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# RIVER WATER QUALITY AND TRACE CONTAMINANTS IN GLOBAL RESEARCH WITH SCIENTOMETRIC ANALYSIS

**Sevtap TIRINK[1], Kshitiz KANDEL*[2,3], Sema ARIMAN[4]**

*[1]Iğdır University, Health Services Vocational School, Department of Medical Services and Techniques, Environmental Health Program, 76000, Iğdır, Türkiye*
*[2]University of Chinese Academy of Sciences, 100049, Beijing, China*
*[3]Research Insight-Nepal (RI), Bharatpur, 44200, Chitwan, Nepal*
*[4]Samsun University, Department of Climate Science and Meteorological Engineering, Faculty of Aeronautics and Astronautics, 55420, Samsun, Türkiye*

**Abstract:** Rivers play a vital role in sustaining ecological systems, human societies, and regional economies, yet their water quality is increasingly threatened by trace contaminants and intensifying anthropogenic pressures. Despite the rapid growth of scientific output in this domain, global knowledge remains fragmented across regions, pollutants, and methodological approaches. This study provides a comprehensive scientometric assessment of research on river water quality and trace contaminants using 2,428 publications retrieved from the Web of Science Core Collection (1976–2025). A structured search strategy and exclusion criteria were applied to isolate records focusing specifically on trace elements, heavy metals, micropollutants, and related hydrochemical processes in riverine environments. Scientometric analyses—conducted using the bibliometrix package and Biblioshiny—include performance metrics, collaboration mapping, co-citation structures, bibliographic coupling, and co-word networks. The results reveal an accelerating annual growth rate (11.36%), dominated by contributions from China, India, and the USA, alongside a rising but uneven pattern of international collaboration. Keyword co-occurrence and clustering analyses identify three major thematic domains: (i) heavy-metal contamination and pollution assessment; (ii) basin-wide hydrochemical processes and source apportionment; and (iii) toxicological evaluations of individual trace metals. Emerging research fronts highlight increasing integration of advanced statistical techniques, GIS-based modelling, and ecological risk frameworks. Overall, this study elucidates the intellectual structure, knowledge gaps, and evolving research directions within global river contamination studies. The findings provide an evidence-based foundation for strengthening monitoring strategies, guiding policy development, and advancing interdisciplinary approaches essential for sustainable river basin management.

**Keywords:** River water quality, Hydrochemistry, Trace contaminants, Heavy metals, Scientometric analysis

***Corresponding author:** University of Chinese Academy of Sciences, 100049, Beijing, China
**E mail:** kshitizkandel310@gmail.com (K. KANDEL)
Sevtap TIRINK https://orcid.org/0000-0003-0123-0054
Kshitiz KANDEL https://orcid.org/0000-0001-7461-613X
Sema ARIMAN https://orcid.org/0000-0001-7201-9243

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## 1. Introduction

Water resources form the foundation of ecological integrity, social well-being, and economic sustainability (Pant et al., 2025). Among these resources, surface waters—particularly rivers—play a pivotal role in regional water management by providing drinking-water supplies, hydropower generation, irrigation for agriculture, industrial water demands, ecological habitat maintenance, and essential urban services (Kannel et al., 2007; Jiang et al., 2012; Al-Badaii et al., 2013; Tırınk et al., 2025). However, accelerating global water demand, coupled with the intensifying impacts of climate change, has placed unprecedented pressure on river water quality (Pant et al., 2025). The chemical composition of river systems is shaped by an interplay of natural factors—such as geology, flow regime, and hydrodynamics—and a wide range of anthropogenic inputs, including industrial and domestic effluents, agricultural nutrient enrichment, pesticide application, mining activities, and rapid urban expansion (Hamid et al., 2019; Akhtar et al., 2021; Tırınk and Özkoç, 2021; Anh et al., 2023; Böke Özkoç et al., 2025).

In recent years, increasing attention has focused on emerging micropollutants—including pharmaceuticals, heavy metals, and microplastics—which may exert toxic effects even at trace concentrations and are often insufficiently removed by conventional treatment processes (Morin-Crini et al., 2022; Wilkinson et al., 2017; Folorunsho et al., 2025; De Heredia et al., 2024; Arıman et al., 2026). Seasonal hydrological fluctuations further modulate the distribution, persistence, and transport of these contaminants in riverine environments (Anh et al., 2023; De Heredia et al., 2024; Pant et al., 2023). In addition to seasonal hydrological fluctuations, several other factors influence the behavior and environmental impact of trace contaminants in river systems, including changes in flow regime, sediment–water interactions, physico-chemical parameters (e.g., temperature, pH, dissolved oxygen), land-use pressures, industrial and agricultural discharges, and extreme climatic events (Tırınk et al., 2025; Arıman et al., 2026). Evidence from multiple continents demonstrates that rivers are highly sensitive to both anthropogenic disturbances and climate-driven alterations, which jointly influence their chemical, hydrological, and ecological functioning (Shrivastava et al., 2025; Whitehead et al., 2009; Liu et al., 2024; Abushandi, 2025; Pant et al., 2025).

