

Review

A Bibliometric Analysis of Water Pollution with Nutrients and Water Quality

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Abstract

Water quality is crucial for both human well-being and the environment, and nutrient pollution poses a significant threat, leading to the degradation of water resources. To advance our understanding of water quality formation and pollution dynamics, a bibliometric analysis was conducted on articles related to water pollution with nutrients published in the Scopus database between 1979 and 2022. A total of 324 articles were reviewed, with the majority being research papers (81.5%). This study provides insights into the growing concern over nutrient pollution, highlighting key trends in publication volumes, influential authors, institutions, and the geographical distribution of research. Notably, the analysis reveals a shift toward increasing global research activity in the field, with a focus on the impacts of nutrient pollution on regional and global water quality. The findings emphasize the importance of addressing water quality challenges with tailored solutions that account for regional variations in nutrient pollution sources and impacts. Future research should prioritize investigating the migration and transformation of nitrogen and phosphorus in water bodies, which are central to nutrient pollution. This will contribute to more effective, region-specific strategies for managing water quality and mitigating the impacts of nutrient pollution.

Keywords: bibliometric, research hotspots, worldwide, water quality, nitrogen

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Introduction

Water is one of the most crucial resources for domestic, agricultural, industrial, and environmental purposes [1-3]. Water quality has a direct impact on aquatic ecosystems, including rivers, lakes, and oceans. Pollutants like excess nutrients, heavy metals, and pharmaceuticals can disrupt aquatic ecosystems, harming aquatic life, plants, and microorganisms [4-6]. Due to its central role in food security and socioeconomic welfare, water quality is an increasingly global concern, as both environmental conditions and human well-being depend on it [7-9]. Poor water quality and severe water pollution lead to health risks, decrease social well-being, and contribute to economic crises [8, 10, 11]. In addition, water quality plays a significant role in maintaining the ecosystem functions [12-14]. The quality of water resources is continuously changing, largely a result of human-induced sources of change, such as eutrophication, secondary salinization, sedimentation, microbial pollution, and toxic point sources [15-17]. Some studies have proven that salts, heavy metals, organic chemicals, nutrients, microbes, fertilizers, pesticides, fecal matter, pharmaceuticals, drugs, plastics, radioactive waste, and industrial oil sludge are the main contaminants of water resources [18-22]. These pollutants significantly deteriorate the water quality around the world. Physical, chemical, and biological attributes are used to measure water quality [7, 23]. Addressing water quality pollution is intricately linked to several Sustainable Development Goals (SDGs) established by the United Nations to create a more equitable, sustainable, and prosperous world. Water quality plays a vital role in achieving SDG 3: Good Health and Well-being, SDG 6: Clean Water and Sanitation, SDG 12: Responsible Consumption and Production, and SDG 14: Life Below Water. To emphasize the importance of addressing water quality pollution, it is essential to highlight its role in hindering progress toward multiple SDGs [24, 25]. By taking concerted action to improve water quality, significant strides can be made in achieving sustainable development, improving human well-being, protecting ecosystems, and fostering global cooperation [26-28].

Nitrogen in the form of nitrate ions and ammonium ions assimilated by organisms enters lakes mainly from their watersheds and from the atmosphere, and partially through the activity of some blue-green algae capable of utilizing elemental nitrogen from the atmosphere [29, 30]. Soluble phosphorus compounds, assimilated by organisms, enter lakes through the waters of their tributaries and with atmospheric precipitation [31]. Finally, soluble forms of silicon come from watersheds as a result of rock weathering [32, 33]. In addition, these nutrients enter lake waters through the decomposition of dead organisms in lake sediments [34, 35]. Concentrations of nutrients in water and their ratios determine the trophic status of lakes and water quality [36, 37]. Many lakes have become eutrophic, excessively

rich in living matter, within very short periods of time due to the accumulation of excessive nutrients caused by human activities (for example, as a result of fertilizer washing away) [38, 39]. Mass blooms of blue-green algae occur on the surface of eutrophic lakes, emitting an unpleasant odor and sometimes releasing toxins into the water [40-41]. The increased algae growth can also reduce water transparency, leading to low visibility in the water [42]. The dead biomass settles to the bottom. To decompose it, the microorganisms use oxygen, taking it from the water. When the concentration of dissolved oxygen drops significantly, benthic organisms die; for example, mass death of fish occurs [43, 44]. The decrease in oxygen levels can also lead to the production of hydrogen sulfide (H_2S) near the bottom, further exacerbating the degradation of the ecosystem. Additionally, the loss of submerged vegetation, which is vital for maintaining water clarity and oxygen levels, is often observed in eutrophic lakes [45]. Among nutrients, phosphorus plays a special role in the eutrophication of lakes [46].

The bibliometric analysis has so far proven to be an appropriate tool for addressing global academic research production. The analysis combines both statistical and mathematical methods to map the state of research fields over time [47]. There has been widespread use of the approach in the various fields and disciplines such as assessment of landslide susceptibility [48], soil erosion modeling [49], water resource management [50], water systems – adaptation to climate change [51], water science and technology [52], groundwater vulnerability assessment [53], arsenic in drinking water [54], water ecosystem services [55], assessment of water distribution networks [56], estuary pollution [57], plastic pollution in water ecosystems [58], artificial intelligence in renewable energy [59] and plant-microbial fuel cells [60].

