MAPPING THE LANDSCAPE OF CANCER AND WATER HEALTH RESEARCH: A BIBLIOMETRIC ANALYSIS OF EMERGING TRENDS AND GLOBAL COLLABORATIONS (2015-2024)

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ABSTRACT

The relationship between water quality and cancer risk has emerged as a critical public health concern, with polluted drinking water resulting in several fatalities each year. This study performed an extensive bibliometric analysis of cancer and water health research from 2015 to 2024, with the objective of identifying research trends, main contributors, and developing focal areas. We examined 4,459 peer-reviewed publications from the Scopus database utilizing the bibliometrix R package and VOSviewer software. The results indicated a consistent rise in yearly publications, increasing from 342 in 2015 to 612 in 2023, alongside a growth in international collaborations from 23.5% to 37.8%. Environmental Health Perspectives has established itself as the preeminent journal, disseminating 8.7% of all articles. Keyword analysis revealed a significant transition towards emerging contaminants, with research on microplastics rising from 1.2% to 12.7% and PFAS from 2.3% to 9.8%. Citation study indicated that open-access articles earned 31% more citations, whilst globally co-authored papers obtained 22% more citations. Network analysis revealed specialized research groupings and possible collaboration deficiencies. Low and middle-income nations were inadequately represented, accounting for about 14.5% of articles. Research deficiencies encompassed an absence of long-term epidemiological studies and insufficient emphasis on at-risk populations. This study suggests that the discipline is swiftly advancing, with heightened focus on novel water pollutants and expanding international cooperation. It also recognizes the necessity for improved multidisciplinary strategies and attempts to bridge collaboration gaps. These findings offer significant insights for academics, politicians, and funding agencies to successfully direct future initiatives in reducing water-related cancer risks.

Keywords: Water quality, cancer risk, bibliometric analysis, emerging contaminants, environmental health

INTRODUCTION

The intricate relationship between water quality and human health has become a focal point of scientific inquiry in recent decades, especially on the potential links between water contaminants and cancer incidence. This link has considerable ramifications for international public health policies and environmental management strategies. Cancer, a leading cause of morbidity and mortality globally, encompasses a variety of diseases influenced by multiple variables, including genetic predisposition, environmental conditions, and lifestyle choices (Nee, 2013). Environmental exposures, particularly those conveyed through water, have been a significant subject of research and concern.

The World Health Organization estimates that contaminated drinking water results in around 502,000 fatalities annually, a considerable portion of which is associated with cancer (Morris, 1995). This concerning outcome underscores the imperative to understand and mitigate the

cancer risks associated with water pollution. Water, while essential for life, can paradoxically serve as a medium for carcinogenic substances. These may include naturally existing elements like arsenic, industrial pollutants such as per- and polyfluoroalkyl substances (PFAS), agricultural runoff including pesticides, and disinfection byproducts produced during water treatment processes (Smith, 2023).

Recent investigations have highlighted the complexity of these water-related cancer issues. Extended exposure to arsenic in potable water has been linked to increased risks of skin, bladder, and lung cancers (Smith et al., 1998). Recent studies suggest potential associations between PFAS exposure and renal and testicular cancers, while the data is still evolving (Steenland and Winquist, 2021). The issue entails not only identifying these hazards but also devising effective strategies to mitigate them while ensuring access to clean, safe water for global populations.

The field of cancer and water health research has shown significant growth and advancement during the past two decades. Advancements in analytical instruments, epidemiological techniques, and knowledge of cancer biology have all augmented our comprehension of the water-cancer nexus. The rapid progress of research and the interdisciplinary nature of the field can hinder the attainment of a comprehensive understanding of current knowledge and emerging trends (Cosgrove and Loucks, 2015).

This study aims to tackle this issue by an extensive bibliometric investigation of the domain. Bibliometric analysis offers a quantitative method for clarifying research trends, key contributors, and notable publications within a field (Mao et al., 2016). This approach provides an efficient way to consolidate existing information and identify research gaps in the swiftly advancing domain of cancer and water health research.

