	10	1.81
Canada	9	1.63
Japan	9	1.63
Brazil	8	1.45
Viet Nam	8	1.45
Germany	6	1.09
Egypt	5	0.91
Iraq	5	0.91
Pakistan	5	0.91
Romania	5	0.91

Authorship and Co-Authorship Analysis

Table 9 shows the number of authors per document. A total of 14 (3.47%) documents were single-authored publications, while the highest percentage (20.05%) were four-author publications. The productive authors based on publication numbers are shown in Table 10. Islam A.R.M.T. had the most publications with 5 papers, followed by Gholami, V., Kumar, P., and Selvam, S., with 4 publications. The rest of the authors mostly had three publications or below.

Table 9: Number of Author(s) per Document

Author Count	Total Publications (TP)	Percentage (%)
1	14	3.47
2	46	11.39
3	78	19.31
4	81	20.05
5	71	17.57
6	36	8.91
7	27	6.68

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8	23	5.69
9	10	2.48
10	11	2.72
11	3	0.74
12	3	0.74
15	1	0.25
Total	**404**	**100.00**

Table 10: Most Productive Authors

Author's Name		Total Publications (TC)	Percentage (%)
Islam, A.R.M.T.	Bangladesh	5	1.78
Gholami, V.	Iran	4	1.42
Kumar, P.	Australia	4	1.42
Selvam, S.	India	4	1.42
Avtar, R.	Japan	3	1.07
Bodrud-Doza, M.	Canada	3	1.07
Chung, S.Y.	South Korea	3	1.07
El-Shafie, A.	Malaysia	3	1.07
Jia, C.	China	3	1.07
Khaleghi, M.R.	Iran	3	1.07
Kurniawan, T.A.	China	3	1.07
Shi, L.	China	3	1.07
Venkatramanan, S.	India	3	1.07
Wang, M.	China	3	1.07
Yang, X.	China	3	1.07
Yin, W.	China	3	1.07
Aalami, M.T.	Iran	2	0.71
Ahmad, S.R.	Pakistan	2	0.71
Ahmad, W.S.	India	2	0.71
Ahmed, A.N.	Malaysia	2	0.71

Figure 3 depicts the network visualization map representing co-authorship across countries, considering those with a minimum of five citations and three documents. Meanwhile, Figure 4 presents the network visualization map of co-authorship among authors with a minimum of five citations and one document. Additionally, Figure 5 and Figure 6 showcase the VOSviewer visualization of term co-occurrence networks. Figure 5 is based on title and abstract fields, while Figure 6 is based solely on title fields.

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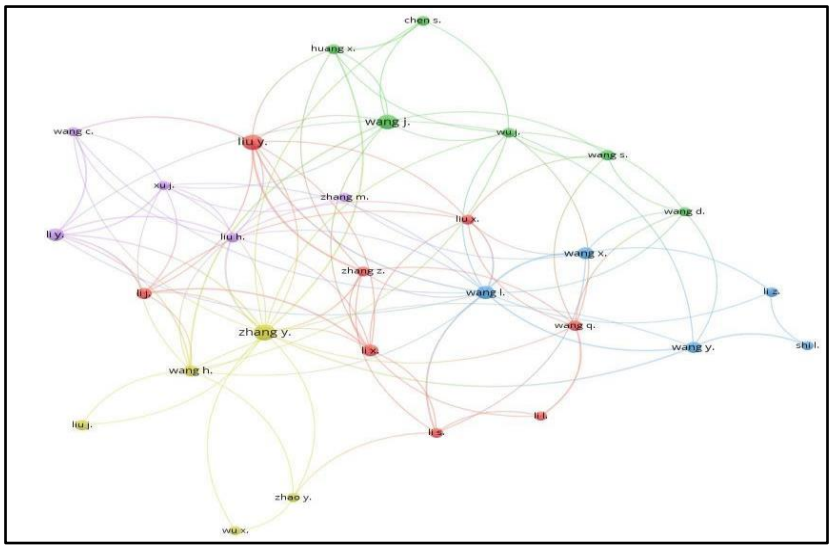

Figure 3: Network Visualization Map Of The Co-Authorship Based On Countries That Have A Minimum Of Five Citations And Three Documents (Fractional Counting)