The purpose of this study is to figure out and analyze recent and historical bibliometric data worldwide in terms of water quality and nutrient pollution. To highlight top authors, countries, publishers, and funding sponsors using bibliometric statistics. This research will provide a guideline and a reference in the study of water quality and pollution with nutrients.

Material and Methods

The bibliometric method was used to analyze the global literature regarding water quality and water pollution with nutrients from the Scopus database. In order to analyze all journals, the specific search keywords such as “water quality” AND “water pollution” AND “nutrients” were used. The research period was chosen from the earliest date, 1979, to September 16, 2022. Searching results involved 324 papers in English. The articles selected for analysis included studies on both inland waters (rivers, lakes, and river-lake systems) as well as marine waters.

While the primary focus was on inland water systems, several articles also addressed marine environments, providing a broader understanding of nutrient-related pollution across different aquatic ecosystems. Research articles that discussed nutrients in the atmospheric context, such as those involving carbon (CO₂), hydrogen (H₂O), and oxygen for plant photosynthesis, were excluded from the list to maintain the focus on nutrients in water. In addition to reviewing pollution data from the selected studies, we also identified recommendations for reducing or eliminating pollution in the aquatic systems examined. These included strategies such as improved agricultural practices, wastewater treatment innovations, and the restoration of aquatic habitats. A database was reviewed and divided into categories, such as a list of journals, number of papers, list of top authors, map of top countries, publication type, list of top publishers, number of citations per journal, list of top funding sponsors, and percentage of publications

by subject areas. The flowchart of the methodology is shown in Fig. 1.

Results

Trend of Publications on Water Quality and Pollution with Nutrients

The number of yearly published papers related to water quality and water pollution with nutrients was divided into two time periods. In the first period, between 1979 and 2006, the number of papers fluctuated from 1 to 6 papers per year. In the second period, between 2007 and 2022, the number of papers per annum started to increase. The largest number of published papers was in 2020, with 31 papers, which was 10 times more than the average number of papers published between 1979-2006 (Fig. 2). The interest in water quality and

Research base	Scopus database
Selected years	1979-2022
Language	English
Subject area	Environmental, Earth and Planetary, Agricultural and Biological Sciences
Key words	water quality, water pollution, nutrients
Statistical analysis	Origin Pro, MS Excel Publication types, years, authors, countries, sources, subject areas, funding sponsors and affiliations of published papers
	VOSviewer Co-authorship and co-occurrence

Fig. 1. Flowchart of the methodology.

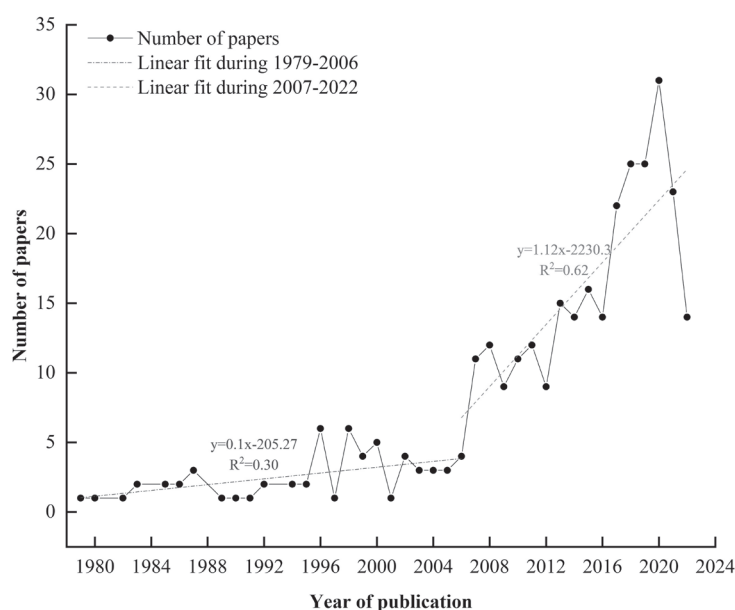


Fig. 2. Number of papers on water quality and pollution with nutrients (1979-2022).

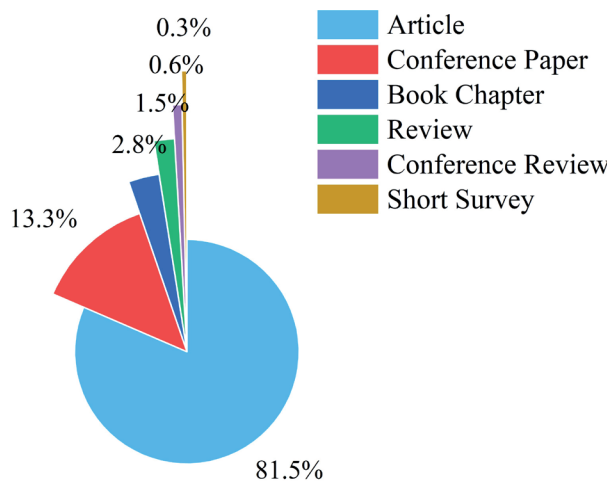


Fig. 3. Publication type on water quality and pollution with nutrients.

pollution with nutrients started to considerably rise in the second period and the number of published papers consist 86,7% from the total number. Thus, research shows a significant concern in the subject of water quality and pollution with nutrients. Further analysis showed that 264 (81.5%) out of 324 published documents were research articles, followed by 43 (13%) conference papers, 9 (3%) book chapters, 5 (1%) reviews, and 2 (1%) conference reviews. This information suggests that researchers preferred to publish in journals rather than in conferences (Fig. 3). Moreover, 55% focused on rivers, 30% on lakes, and 10% on river-lake systems. Marine waters were discussed less frequently in the

context of nutrient pollution, accounting for only 5% of the selected studies.