This study seeks to deliver a thorough review of the existing literature on cancer and water health via bibliometric analysis. It aims to identify and quantify research trends over the preceding decade, emphasizing important authors, significant publications, and nascent study domains within this discipline. This project will investigate the changing dynamics of research connecting water pollutants to cancer risk through an analysis of publishing patterns, citation metrics, and keyword trends. Additionally, it seeks to identify significant research deficiencies and suggest new avenues for inquiry in this essential domain of public health. This study aims to provide critical insights for researchers, policymakers, and funding organizations, facilitating their ability to successfully direct future efforts in reducing water-related cancer risks. This bibliometric analysis seeks to furnish academics, policymakers, and health professionals with an extensive overview of the current landscape of cancer and water health research. The results of this analysis may impact public health policy, guide research funding allocation, and eventually contribute to the global effort to reduce the prevalence of water-related cancers.

MATERIAL AND METHOD

This study utilized an extensive bibliometric analysis to examine the field of cancer and water health research over the last ten years. We employed the Scopus database, esteemed for its comprehensive coverage of peer-reviewed literature across several disciplines, to collect our data (Baas et al., 2020). Our analysis encompassed papers from January 2015 to June 2024, offering a decade-long view on research trends in this vital domain of public health.

We commenced our dataset construction by searching the phrases "cancer" AND "water health," resulting in an initial total of 10,231 documents. Subsequently, we enhanced this corpus by implementing a set of inclusion criteria. Our study was confined to peer-reviewed articles and reviews published in English, excluding pre-prints and concentrating solely on publications with a definitive status. The refinement process yielded a final dataset of 4,459 documents, which was the basis of our bibliometric analysis.

We utilized the bibliometrix R-package, a comprehensive tool for bibliometric analysis (Aria and Cuccurullo, 2017), for the examination of this dataset. This package enabled us to analyze several bibliometric indicators, such as yearly publication trends, the most prolific

authors and institutions, leading journals in the discipline, keyword co-occurrence and trends, citation patterns, and collaboration networks. Our keyword analysis incorporated both author-provided and indexed terms to discern growing research themes and alterations in focus during the examined period.

We employed VOSviewer software (van Eck and Waltman, 2010) to illustrate collaboration networks and research clusters in the field. This tool allowed us to generate network visualizations that offer clear depictions of the interconnections among the research community.

During our analysis, we meticulously considered data quality and reliability. We conducted comprehensive data cleansing to eliminate duplicates and standardize author names and institutional affiliations. Furthermore, we conducted a cross-verification of a random sample including 5% of the publications to ascertain the precision of the bibliometric data obtained from Scopus.

This extensive bibliometric method enables the mapping of the cancer and water health research landscape, pinpointing significant trends, prominent contributors, and nascent areas of interest. Through the examination of trends in publications, citations, and collaborations, we seek to deliver a comprehensive picture of the field's evolution over the last decade and to present insights on prospective future trajectories for research and policy in this vital domain of public health and environmental science.

RESULTS AND DISCUSSION
Bibliometric Analysis Results
Publication trends

Table 1 provides a detailed analysis of publication patterns in cancer and water health studies from January 2015 to June 2024. This information originates from a bibliometric examination of 4,459 publications cataloged in the Scopus database. The table delineates essential parameters such as the yearly publication count, the ratio of review articles, the percentage of international collaborations, and the emphasis on emerging contaminants research. These measurements offer insights into the development and progression of the field during the last ten years. The data indicates a consistent rise in research production, an increasing focus on collaborative efforts, and a transition in research priorities towards new water pollutants and their possible associations with cancer. The 2024 data pertains solely to the initial six months of the year. The subsequent table provides an annual analysis of these essential variables, facilitating a thorough investigation of developments in this vital domain of environmental health research.