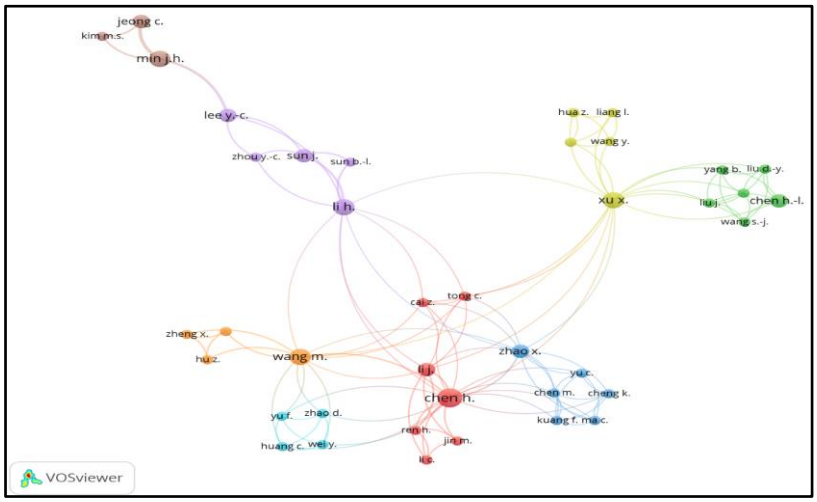

Figure 4: Network Visualization Map Of The Co-Authorship Based On Authors That Have A Minimum Of Five Citations And One Document (Fractional Counting)

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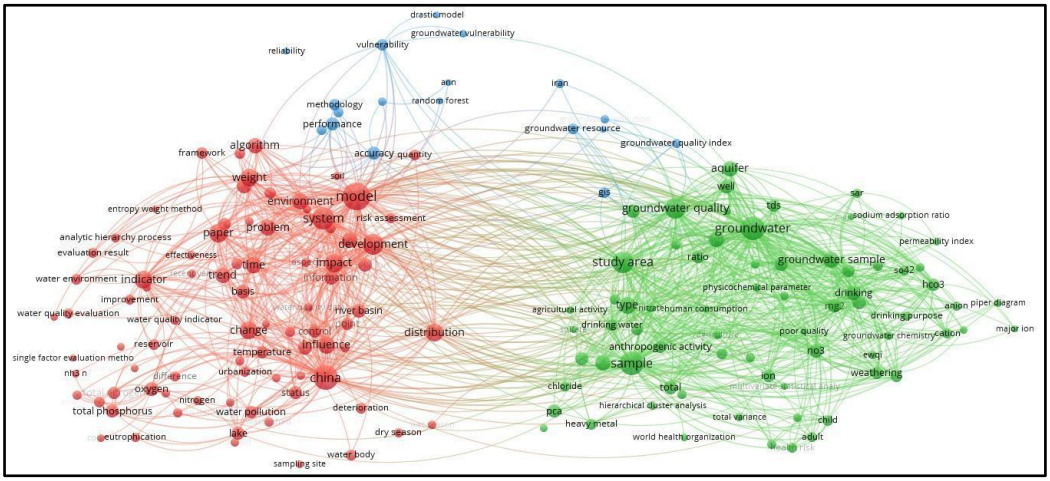

Figure 5: VOSviewer Visualization Of A Term Co-Occurrence Network Based On Title And Abstract Fields (Binary Counting)

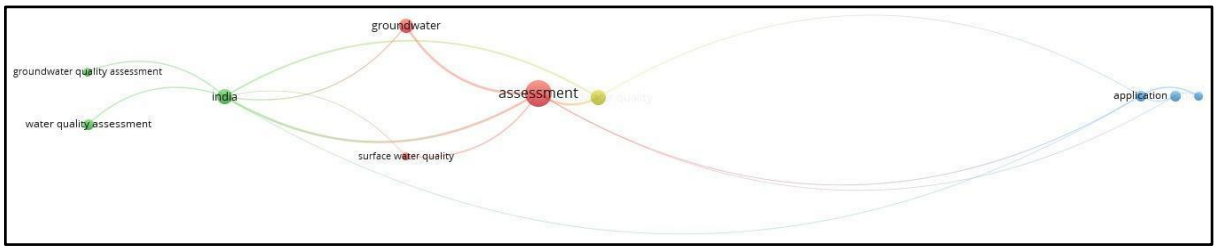

Figure 6: VOSviewer Visualization Of A Term Co-Occurrence Network Based On Title Fields (Binary Counting)