Journals

Scholars use a variety of journals throughout the world for publishing their research. In this paper, 134 journals from 68 countries were involved. Mostly papers related to the water quality and pollution with nutrients were published in journals Science of the Total Environment (20) and Marine Pollution Bulletin (16). Table 1 shows journal titles with 3 or more published papers in this research field. The publishing country and impact factors (IF) of the top 10 journals were analyzed. Three of these journals were published in the United Kingdom, two each in the United States, the Netherlands, Germany, and one journal from Poland. The average IF of the top 10 journals was 5.73. Among the top 10 journals, the Science of the Total Environment had the highest IF (Table 2).

Authors and Their Affiliated Country

It was found that 159 authors from 68 countries published papers related to water quality and water pollution with nutrients between 1979 and 2022. The top 10 authors were noted with 2 or more published papers related to current research (Fig. 4). Among them, Litvinaitis (Lithuania) and Doumenq (France) dominated with 4 research papers, followed by Syakti (Indonesia), Pietruszynski (Poland), Paton-Walsh (Australia), Cieslinski (Poland), Bonislawska (Poland), and Asia (France) with 3 papers, Cesoniene (Lithuania)

Table 1. List of journals on water quality and pollution with nutrients.

Scopus Source title	Number of articles	Scopus Source title	Number of articles
Science of the Total Environment	20	Water, Air, and Soil Pollution	4
Marine Pollution Bulletin	16	Water Research	4
Environmental Science and Technology	11	Water Switzerland	4
Environmental Pollution	9	Atmosphere	3
Water Resources	8	Bioresource Technology	3
Environmental Monitoring and Assessment	7	E3s Web of Conferences	3
Environmental Science and Pollution Research	7	Environmental Toxicology and Chemistry	3
Journal of Ecological Engineering	7	Hydrobiological Journal	3
Atmospheric Chemistry and Physics	6	Journal of Environmental Sciences China	3
International Multidisciplinary Scientific Geoconference Surveying Geology and Mining Ecology Management Sgem	5	Journal of Geophysical Research Atmospheres	3
Iop Conference Series Earth and Environmental Science	5	Polish Journal of Environmental Studies	3
Chemosphere	4	Rocznik Ochrona Srodowiska	3
International Journal of Environmental Research and Public Health	4	Water Science and Technology	3

Table 2. Distribution of research output in prolific journals.

Journal title	Total number of publications (%)	Publishing country	IF
Science of the Total Environment	6.17	Netherlands	9.8
Marine Pollution Bulletin	4.94	United Kingdom	5.8
Environmental Science and Technology	3.39	United States	9.5
Environmental Pollution	2.77	United Kingdom	8.9
Water Resources	2.47	United States	1
Environmental Monitoring and Assessment	2.16	Netherlands	3
Environmental Science and Pollution Research	2.16	Germany	5.8
Journal of Ecological Engineering	2.16	Poland	1.3
Atmospheric Chemistry and Physics	1.85	Germany	7.2
Total	28	Average	5.8

and Zubala (Poland) with 2 papers. The mentioned authors published research papers in our field during the second period, from 2001 to 2022.

In general, the quality of papers published by researchers at an institution determines its ranking. One hundred sixty different institutions, working independently or in collaboration, published 324 papers on water quality and water pollution with nutrients worldwide between 1979 and 2022. In order to identify the most productive institutions in terms of our field, the top 10 institutions have been analyzed. It should be noticed that the top 10 institutions included 4 institutions from China, 2 from Lithuania, and one each from Russia, Poland, the United States, and France. These institutions contributed around 24.7% of the total output. Among these, the leading position was taken by the Chinese Academy of Sciences, with 17 publications, followed by the Russian Academy of Sciences, with 12

publications, and Peking University, with 9 publications (Fig. 5).

An indicator of internationalization might be the number of countries that participate in research activities on a particular research field. Between 1979 and 2022, a total of more than 68 countries collaborated on water quality issues. Fig. 6 focuses on the top 10 countries involved in publishing at least 13 or more academic papers related to our research field. Despite institutions, the dominant country, with 67 publications, represented the United States, which contributed 20.7% of the total amount. China and Poland have been the second-place holder with 44 publications (13.6%), followed by Russia (32, 9.9%), France (19, 5.9%), Canada (16, 4.9%), Germany (14, 4.3%), Lithuania (14, 4.3%), Italy (13, 4%), United Kingdom (13, 4%). An overall 85% of the total number of publications came from these top 10 countries.

Top Funding Sponsors and Publishers

Among the funding sponsors, the most influential was the National Natural Science Foundation of China, with 31 funded papers. In total, 158 funding sponsors contributed to the research field of water quality and water pollution with nutrients. The top ten funding sponsors are shown in Fig. 7. If we look in detail, 4 funding sponsors were from China, then 2 from the U.S. and Japan, and 1 from Europe and Brazil (Fig. 7). It was found that the large number of papers were published by Elsevier (65), followed by Springer (19) and MDPI (12). Fig. 7 shows the top ten publishers in our research area.