Despite their critical importance, significant knowledge gaps persist—particularly in low- and middle-income regions—where monitoring infrastructures remain insufficient and data on both traditional and emerging contaminants are fragmented or unavailable (Morin-Crini et al., 2022; De Heredia et al., 2024; Kandel et al., 2024). Existing studies are predominantly basin- or site-specific, resulting in limited global syntheses and a scarcity of long-term, multi-parameter datasets that would allow robust comparative assessments (Morin-Crini et al., 2022; Wilkinson et al., 2017; Sun and Song, 2025). Furthermore, the disconnect between scientific evidence and policy implementation continues to hinder the development of effective river basin management frameworks (Akhtar et al., 2021; Ren et al., 2025). Such constraints underscore the need for more comprehensive, longitudinal, and integrative research efforts, as well as standardized monitoring protocols that can support evidence-based water governance at global and regional scales (Kandel et al., 2024; Tırınk et al., 2025).

Although research output on water quality has expanded rapidly, scholarly contributions remain unevenly distributed across geographical regions, contaminant categories, and methodological approaches. This fragmentation complicates cross-regional comparisons, obscures global patterns, and limits the development of universally applicable management strategies (Kandel et al., 2024). Moreover, despite the proliferation of studies, systematic evaluations capable of mapping the intellectual structure of the field—its conceptual evolution, leading contributors, and emerging research fronts—are still insufficient.

Scientometric analysis has therefore emerged as a powerful tool to address these shortcomings. By quantitatively examining publication trends, citation structures, collaborative authorship networks, and thematic clusters, scientometric methods reveal the cognitive architecture of a research domain and elucidate its developmental trajectories (Pritchard, 1969; Donthu et al., 2021). Such analyses also illuminate methodological shifts, including the increasing integration of advanced statistical techniques, GIS-based modeling, and machine-learning approaches into river water quality assessment. Synthesizing dispersed studies through scientometric techniques enables researchers to identify evolution patterns in scientific inquiry, determine which contaminants and processes dominate academic attention, and pinpoint persisting knowledge gaps that require targeted investigation.

In this context, the present study conducts a comprehensive scientometric assessment of global research on river water quality and trace contaminants using the Web of Science (WoS) Core Collection. Specifically, the study aims to: (i) map dominant, emerging, and declining thematic structures within the literature; (ii) identify spatial and conceptual knowledge gaps requiring further research; and (iii) examine global scientific collaboration by analyzing co-authorship, institutional linkages, and country-level research networks. By integrating these components, this work provides an evidence-based overview of the field's intellectual evolution and supports the development of more effective monitoring frameworks and sustainable management strategies for river systems worldwide.

## 2. Material and Methods

### 2.1. Data Source and Search Strategy

The scientific dataset used in this study was obtained from the Web of Science (WoS) Core Collection, one of the most widely recognized and rigorously curated multidisciplinary citation databases. WoS is commonly used in scientometric studies due to its transparent indexing criteria, comprehensive metadata, and robust citation structure (Donthu et al., 2021). WoS was selected because it provides robust citation information and comprehensive metadata on publications across water sciences, environmental engineering, hydrology, and geochemistry.

All records were retrieved from WoS Core Collection on [30.11.2025], ensuring dataset reproducibility. The search included all WoS indices accessible through the Core Collection interface. Only research articles and review articles indexed in WoS Core Collection were included. Document types such as conference proceedings, book chapters, editorial materials, and meeting abstracts were excluded. Additionally, Early Access publications and records assigned to the publication year 2026 were filtered out to maintain consistency in the temporal distribution of the dataset. No language restrictions were applied initially; however, only English-language publications were retained for analysis to ensure standardized keyword interpretation.