Most Influential Institutions

Table 11 presents information on the institutions that have been sorted based on the total publications. The table shows the highest number of publications is 18 (4.46%) for the Ministry of Education of the People's Republic of China, followed by the Chinese Academy of Sciences with 15 (3.71%) publications. Next Hohai University contributed a total of 14 (3.47%) publications. This showed why most publications were from China since they were sponsored by the Ministry of Education of the People's Republic of China.

Table 11: Most Influential Institutions With A Minimum Of Five Publications

Institution	Total Publications (TC)	Percentage (%)
Ministry of Education of the People's Republic of China	18	4.46
Chinese Academy of Sciences	15	3.71
Hohai University	14	3.47
Beijing Normal University	12	2.97
China Institute of Water Resources and Hydropower Research	9	2.23
Chinese Research Academy of Environmental Sciences	9	2.23
University of Chinese Academy of Sciences	7	1.73
Nanjing University	7	1.73

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Shandong University of Science and Technology	6	1.49
University of Tabriz	6	1.49
Jilin University	6	1.49
Southwest Jiaotong University	6	1.49
Shandong University	6	1.49
Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences	6	1.49
Begum Rokeya University	5	1.24
Zhengzhou University	5	1.24
Tianjin University	5	1.24
Nanjing Hydraulic Research Institute	5	1.24
University of Tehran	5	1.24
Tsinghua University	5	1.24

Citation Analysis

The citation metrics were summarised in Table 12 as the documents were retrieved on September 25, 2023. Harzing's Publish and Perish software was used to produce the result by importing RIS-formatted files from the Scopus database. As a result, the number of publications predicting water quality assessment using the fuzzy approach reported from 2015–2023 was 404, with 6408 citations and an average of 801 citations per year. Besides that, there are 15.86 citations per paper, and the total h-index and g-index were 40 and 65, respectively.

Table 12: Citations Metrics

Metrics	Data
Publication years	2015-2023
Citation years	8 (2015-2023)
Papers	404
Citations	6408
Citations/year	801
Citations/paper	15.86
Citations/author	1702.78
Papers/author	112.17
h-index	40
g-index	65

Table 13 revealed the most-cited publications with their total citations. The article entitled "Development of river water quality in India: A review" by Sutadian et al. (2016) has received the highest number of citations (58 citations with an average of 32.86 citations per year), followed by Wang et al. (2019) with 57 citations per year.

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Table 13. Top Ten Most Cited Publications.

No	Authors	Title (Source)	Year	Citations	Citations per Year
1	J. Wang, Z. Fu, H. Qiao, F. Liu	Assessment of eutrophication and water quality in the estuarine area of Lake Wuli, Lake Taihu, China	2019	57	57
2	Z. Han, H. Ma, G. Shi, L. He, L. Wei, Q. Shi	A review of groundwater contamination near municipal solid waste landfill sites in China	2016	40	34.57
3	A.D. Sutadian, N. Muttil, A.G. Yilmaz, B.J.C. Perera	Development of river water quality India case: a review	2016	58	32.86
4	P. Li, S. He, N. Yang, G. Xiang	Groundwater quality assessment for domestic and agricultural purposes in Yan'an City, northwest China: implications to sustainable groundwater quality management on the Loess Plateau	2018	36	28.4
5	A.R.M.T. Islam, N. Ahmed, M. Bodrud-Doza, R. Chu	Characterizing groundwater quality ranks for drinking purposes in Sylhet district, Bangladesh, using entropy method, spatial autocorrelation index, and geostatistics	2017	32	21.17
6	Y. Zhang, C. Chu, T. Li, S. Xu, L. Liu, M. Ju	A water quality management strategy for regionally protected water through health risk assessment and spatial distribution of heavy metal pollution in 3 marine reserves	2017	20	20.33
7	T.K. Boateng, F. Opoku, S.O. Acquaah, O. Akoto	Groundwater quality assessment using statistical approach and water quality index in Ejisu-Juaben Municipality, Ghana	2016	32	18.14
8	S. Shrestha, D.J. Semkuyu, V.P. Pandey	Assessment of groundwater vulnerability and risk to pollution in Kathmandu Valley, Nepal	2016	40	17.29
9	S. Huang, J. Chang, G. Leng, Q. Huang	Integrated index for drought assessment based on variable fuzzy set theory: A case study in the Yellow River basin, China	2015	28	14.13
10	F.A.L. Pacheco, L.M.G.R. Pires,	Factor weighting in DRASTIC modelling	2015	26	12.88