Top-Cited Journals on Water Quality and Pollution with Nutrients

The number of citations is assumed to be an indicator of the paper's quality, reflecting its novelty and importance in the field. The top ten cited journals on

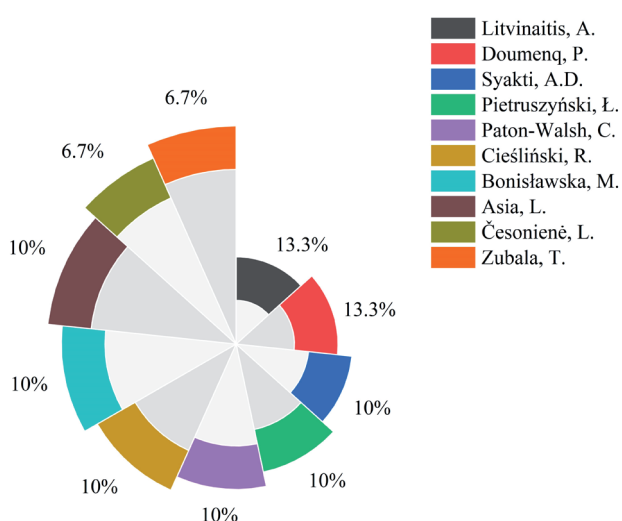


Fig. 4. List of top authors published on water quality and pollution with nutrients.

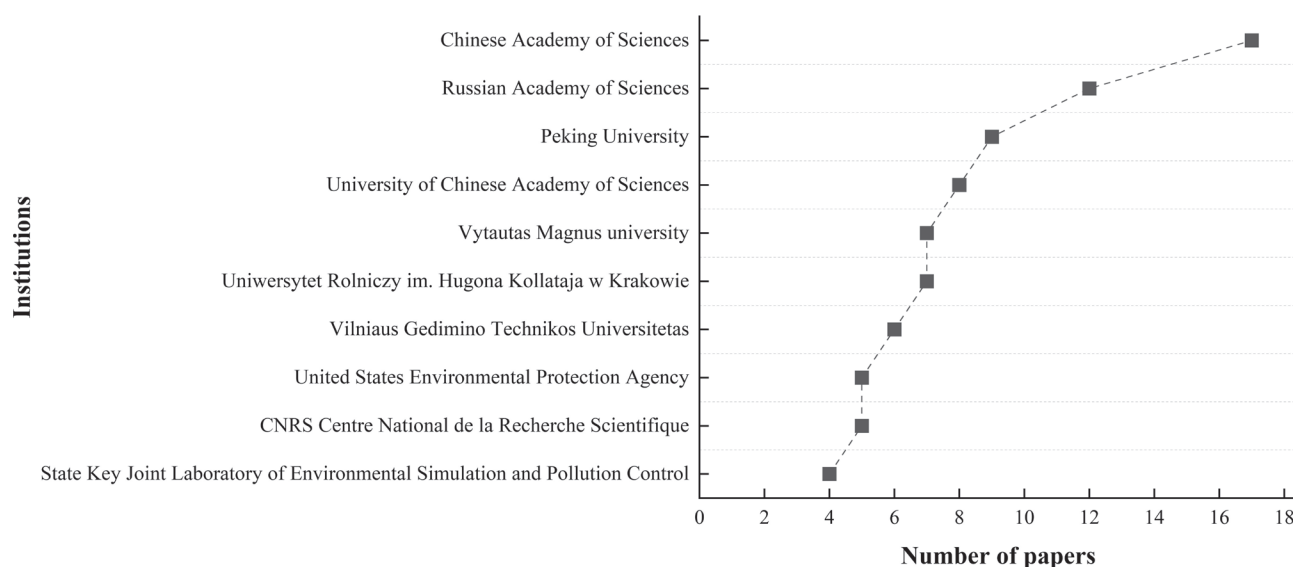


Fig. 5. List of top institutions on water quality and pollution with nutrients.