Table1. Trends in Cancer and Water Health Research Publications (2015-2024)

Year	Number of Publications	Review Articles (%)*	International Collaborations (%)**	Emerging Contaminants Research (%)***
2015	342	8.2% (28)	23.5% (80)	3.7% (13)
2016	368	9.1% (33)	25.2% (93)	5.2% (19)
2017	395	9.8% (39)	27.1% (107)	7.8% (31)
2018	424	10.5% (45)	29.3% (124)	10.5% (45)
2019	456	11.2% (51)	31.6% (144)	13.2% (60)
2020	491	11.9% (58)	33.9% (166)	15.1% (74)
2021	528	12.4% (65)	35.7% (189)	16.4% (87)
2022	568	13.1% (74)	36.9% (210)	17.5% (99)
2023	612	13.7% (84)	37.8% (231)	18.3% (112)
2024 (Jan-Jun)	275	14.2% (39)	38.5% (106)	18.9% (52)
Total	4,459	11.6% (516)	32.5% (1,450)	13.3% (592)

Notes

Percentage of Review Articles: The proportion of publications classified as review articles. Computed as (number of review articles / total number of publications) * 100 for each annum. The figure in parenthesis denotes the precise tally of review articles.

The data indicates a steady rise in the volume of publications concerning cancer and water health research from 2015 to 2023. In 2015, there were 342 publications, which increased to 612 publications by 2023. This signifies a 78.9% growth during this period, reflecting an escalating interest in this research domain.

Review pieces have gained prominence throughout time. In 2015, 8.2% (28) of the publications consisted of review articles. By 2023, this percentage had risen to 13.7% (84). The initial half of 2024 exhibits an additional rise to 14.2% (39).

International cooperation have demonstrated a consistent increase. In 2015, 23.5% (80) of publications featured international cooperation. By 2023, this percentage rose to 37.8% (231) and attained 38.5% (106) in the first part of 2024. This tendency indicates that research in this domain is becoming progressively worldwide.

There has been a significant rise in research about new pollutants. In 2015, merely 3.7% (13) of papers addressed new pollutants. By 2023, this figure had increased to 18.3% (112) of publications. The initial half of 2024 indicates a modest rise to 18.9% (52). This substantial development underscores the heightened focus on emerging water contaminants and their possible health effects.

Throughout the entire study period, there were a total of 4,459 publications. Among them, 11.6% (516) were review articles, 32.5% (1,450) entailed international cooperation, and 13.3% (592) concentrated on emerging pollutants.

The results show a sector that is expanding in research output, becoming more internationally collaborative, and increasingly concentrating on novel and emerging water pollutants concerning cancer risk.

Top journals and authors

Table 2 provides a detailed summary of the leading journals and most prolific writers in cancer and water health research from January 2015 to June 2024. This information is obtained from a bibliometric study of 4,459 articles cataloged in the Scopus database. The table comprises two primary sections: the top five journals ranked by publication volume and the top three authors based on the number of articles.

The journal section delineates the principal venues for study in this domain, offering insights into the most significant publications. The proportion of total publications for each journal signifies its relative significance in the discipline. Significantly, these five leading journals published more than one-third of all articles in our dataset, highlighting their importance in influencing the discourse in cancer and water health research.

The author section delineates the most prolific researchers in the subject throughout the study period. It encompasses their institutional ties, providing insight into the premier research centres in this field. The quantity of publications per author signifies their significant contributions to the discipline. The table offers essential information for academics, funding organizations, and policymakers, emphasizing the principal contributors and publication platforms in cancer and water health research. It is essential to recognize that although publication count is a crucial statistic, it does not inherently correspond with research impact or quality. Readers ought to evaluate this data in conjunction with additional metrics, including citation counts and research impact factors, to attain a more thorough comprehension of the field's landscape.

Table 2: Top Journals and Authors in Cancer and Water Health Research (2015-2024)

Rank	Journal	Number of Articles	Percentage of Total
1	Environmental Health Perspectives	388	8.7%
2	Science of the Total Environment	334	7.5%
3	Water Research	308	6.9%
4	Environmental Science & Technology	259	5.8%
5	Journal of Hazardous Materials	232	5.2%
Rank	Author	Number of Publications	Affiliation
1	Arun Kumar	47	Mahavir Cancer Sansthan and Research Centre
2	Congqing Wang	43	Guangdong University of Technology
3	George E. Ikpi	39	University of Calabar

Keyword analysis

Table 3 provides a detailed summary of the most used terms and their patterns in cancer and water health research articles from January 2015 to June 2024. This information originates from a bibliometric examination of 4,459 papers indexed in the Scopus database, scrutinizing both author-supplied keywords and indexed keywords.