To identify global research related to trace contaminants and river water quality, a Topic Search (TS) query was constructed using Boolean operators. The TS field retrieves terms appearing in the title, abstract, author keywords, and Keywords Plus. The final search query was:

TS=("water quality" OR "hydrochemistry" OR "hydrogeochemistry" OR "pollution assessment")
AND

TS=("trace elements" OR "trace metals" OR "heavy metals" OR "emerging contaminants"
OR "micropollutants" OR "metal contamination" OR "metal pollution")
AND
TS=("river" OR "rivers" OR "stream" OR "streams" OR "river water" OR "lotic system" OR "fluvial system")
NOT
TS=("wastewater" OR "groundwater" OR "lake" OR "reservoir" OR "sewage" OR "estuary" OR "coastal")

**2.2. Scientometric Analysis**

In this study, a scientometric approach was employed to investigate how machine learning applications for live-weight estimation have evolved within the scientific landscape, with emphasis on publication dynamics, collaboration structures, and methodological trends. Scientometric analysis provides a systematic framework for evaluating the quantitative characteristics of scientific output in a specific domain, including publication volume, scientific impact, thematic structures, and patterns of scholarly cooperation (Pritchard, 1969; Donthu et al., 2021). By quantitatively examining the existing literature, it becomes possible to track the development of the field, assess research performance, identify dominant themes, and detect emerging directions for future inquiry.

Scientometric analysis and network visualization were conducted using the *bibliometrix* package in R (version 2025.09.2) and the Biblioshiny interface, which provides a web-based implementation of the *bibliometrix* framework (Aria and Cuccurullo, 2017; R Core Team, 2022).

The methodological workflow followed established scientometric mapping principles and consisted of:

**2.2.1. Performance analysis**

Performance analysis, including publication trends, productive countries, influential journals, and citation patterns.

**2.2.1. Science mapping**

Science mapping, incorporating**:**

-co-authorship networks (collaboration structures),
-co-citation analysis (intellectual foundations),
-bibliographic coupling (current thematic convergence),
-co-word analysis (emerging research frontiers via term co-occurrence).

Cluster detection relied on association normalization and Louvain modularity optimization, a robust and widely recommended algorithm for identifying thematic communities in scientometric networks (Donthu et al., 2021). Network nodes and edge weights were interpreted using centrality measures to highlight leading contributors, evolving research topics, and scientifically influential countries.

## 3. Results

Figure 1 provides an overview of the fundamental scientometric characteristics of the dataset obtained from the Web of Science Core Collection. This summary offers a concise snapshot of the scope, productivity, and collaborative nature of global research on trace contaminants and river water quality. The figure serves as the foundation for interpreting publication trends, authorship patterns, and thematic diversity within the field.


**Figure 1.** Main scientometric indicators of the dataset retrieved from the Web of Science Core Collection (1976–2025).

Figure 1 shows that the dataset includes 2,428 peer-reviewed documents published between 1976 and 2025, representing nearly five decades of scientific development. These publications are distributed across 633 scholarly sources, demonstrating the multidisciplinary nature of the field. The annual growth rate of 11.36% highlights a rapidly expanding research landscape, driven by growing global concern over riverine pollution and emerging contaminants.

A total of 9,862 authors contributed to the dataset, with an average of 4.95 co-authors per publication, indicating substantial collaboration. International co-authorship accounts for 23.52% of all outputs, reflecting the global importance of river water quality issues and the increasing internationalization of environmental research.

The dataset contains 5,715 author keywords, evidencing significant thematic heterogeneity. With an average document age of 8.77 years, the field can be considered relatively young yet influential, as shown by a mean citation rate of 27.73 citations per article. Collectively, these metrics reveal an active, fast-growing, and internationally collaborative research domain focused on understanding and mitigating trace contaminant dynamics in river systems.

Figure 2 illustrates the temporal evolution of scientific output related to river water quality and trace contaminants. Examining annual publication trends provides insight into how research interest, funding priorities, and global environmental concerns have shifted over time. The trend displayed in Figure 2 shows a pronounced and sustained increase in scientific production from 1976 to 2025. For nearly two decades after 1976, annual publication numbers remained relatively low, reflecting the early developmental stage of research in hydrochemistry and pollutant monitoring. Beginning in the mid-1990s, however, the number of publications started to rise steadily, coinciding with advancements in analytical chemistry, environmental regulation frameworks, and increasing attention to riverine pollution.