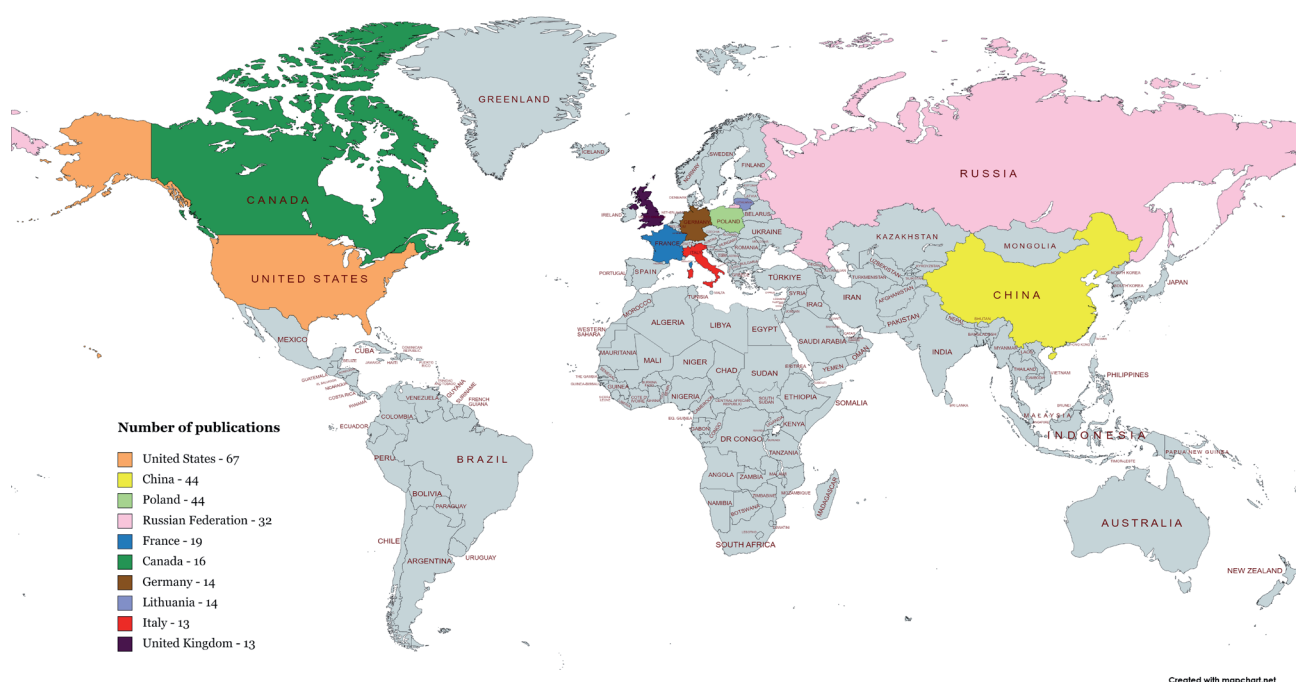


Fig. 6. Map of top countries publishing on water quality and pollution with nutrients.

water quality and pollution with nutrients are provided in Fig. 8. The most cited journal is *Oceanography and Marine Biology* with 780 citations, followed by *Environmental Science and Technology* – 565 citations, and *Nature* – 337 citations. Furthermore, there are other journals with more than 132 citations which have been considered as top cited journals as *Atmospheric Environment*, *Environmental Health Perspectives*, *Biotechnology Advances*, *Environmental Pollution*, *Science of the Total Environment*, *Bioresource Technology*, and *Water Research*.

Publications by the Subject Area on Water Quality and Water Pollution with Nutrients

The subject area with the highest privilege is *Environmental Science*, which accounts for 53%, followed by *Earth and Planetary Science* at 23%, *Agricultural and Biological Science* at 14%, and *Chemistry and Engineering* at 5% each (Fig. 9).

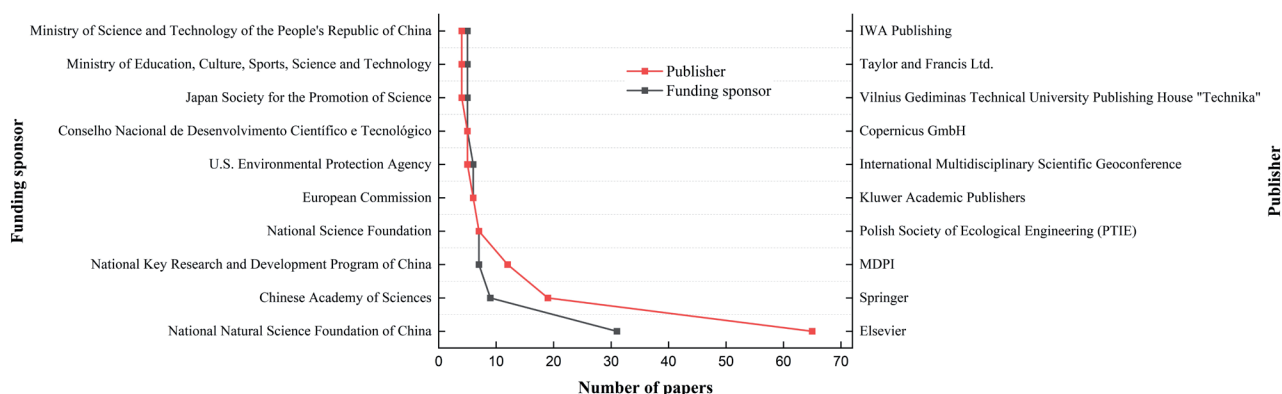


Fig. 7. List of top funding sponsors and publishers on water quality and pollution with nutrients.