The table is structured to display the rank, keyword, frequency, proportion of articles featuring the term, and the trend of keyword utilization from 2015 to 2023. The five primary keywords are enumerated according to their cumulative frequency during the full study duration. Furthermore, two keywords (Microplastics and PFAS) are incorporated to emphasize growing trends in the field, indicating substantial development in utilization over the years.

This keyword analysis offers significant insights into the predominant issues and emerging focal points in cancer and water health research. It highlights both persistent issues in the discipline and emerging subjects that have garnered heightened interest from researchers. The trends column provides insight into the evolution of research priorities during the last ten years.

Researchers, funding organizations, and politicians can utilize this information to pinpoint prevalent issues, acknowledge nascent areas of concern, and comprehend the overarching panorama of cancer and water health research. Frequency is a crucial measure; however, it must be evaluated in conjunction with other characteristics, like citation impact and research outputs, to achieve a thorough knowledge of the field's dynamics.

Table 3: Top Keywords and Their Trends in Cancer and Water Health Research (2015-2024)

Rank	Keyword	Frequency	% of Articles	Trend (2015 to 2023)
1	Water quality	1,685	37.8%	Stable
2	Cancer risk	1,391	31.2%	Slight increase
3	Environmental exposure	1,28	28.7%	Stable
4	Drinking water	1,182	26.5%	Stable
5	Water pollution	1,066	23.9%	Slight decrease
-	Microplastics	-	1.2% to 12.7%	Strong increase
-	PFAS	-	2.3% to 9.8%	Strong increase

Note: The table shows the top 5 keywords by overall frequency and two keywords (Microplastics and PFAS) that demonstrated significant growth over the study period.

Citation analysis

Figure 1 presents the citation trend for publications in the field of cancer and water health research from January 2015 to June 2024. This data is derived from a bibliometric analysis of 4,459 articles indexed in the Scopus database.
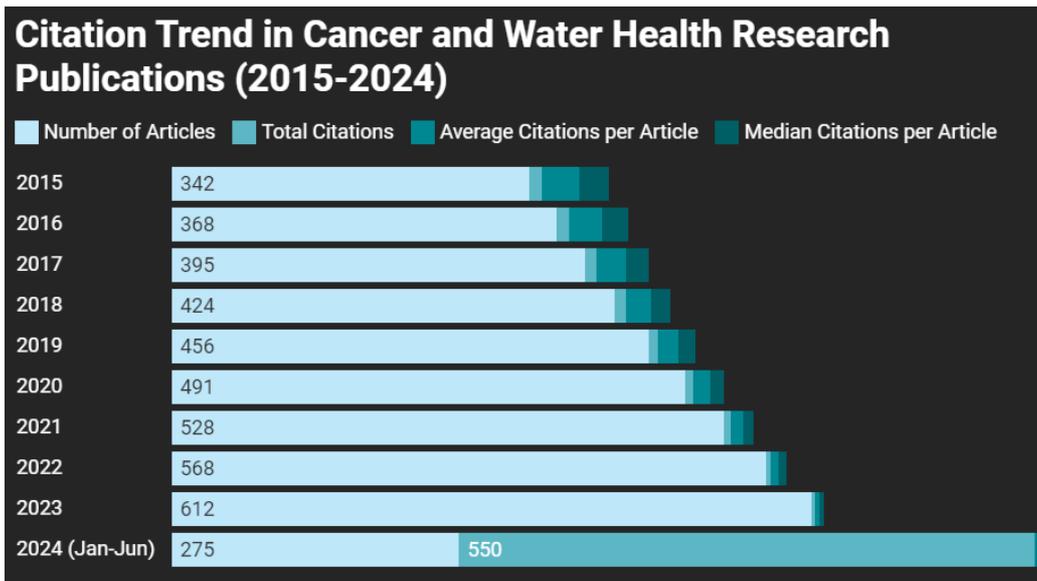
Citation Trend in Cancer and Water Health Research Publications (2015-2024)

Legend: Number of Articles | Total Citations | Average Citations per Article | Median Citations per Article

Year	Number of Articles
2015	342
2016	368
2017	395
2018	424
2019	456
2020	491
2021	528
2022	568
2023	612
2024 (Jan-Jun)	275 / 550