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Figure 7 illustrates the network visualisation map depicting citations based on countries, with a minimum requirement of one document per author and a minimum of five citations for each author. Additionally, Figure 8 visually represents citations based on documents, considering a minimum of five citations for each document.

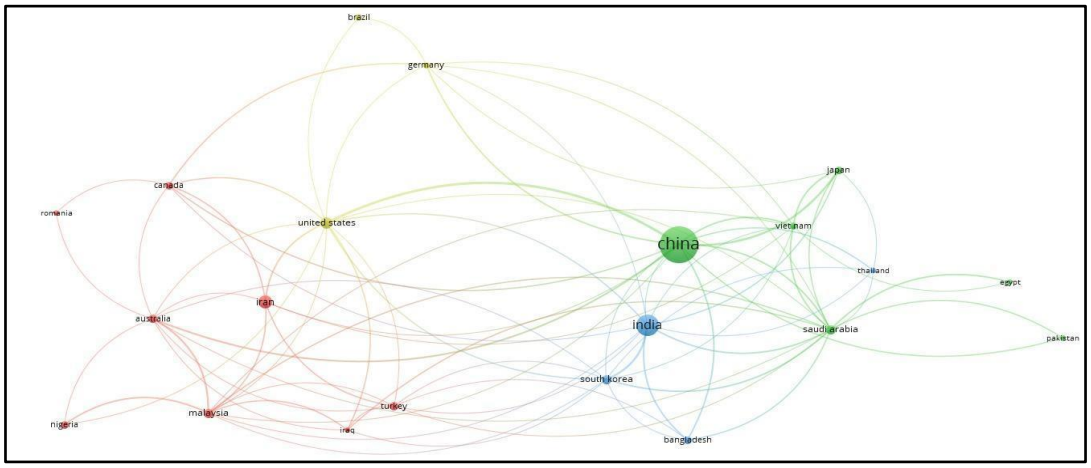

Figure 7: Network Visualisation Map Of The Citation By Countries. (Minimum Number Of Documents Of An Author = 1), (Minimum Number Of Citations Of An Author = 5)