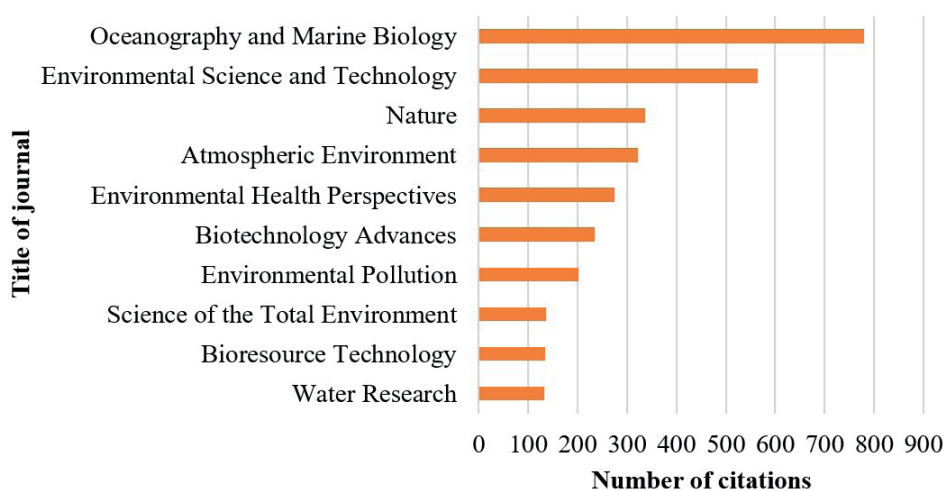


Fig. 8. Top cited journals on water quality and pollution with nutrients.

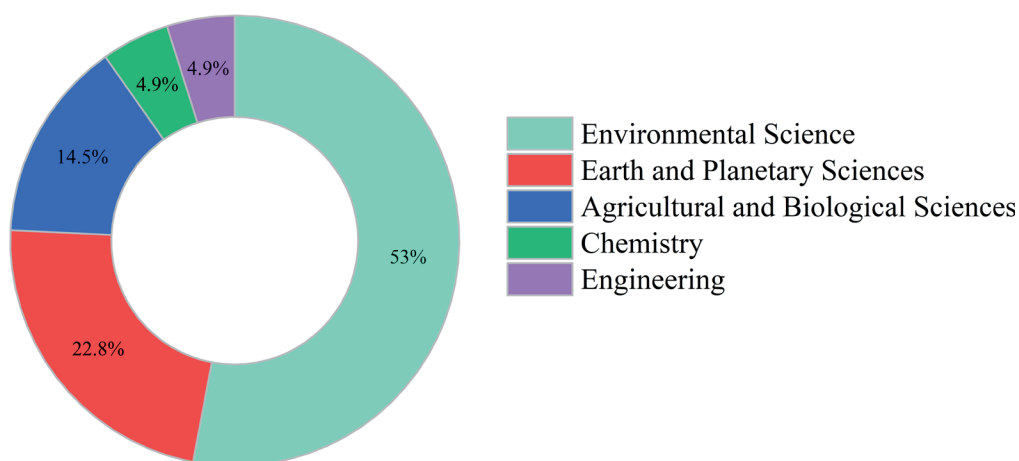


Fig. 9. Top subject areas on water quality and pollution with nutrients.

Top Co-Authorships and Co-Occurrences on Water Quality and Pollution with Nutrients

In order to analyze the top co-authorships and co-occurrences (keywords), VOSviewer was used. This

software can help visualize bibliometric data from the Scopus and Web of Science databases. Using VOSviewer, we design top co-authorships and co-occurrences on water quality and pollution with nutrients, shown in Figs. 10 and 11. During the co-authorship analysis,

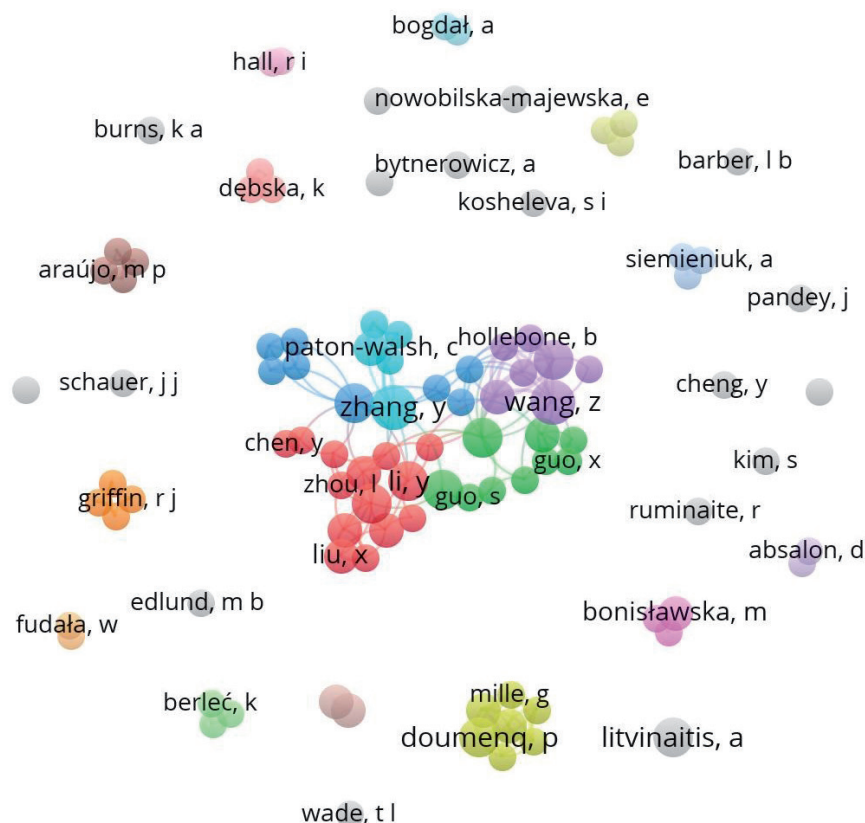


Fig. 10. Network map of co-authorship on water quality and pollution with nutrients.

it was found that if the minimum number of documents of an author is 4 – then 10 authors out of 1353 met the threshold; in case of 3 and 2 minimum number of documents – 22 and 100 met the threshold, respectively. In this research, we have chosen 100 authors who have a minimum of 2 publications in co-authorships. As a result, the software has generated 35 clusters, which included 100 items, 168 links, and indicated a total link strength of 245 (Fig. 10).