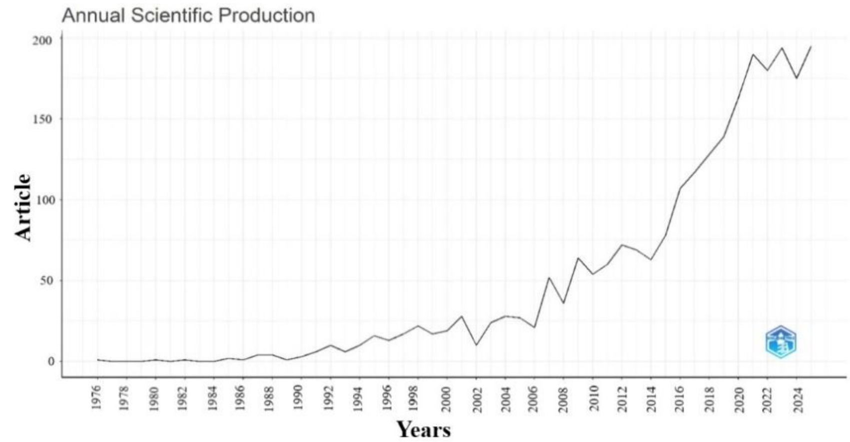


**Figure 2.** Annual scientific production (1976–2025) related to river water quality and trace contaminants.

A sharper upward trajectory becomes visible after 2005, followed by accelerated growth after 2015. This surge aligns with heightened global awareness of emerging contaminants, the proliferation of high-resolution monitoring technologies, and increased scientific emphasis on river systems as critical indicators of environmental change. The most substantial growth occurred between 2018 and 2024, when annual publication counts exceeded 150 articles per year, demonstrating intensified research activity across multiple disciplines including hydrology, environmental toxicology, and geochemistry.

Overall, the observed exponential growth pattern reflects a rapidly expanding research domain and underscores the growing urgency to address contamination risks, climate-driven hydrological changes, and water-resource sustainability challenges in river basins worldwide.

Figure 3 visualizes the relational structure among the most productive countries, leading authors, and frequently occurring author keywords in the field. This three-dimensional Sankey diagram provides an integrated view of how geographical research activity connects to influential contributors and thematic focuses. The diagram reveals that China, India, and the United States dominate publication output, forming the strongest nodes within the global research network. These countries exhibit extensive linkages to multiple authors and research themes, reflecting their large scientific communities and long-standing engagement with riverine pollution and trace element studies. Emerging contributors such as Türkiye, South Africa, Pakistan, Germany, and the United Kingdom also display noticeable connectivity, demonstrating increasing regional involvement in contamination assessment and hydrogeochemical research.

At the author level, individuals such as Clements W.H., Li J., Kumar V., Iwasaki Y., Tokatlı C., Neal C., Bąborowski M., and Ustaoğlu F. appear as prominent nodes with strong thematic linkages. Their research primarily spans toxicity assessment, sediment contamination, trace-element dynamics, and hydrochemical evaluation—topics that align with global environmental monitoring priorities.

On the thematic side, frequently occurring keywords such as “heavy-metals,” “contamination,” “sediments,” “river,” “pollution,” “water-quality,” “trace-elements,” and “surface-water” indicate that research in this domain is heavily oriented toward understanding contaminant sources, sediment–water interactions, and ecological risks in river systems. The structural alignment between authors and keywords suggests clear thematic clustering around pollution assessment, toxicity, accumulation processes, and basin-scale hydrochemical studies.

Overall, Figure 3 illustrates a well-defined global research structure in which geographically diverse contributors converge around shared scientific issues. The strong overlap between leading countries, influential authors, and dominant environmental keywords highlights the maturation and thematic coherence of research on trace contaminants in riverine environments.

Figure 4 visualizes the relative frequency and thematic distribution of author keywords using a treemap layout.

Treemaps are effective for summarizing dominant research concepts and illustrating how thematic importance is allocated across the field.

The treemap reveals that “river” (1,014 occurrences) and “water” (980 occurrences) are the most prevalent keywords, each accounting for approximately 10% of total keyword usage. Their dominance reflects the central focus of the scientific literature on fluvial systems and hydrological processes. Keywords such as “quality” (600.6%), “assessment” (551.6%), “heavy” (503.5%), and “metals” (420.4%) further demonstrate that water-quality evaluation and metal contamination represent the core thematic pillars of the field.