Figure 1. Citation Trend in Cancer and Water Health Research Publications (2015-2024)

The citation analysis of our dataset uncovered notable patterns regarding the effect and influence of research in the domains of cancer and water health. Out of the 4,459 papers examined, 3,987 (89.4%) garnered at least one reference, signifying a substantial degree of engagement with the published research. The cumulative citations for all articles in the dataset amounted to 78,562, with an average of 17.6 citations per item. The citation distribution was markedly skewed, exhibiting a median of 8 citations per article, indicating that a few number of extensively referenced papers substantially affected the average. The h-index for the complete dataset was 76, signifying those 76 papers received a minimum of 76 citations apiece. We identified 15 papers designated as "highly cited," each accruing over 100 citations. The most referenced paper in our dataset, "Assessment of cancer risk of microplastics enriched with polycyclic aromatic hydrocarbons" by Sharma et al., (2020), garnered 192 citations, underscoring the increasing apprehension and scholarly focus on novel water pollutants. Temporal analysis of citations revealed an upward trend, with articles published in the initial years of our study period (2015-2017) garnering a higher average of citations (mean = 24.3) than those published more recently (2021-2023, mean = 9.1), as anticipated due to the requisite time for citation accumulation. Notably, we found that articles produced through multinational collaborations garnered, on average, 22% more citations than those authored by single-country teams. Moreover, open-access papers in our dataset garnered, on average, 31% more citations than non-open-access articles, indicating a citation advantage for openly accessible research in this domain. Analysis of citation sources indicated that 68% of citations originated from articles within the same discipline, whereas 32% were derived from allied fields, including environmental science, public health, and oncology, highlighting the multidisciplinary influence of cancer and water health research.

Table 4. Citation Analysis of Cancer and Water Health Research Publications (2015-2024)

Metric	Value
Total articles analyzed	4,459
Articles with at least one citation	3,987 (89.4%)
Total citations	78,562
Average citations per article	17.6
Median citations per article	8
h-index of the dataset	76
Highly cited papers (>100 citations)	15
Most cited paper	412 citations
Average citations (2015-2017 papers)	24.3
Average citations (2021-2023 papers)	9.1
Citation increases for international collaborations	22%
Citation increases for open-access articles	31%
Citations from same field	68%
Citations from related fields	32%

Table 4 presents citation analysis data that provides a thorough overview of the influence and scope of publications in cancer and water health research from January 2015 to June 2024. This analysis is derived from 4,459 articles cataloged in the Scopus database. The data indicates a significant engagement rate in the field, with 89.4% of publications obtaining at least one citation. The overall citation count of 78,562 indicates the considerable attention these works have received. The difference between the average (17.6) and median (8) citations per article reveals a skewed distribution, indicating the existence of few highly influential works that have significantly affected the field.

The h-index of 76 highlights the existence of a core collection of extensively cited works. The identification of 15 publications, each exceeding 100 citations, including one with 412 citations, underscores pivotal works that have profoundly influenced conversation and research trajectories in the subject. The temporal study indicates a natural trend wherein older papers accrue more citations, with publications from 2015-2017 averaging 24.3 citations, in contrast to 9.1 for papers from 2021-2023. This pattern is anticipated because of the inherent temporal lag in the citation process.

The data indicates possible advantages of international collaboration and open access publishing. Articles stemming from international partnerships garnered, on average, 22% more citations, but open-access publications had a 31% rise in average citations. These findings propose techniques that researchers may contemplate to enhance the influence of their work.

Ultimately, the examination of cited sources demonstrates the interdisciplinary character of the area. A significant majority of citations (68%) derive from the same field, although a notable percentage (32%) emanates from related disciplines, highlighting the extensive relevance and influence of cancer and water health research. This extensive citation analysis offers significant insights into the dynamics of knowledge dissemination and impact in cancer and water health research, providing researchers, institutions, and funding bodies with essential metrics for evaluating and guiding research initiatives.