For analyzing the keywords, the minimum number of co-occurrences of a keyword was chosen as 5 in order to show the high relevance by excluding the low rate of occurrences. In total, there were 4262 keywords from which only 287 met the threshold. Appropriately, in co-occurrences, 3 clusters were created, which included 29 items. The most used keyword was identified as “water quality”. The size of the dots represents the repeatability and importance of the keyword (Fig. 11).

Discussion

The paper observes a distinct shift in the number of published papers related to water quality and pollution with nutrients over two time periods. In the earlier period (1979-2006), the number of papers was limited and variable. However, in the later period (2007-2022), there was a remarkable increase in the annual publication count. The peak in 2020 with 31 papers

marked a significant surge, suggesting growing interest and research activity in this field. The substantial rise in the number of papers during the second period, constituting 86.7% of the total publication count, indicates a shift in research focus toward the study of water quality and nutrient pollution. This surge suggests that researchers are recognizing the significance of this issue and its potential implications for aquatic ecosystems and human well-being.

Several of the studies reviewed also proposed strategies for mitigating aquatic pollution [61-63]. These included the implementation of best management practices in agriculture to reduce nutrient runoff, the use of artificial wetlands for water treatment, and the development of policies aimed at stricter control of industrial effluents. These recommendations reflect the increasing recognition of the urgent need to address water quality issues. However, the effectiveness of these strategies varied depending on the specific context, such as the type of water body (river, lake, etc.) and the level of pollution. The type of water body significantly influenced the approaches to pollution management. For instance, nutrient runoff from agriculture was a major concern in rivers and lakes, while marine waters required attention to issues like plastic pollution and oil spills. The mitigation strategies suggested for river-lake systems focused on improving watershed management, whereas those for marine environments emphasized international cooperation for pollution control,

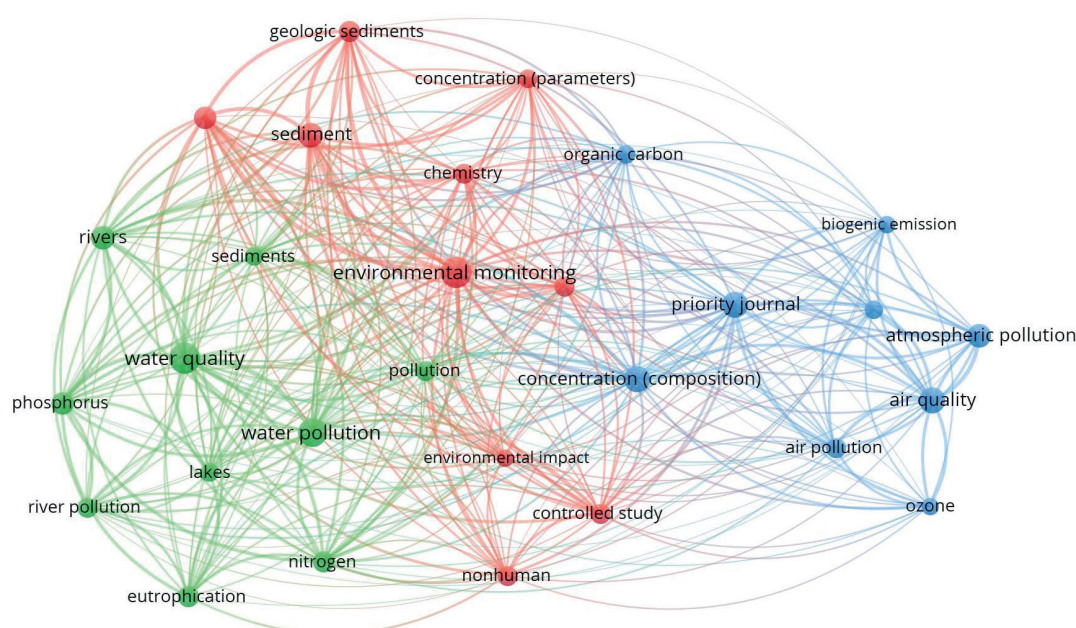


Fig. 11. Network map of co-occurrence on water quality and pollution with nutrients.

illustrating the broader scope of action needed to tackle nutrient pollution across different ecosystems.

The distribution of publication types reveals a preference for research articles over other formats, with 81.5% of the published documents being research articles. This highlights the preference of researchers to communicate their findings through journals, indicating the importance of academic discourse and peer-reviewed outlets in advancing the understanding of water quality and nutrient pollution.