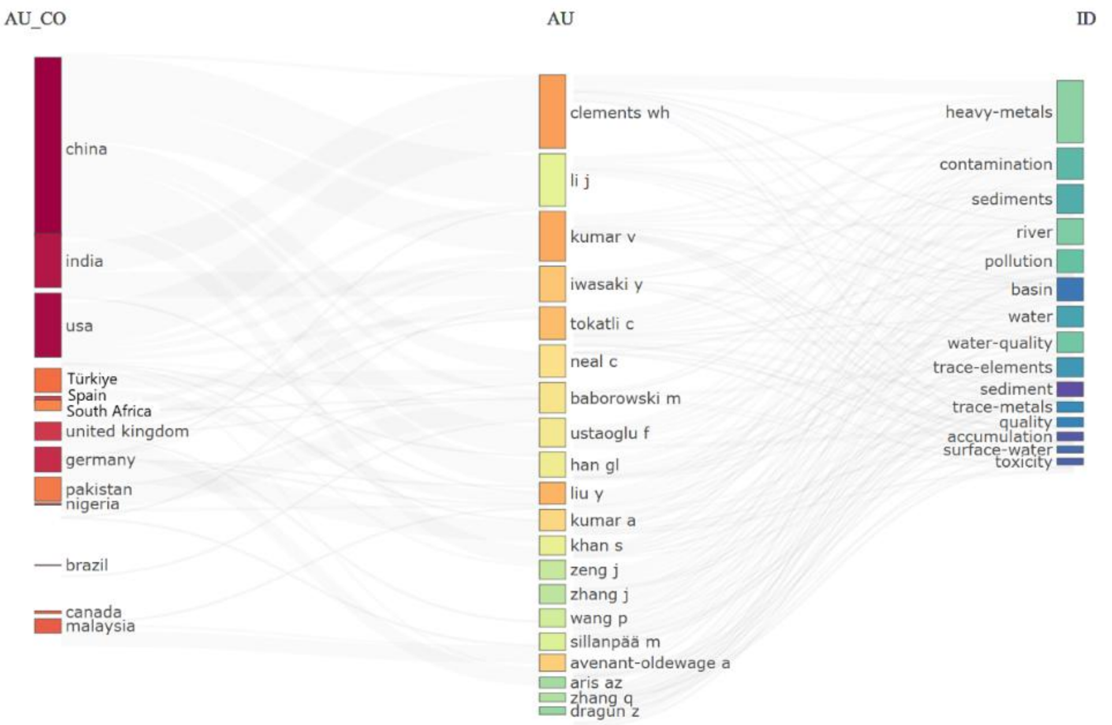


**Figure 3.** Sankey diagram showing the relationships among the most productive countries (AU_CO), leading authors (AU), and the most frequent author keywords (ID).

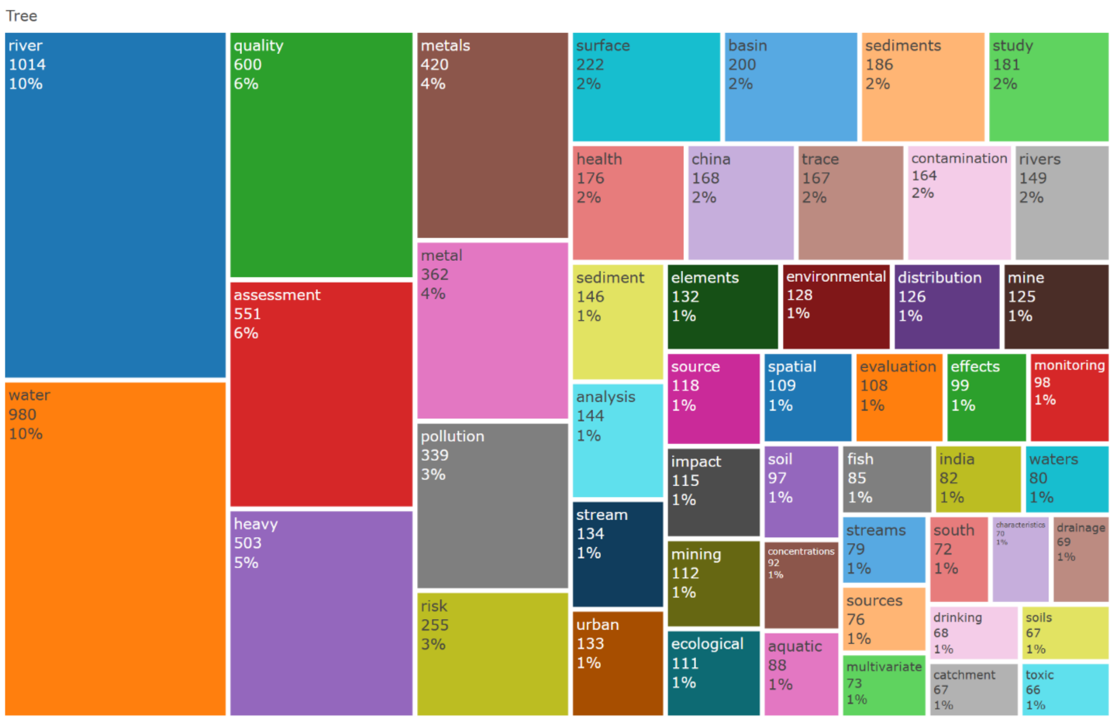


**Figure 4.** Treemap visualization of the most frequent author keywords in the dataset.

Secondary but substantial clusters include keywords related to pollution (339.3%), risk (255. 3%), surface water (222.2%), basin-scale studies (200.2%), sediments (186.2%), and trace elements (167.2%). These terms indicate a strong emphasis on contaminant transport, sediment–water interactions, basin hydrodynamics, and environmental risk assessment.