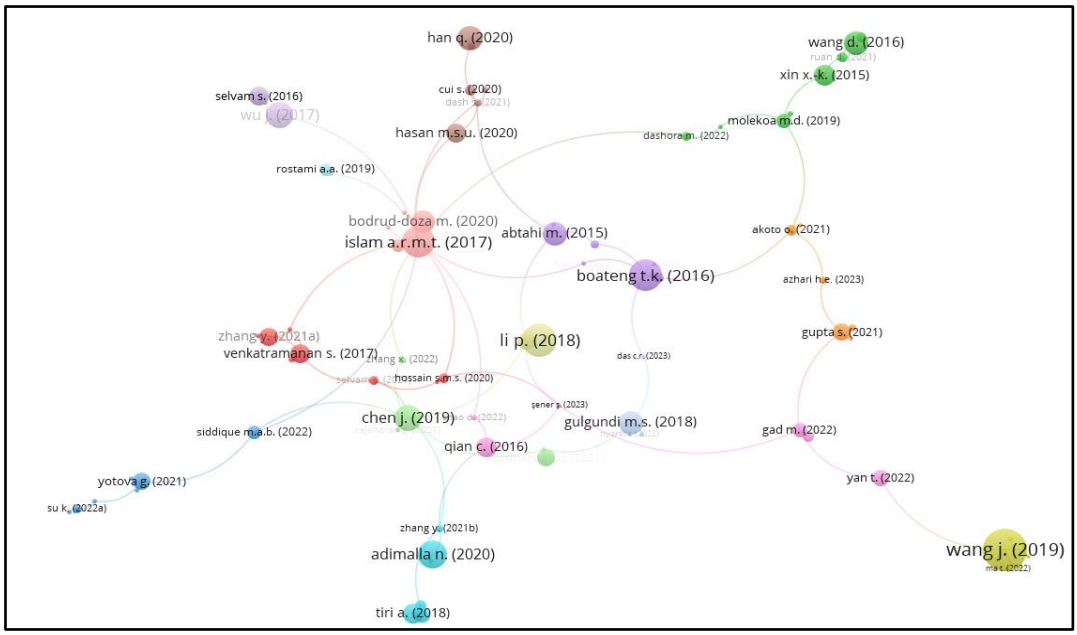

Figure 8: Network Visualisation Map Of The Citation By Documents. Minimum Number Of Citations Of A Document = 5

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Findings From Malaysia's Article

Based on Table 8 above, there are 13 publications from Malaysia. However, there are 6 publications by Malaysian authors related to the focus of this paper. Five universities from Malaysia managed to publish their research based on water quality assessment in the Scopus database. Table 14 summarises the analysis findings from articles in Malaysia.

Table 14. List of Publication from Malaysia

No	Title	Authors	Year	Source	University
1	Assessment of health risks and individuals' willingness to participate in drinking water management at flood-prone Pahang River Basin, Malaysia	Alam, L., Rahman, L.F., Ahmed, M.F., Masud, M.M., Mokhtar, M.B.	2021	Environmental Geochemistry and Health	Universiti Kebangsaan Malaysia, Universiti Malaya
2	Efficient river water quality index prediction considering minimal number of inputs variables	Othman, F., Alaaeldin, M.E., Seyam, M., Sefelnasr, A., El-Shafie, A.	2020	Engineering Applications of Computational Fluid Mechanics	Universiti Malaya, Universiti Tenaga Nasional
3	Sedimentation and water quality deterioration problems at Terengganu Riverbasin, Terengganu, Malaysia	Wahab, N.A., Amri Kamarudin, M.K., Toriman, M.E., Hanafiah, M.M., Harith, H.	2019	Desalination and Water Treatment	Universiti Sultan Zainal Abidin, Universiti Malaya, Universiti Kebangsaan Malaysia
4	Application of vulnerability modeling techniques in groundwater resources management: a comparative study	Mogaji, K.A.	2018	Applied Water Science	Universiti Sains Malaysia
5	Uncertainty assessment of the multilayer perceptron (MLP) neural network model with implementation of the novel hybrid MLP-FFA method for prediction of biochemical oxygen demand and dissolved oxygen: a case study of Langat River	Raheli, B., Aalami, M.T., El-Shafie, A., Ghorbani, M.A., Deo, R.C.	2017	Environmental Earth Sciences	Universiti Malaya

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6	Prediction of water quality index in free surface constructed wetlands	Mohammadpour, R., Shaharuddin, S., Zakaria, N.A., Vakili, M., Chan, N.W.	2016	Environmental Earth Sciences	Universiti Sains Malaysia

Conclusions

Water quality factor assessment indeed has attracted academic researchers, policymakers, and agency authorities. From this bibliometric review, the findings would help researchers gain a comprehensive overview of the water quality assessment using a fuzzy method. Based on the Scopus database from 2015 to 2023, using the keywords "water quality factors" and "fuzzy", the trend of publications regarding this topic is increasing every year. The number of publications in 2023 as of September 2023 is 71, and the highest number of cited publications is 78 in 2022. This study also reveals that the subject area mostly covered in water quality assessment research is environmental science, which is 44.27%. This finding also indicated that the overall research in different methods of water quality factor assessment is currently concentrated mainly in for example, entropy method, spatial autocorrelation index, geo-statistics, machine learning techniques by probabilistic-fuzzy, neural network, and analytic hierarchy process (AHP). It is also clear that this water evaluation and fuzzy approach is gaining more and more popularity. For further study, the authors will focus on the water quality assessment using a combination of interval type 2-fuzzy hesitant methods conducted in Malaysia.

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