Among journals, the highest contribution was made in the journal *Science of the Total Environment*, 6.17% of the total number of publications. As for the highest IF score, the journal *Science of the Total Environment* held the leading position with 9.8. In fact, it was found that *Oceanology and Marine Biology* was the most cited journal (780) compared to other journals. Regarding a particular subject, journals with more specific focuses tend to attract greater attention in terms of citations. This phenomenon can be attributed to the fact that when research is published in specialized journals, it becomes more accessible and relevant to researchers within that specific field. As a result, scholars who are actively engaged in studying the precise topic covered by the journal are more likely to come across and cite the published work. This highlights the significance of selecting targeted journals for publishing research, as it can substantially contribute to the visibility and impact of the findings within the relevant academic community.

The top institutions and authors contributing to this research indicate centers of expertise and research leadership in the field. The dominance of certain institutions and authors suggests their strong influence in shaping the discourse and development of water quality and pollution studies related to nutrients. Our research revealed that top institutions for publishing

articles were firstly Academies of Science, followed by universities, and then National Agencies. This can be explained as follows. Academies of sciences, known for their commitment to fundamental research and substantial funding capacity, are well-suited to lead in-depth explorations of water quality issues. Their significant resources enable extensive research initiatives, aligning with their mission to expand the frontiers of knowledge. Subsequently, universities assume a pivotal role by translating theoretical research into practical applications. Their ability to bridge the gap between fundamental insights and real-world solutions is well-matched to the application-oriented grants they often pursue, addressing immediate environmental concerns effectively. National agencies, integral to environmental governance, benefit from the research outputs of academies and universities. This synergy aligns scientific findings with regulatory frameworks, enhancing evidence-based policy implementation for robust environmental management.

The most active authors were identified as Andrius Litvinaitis (Lithuania) and Pierre Doumenq (France). Analysis has shown that countries identified as the top ten countries with the largest number of publications were mostly from developed countries. The prominence of certain funding sponsors and publishers demonstrates their support and investment in advancing research in this area. The role of funding agencies is crucial in facilitating research initiatives that address water quality issues. Likewise, the prevalence of specific publishers reflects the academic outlets that facilitate the dissemination of knowledge in this field.

In terms of institution, funding sponsor, and publisher, the first places were taken by the Chinese Academy of Science, National Natural Science Foundation of China, and Elsevier, respectively. It should

be noted that among the top ten funding sponsors, China has various sources of funding. In current research, it was revealed that papers published with the support of Chinese sponsors occurred in the second period (after 2006), as in this period the government started to give more attention to water quality. This observation implies that China has progressively directed heightened focus toward matters concerning water quality and its contamination attributed to nutrients. In total, 26.5% papers were published with the support of Chinese funding sponsors, which is a great contribution to the research. Within 26.5%, 3% of papers were published in the *Science of the Total Environment Journal*, which is a Q1 journal with a high impact factor of 9.8. This journal, in the list of the top ten journals, has the highest impact factor. Furthermore, the *Journal of Environmental Sciences (China)* has hosted the dissemination of 1.23% of these articles, underscoring China's engagement in scholarly dialogue within this particular journal. In the realm of citations, Chinese-sponsored papers garnered recognition in the form of citations, accounting for 11.6% of the cumulative tally. This substantial proportion underscores the significance and influence of these papers within the domain of water quality research.

The distribution of publications across subject areas provides insight into the multidisciplinary nature of research on water quality and nutrient pollution. The prominence of Environmental Science, Earth and Planetary Science, and others signifies the interdisciplinary approach required to comprehensively address these issues.

The co-authorships were mostly distributed among Chinese researchers as Zhang Y., Wang Z., Wu Y., and others. Additionally, the co-occurrence analysis of keywords offers insights into the interconnected concepts and themes driving research in this field. In co-occurrence, the keywords “environmental monitoring”, “water quality”, and “water pollution” were the most popular keywords. Based on the findings of this study, the term “environmental monitoring” signifies that monitoring holds a central role in connecting various research areas, including but not limited to eutrophication, geological sediments, air pollution, and related topics.

Conclusions

These findings collectively suggest a growing awareness of the importance of water quality and pollution with nutrients. The increasing number of publications, collaboration among countries, and interdisciplinary engagement indicate a proactive approach to addressing these challenges. Furthermore, the emergence of influential institutions, funding sponsors, and high-impact journals signals the potential for continued growth and impact in the field. The evolving research landscape underscores the urgency

of understanding and mitigating the impact of nutrient pollution on aquatic ecosystems and human societies.

Future studies focusing on water quality and water pollution caused by nutrients should encompass the migration and transformation of nitrogen and phosphorus compounds. The comprehensive perspective offered by this research can guide further analyses and research planning. It is crucial to recognize that efforts to combat nutrient pollution and its future trajectory are shaped by policies, regulations, technological advancements, and public awareness. Sustainable agricultural practices, enhanced wastewater treatment, nutrient management strategies, and climate adaptation measures are pivotal factors that will influence the evolution of water quality pollution with nutrients.

Moreover, in the realm of water quality research, a deeper exploration of the complex interplay between human activities, regulatory frameworks, and environmental dynamics is essential to refine management strategies. Facilitating international collaboration and knowledge exchange across regions is paramount to sustaining water quality improvements. Comparative studies that scrutinize successful approaches and extract lessons from diverse countries hold the potential to inform the formulation and execution of effective water management policies. Overall, future research endeavors should seek to contribute to the development of holistic and adaptable approaches that address the multifaceted challenges posed by water quality issues in an ever-changing world.

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Conflict of Interest

The authors declare no conflict of interest.

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