A diverse range of emerging and context-specific keywords also appears, such as "health," "environmental," "distribution," "evaluation," "monitoring," "soil," "fish," "mining," "urban," "ecological," "aquatic," "multivariate," and "toxic." Their presence highlights the interdisciplinary expansion of the field toward ecological risk modeling, human-health implications, land-use effects, and the adoption of advanced analytical and statistical approaches.

Geographical identifiers like "China," "India," and "South" also appear among the frequent keywords, reinforcing earlier findings that specific regions—particularly Asia—play a major role in global research production on riverine contamination.

Overall, the treemap demonstrates that while the field is strongly anchored in pollution assessment, metal contamination, and river water quality, it is simultaneously diversifying toward ecological, methodological, and region-specific research fronts. This thematic distribution underscores both the maturity and the expanding multidimensionality of research on trace contaminants in river systems.

Table 1 presents the scientometric performance indicators of the top contributing authors in the domain of river water quality and trace contaminants. Evaluating author-level metrics such as the h-index, g-index, m-index, total citations, and publication productivity provides insight into individual scientific influence and long-term contribution dynamics.

**Table 1.** Scientometric performance indicators of the most influential authors in the field of river water quality and trace contaminants, including h-index, g-index, m-index, total citations

| Author | h_index | g_index | m_index | TC | NP | PY_start |
|---|---|---|---|---|---|---|
| CLEMENTS WH | 15 | 21 | 0.441 | 1,140 | 21 | 1992 |
| BABOROWSKI M | 9 | 9 | 0.429 | 225 | 9 | 2005 |
| NEAL C | 9 | 10 | 0.31 | 498 | 10 | 1997 |
| TOKATLI C | 9 | 12 | 0.9 | 480 | 12 | 2016 |
| USTAOGLU F | 9 | 9 | 1.286 | 1,126 | 9 | 2019 |
| KUMAR V | 8 | 14 | 0.8 | 759 | 14 | 2016 |
| SILLANPÄÄ M | 8 | 8 | 0.444 | 1,721 | 8 | 2008 |
| AVENANT-OLDEWAGE A | 7 | 10 | 0.467 | 140 | 10 | 2011 |
| ISLAM MS | 7 | 7 | 1.167 | 530 | 7 | 2020 |
| IWASAKI Y | 7 | 11 | 0.412 | 201 | 11 | 2009 |

*h-index:* measures combined productivity and citation impact. *g-index:* emphasizes highly cited publications to reflect broader scholarly influence. *m-index:* h-index normalized by academic age for cross-career comparison. *TC:* total citations received by the author's publications. *NP:* number of publications included in the dataset. *PY_start:* year of the author's first publication recorded in this analysis.

The results show that Clements W.H. is the most influential author, with the highest h-index (15) and g-index (21), supported by 1,140 citations across 21 publications since 1992. His sustained academic output and long citation history reflect foundational contributions to toxicity assessment and riverine pollution research. Among mid-career contributors, Tokatlı C., Kumar V., and Iwasaki Y. exhibit strong citation performance relative to their publication counts. In particular, Tokatlı C. (h = 9; TC = 480) and Kumar V. (h = 8; TC = 759) have rapidly accumulated citations since entering the field in 2016, indicating rising influence and expanding scholarly visibility.

High m-index values, which normalize author impact by academic age, highlight rapidly emerging researchers. Ustaoğlu F. displays the highest m-index (1.286), followed by Islam M.S. (1.167) and Tokatlı C. (0.900). These elevated m-indices suggest accelerated citation growth and demonstrate that these authors have become highly influential within a relatively short period of academic activity. Sillanpää M. stands out with the highest total citation count (1721) among authors with moderate publication numbers (NP = 8), reflecting substantial impact per article. Academic contributors such as Bąborowski M., Avenant-Oldewage A., and Neal C. also maintain steady influence through consistent productivity and notable citation performance. Overall, the author-level indicators reveal a diverse community of established researchers, rapidly emerging scholars, and region-specific contributors. The combination of long-term academic impact and rapidly growing new research profiles suggests that the field is both mature and expanding, driven by rising concerns over contamination processes, ecological risks, and water-quality deterioration in global river systems.

Figure 5 illustrates the geographic distribution of scientific output based on corresponding authors' affiliations. Analyzing these patterns provides insight into which countries lead research efforts in river water quality and trace contaminants, as well as the extent to which international collaboration contributes to knowledge production.

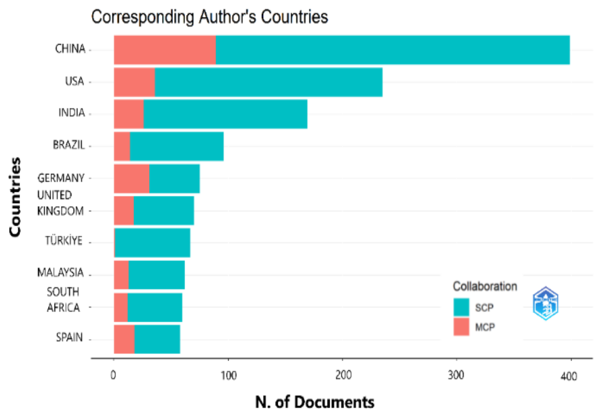


**Figure 5.** Corresponding authors' countries and their contribution to the global scientific output related to river water quality and trace contaminants. (Note. SCP refers to publications authored within a single country, whereas MCP designates articles produced through international collaboration. Article frequency (%) represents each country's share of total publications in the dataset.)

The results show that China is the dominant contributor, accounting for nearly 50% of all publications (36075 articles), with most classified as Single Country Publications (SCP) (30344). However, China's MCP share remains relatively modest (15.9%), suggesting a high volume of domestic research activity with comparatively limited international collaboration.

India and Korea occupy the second and third positions, representing 12% and 6.6% of global output, respectively. Both countries show a balanced mix of SCP and MCP contributions, with India exhibiting a 23.4% MCP rate and Korea 27.2%, indicating a moderately collaborative research environment.

The United States, although contributing fewer total articles than China and India in this dataset (3.5% of publications), demonstrates a significantly higher commitment to international collaboration, with 33.4% of its research produced via MCPs. Similarly, Malaysia, Spain, and Egypt show MCP proportions exceeding 30%, highlighting their substantial involvement in cross-border scientific partnerships.

Notably, Australia stands out with the highest MCP percentage (64.2%), reflecting a highly collaborative research system where the majority of publications are produced with international co-authors despite a relatively modest article count. Countries such as Brazil and Iran exhibit predominantly domestic research structures, evidenced by SCP rates exceeding 75%.

Overall, the distribution underscores two parallel trends:

(1) High-output countries like China and India primarily drive the global publication volume through domestic networks, while

(2) Medium-output but globally integrated countries such as Australia, Malaysia, Spain, and Egypt play a crucial role in knowledge exchange by contributing disproportionately to international collaboration.

These findings highlight a geographically uneven yet increasingly interconnected scientific landscape, where both research capacity and collaboration culture shape global knowledge production in riverine contamination studies. Figure 6 depicts the co-occurrence network of author keywords, revealing how thematic concepts cluster together within the scientific landscape. Mapping these relationships helps identify dominant research domains, emerging directions, and the conceptual structure underlying studies on river water quality and trace contaminants.

The network structure is organized into three major clusters, each representing a distinct thematic domain. The red cluster, which is the most densely connected, centers on keywords such as "heavy-metals," "contamination," "pollution," "river," "sediments," and "water-quality." These terms indicate the field's primary research focus: evaluating heavy-metal pollution in riverine environments, understanding contamination pathways, and assessing ecological and human-health risks. Strong interlinkages within this cluster highlight an extensive body of work dedicated to metal behavior, bioaccumulation, exposure pathways, and sediment–water interactions.

The green cluster reflects a second major thematic dimension associated with hydrological, geochemical, and basin-scale assessments. Keywords such as "quality," "basin," "impacts," "land-use," "geochemistry," "source apportionment," and "surface-water" illustrate studies focused on watershed processes, pollution sources, spatial distribution patterns, and integrated river-basin management. This cluster represents an analytical and systems-level perspective, linking contaminant dynamics with broader hydrological and environmental drivers.

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The blue cluster, although smaller, represents a specialized domain centered on individual trace metals and toxicity effects. Terms such as "lead," "cadmium," "zinc," "copper," and "toxicity" emphasize contaminant-specific toxicological studies, laboratory exposure experiments, and risk evaluation approaches. The separation of this cluster from the others suggests focused subfields dealing with mechanistic and metal-specific toxic responses.

Overall, the network reveals a highly interconnected thematic structure, indicating that research on riverine trace contaminants consistently integrates pollution assessment, chemical behavior, environmental processes, and toxicity outcomes. The concentration of connections around heavy metals demonstrates their enduring prominence as a central environmental concern, while emerging keywords associated with basin-scale processes and geochemical modeling highlight a shift toward more integrative and interdisciplinary approaches.

Figure 7 provides a visual summary of the most frequently occurring author keywords using a word cloud representation. This visualization highlights the dominant conceptual areas in the literature by scaling each term according to its frequency of appearance.

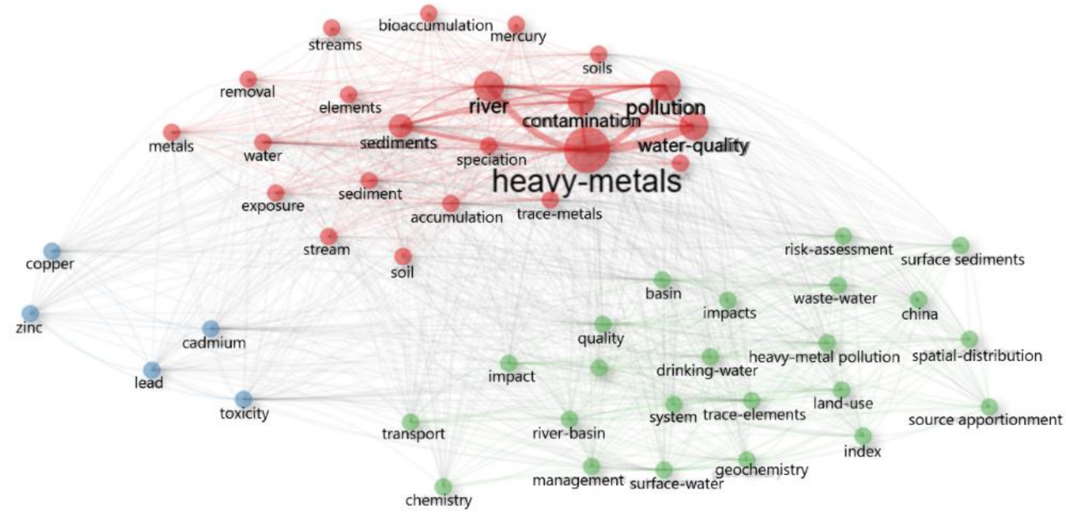


**Figure 6.** Keyword co-occurrence network illustrating thematic clusters in the literature on river water quality and trace contaminants


**Figure 7.** Word cloud showing the most frequent author keywords in the dataset.

The most prominent keywords—including "water quality," "contamination," "river," "pollution," "sediments," and "trace-elements/trace-metals"—indicate that research on riverine environments is strongly concentrated on evaluating pollutant loads, assessing contamination status, and monitoring chemical and ecological conditions. The size of these terms suggests their centrality to the field's conceptual framework, consistent with earlier co-occurrence network findings.

Other frequently appearing keywords such as "surface-water," "basin," "land-use," "waste-water," "spatial-distribution," and "source apportionment" demonstrate an expanding focus on watershed-scale processes, pollution sources, and spatial modeling approaches. These terms also reflect a methodological shift toward integrated hydrological–geochemical assessments and basin-level risk analysis.

The presence of contaminant-specific terms—including "cadmium," "lead," "zinc," "copper," "mercury," and "bioaccumulation"—indicates ongoing attention to metal toxicity, exposure pathways, and bioaccumulation mechanisms within aquatic systems. Meanwhile, keywords such as "impacts," "toxicity," "evaluation," and "drinking-water" underscore the relevance of environmental and human-health risk considerations. Overall, the word cloud reveals a lexicon dominated by pollution assessment and chemical contamination, complemented by emerging interests in watershed processes, spatial analyses, and ecosystem-level impacts. This thematic diversity reflects the field's evolution from pollutant characterization toward more integrative, multidisciplinary approaches in river water quality research.

## 4. Conclusion

This study provides a comprehensive scientometric assessment of global research on river water quality and trace contaminants, revealing a rapidly expanding and increasingly interdisciplinary field. The analysis shows that heavy-metal pollution, hydrochemical processes, and ecological risk assessment remain the core scientific themes, while emerging studies incorporate advanced statistical techniques, geochemical modeling, and basin-scale environmental evaluations. Despite the growing volume of research, geographic and thematic gaps persist, particularly in underrepresented regions where monitoring efforts and long-term datasets are limited.

The findings highlight the need for more standardized assessment protocols, integrated analytical approaches, and stronger connections between scientific evidence and water-management policy. As the pressures of climate change and anthropogenic activities intensify, future research will benefit from broader spatial coverage, improved data quality, and collaborative frameworks that link hydrological, ecological, and geochemical perspectives. Overall, this study maps the intellectual structure of the field and provides a foundation for developing more effective strategies to protect and sustainably manage river ecosystems worldwide.

**Author Contributions**

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

| | S.T. | K.K. | SA. |
|---|---|---|---|
| C | 30 | 40 | 30 |
| D | 30 | 40 | 30 |
| S | 30 | 40 | 30 |
| DCP | 30 | 40 | 30 |
| DAI | 30 | 40 | 30 |
| L | 30 | 40 | 30 |
| W | 30 | 40 | 30 |
| CR | 30 | 40 | 30 |
| SR | 30 | 40 | 30 |
| PM | 30 | 40 | 30 |
| FA | 30 | 40 | 30 |

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

**Conflict of Interest**

The authors declare that there is no conflict of interest.

**Ethical Consideration**

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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