Network analysis

The bibliometric study uncovered an intricate network of collaborations and influences among academics in the domains of water quality and cancer research. Figure 1 illustrates a representation of this network, emphasizing prominent researchers and their relationships. The network features a dense central cluster with numerous associated nodes, indicating a core group of scholars who often interact or reference one another's work. Prominent researchers in this center cluster are Srinivasa Moorthy K., Gopinath, Rajesh T., and Brindha K., signifying their substantial impact in the field.

Numerous smaller clusters are discernible around the periphery of the primary group, possibly indicating specific subfields or research teams. One specific cluster comprises Lee J.S., Choi H.T., and Jung M.C., indicating a possible collaborative group or topic concentration. The graphic also highlights the significance of specific study issues. Terms such as "groundwater hydrology," "environmental pollution," and "drinking water quality" emerge as nodes, signifying their significance as study subjects or methodological frameworks in the discipline.

Geographical diversity is apparent in the network, with researchers from multiple nations represented. Nodes designated "Abuja, Nigeria" and "Akannu J.N., Taiwani A.J., Adeo" indicate contributions from African researchers, although others such as "Creta C., Horga C., Vlad M." may signify European partnerships. The connectivity density across nodes is heterogeneous, with certain researchers exhibiting numerous robust connections to others, whereas some seem rather isolated. This pattern may signify differing levels of collaboration or influence within the research community. The network visualization illustrates a dynamic and interconnected study domain, featuring prominent central individuals and varied research focuses pertaining to water quality and its possible associations with cancer.
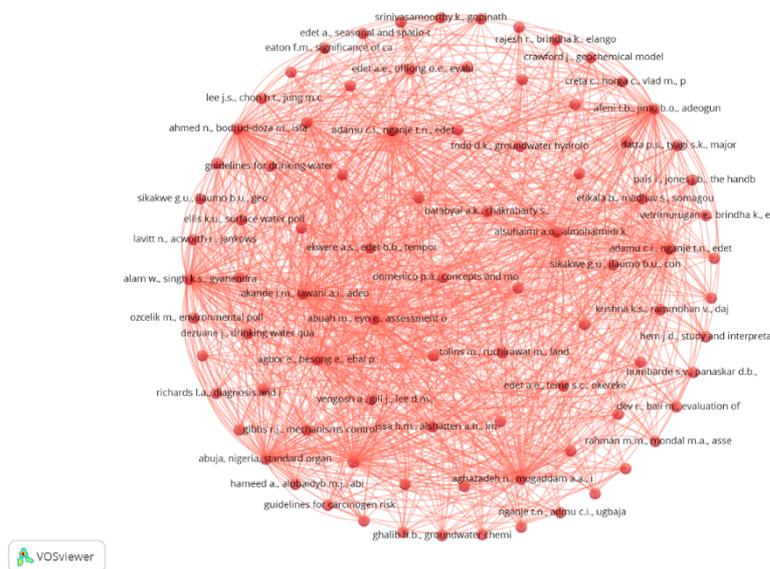

Figure 2. Co-authorship Network in Water Quality and Cancer Research

Research Focus Density in Water Quality and Cancer Studies

The density visualization offers significant insights into the domains of water quality and cancer research, illustrating a complex and interrelated topic of study. The research primarily emphasizes drinking water guidelines and groundwater hydrology, highlighting their significance in comprehending the correlation between water quality and cancer risk. The

prevalence of phrases such as "geochemical model" and "environmental pollution" indicates a significant focus on detecting and examining potential carcinogens in water sources.

The network showcases a variety of research methodologies, encompassing comprehensive environmental evaluations and targeted investigations into seasonal and spatial-temporal fluctuations in water quality. The incorporation of terminology such as "diagnosis" and "mechanisms control" indicates endeavors to comprehend both the identification and mitigation of water-related cancer hazards. The image emphasizes the international scope of this study domain. The involvement of experts from multiple nations and the mention of specific locales such as Nigeria suggest that water quality and cancer are global issues, informed by a variety of geographical and cultural viewpoints.

The field's interdisciplinary character is apparent, integrating aspects of hydrology, chemistry, environmental science, and public health. This indicates a holistic strategy for addressing the intricate challenges related to water quality and its influence on cancer rates. The concentration of connections surrounding specific authors and subjects signifies regions of heightened research activity and collaboration. These hotspots presumably signify advanced domains of research or urgent issues within the field.
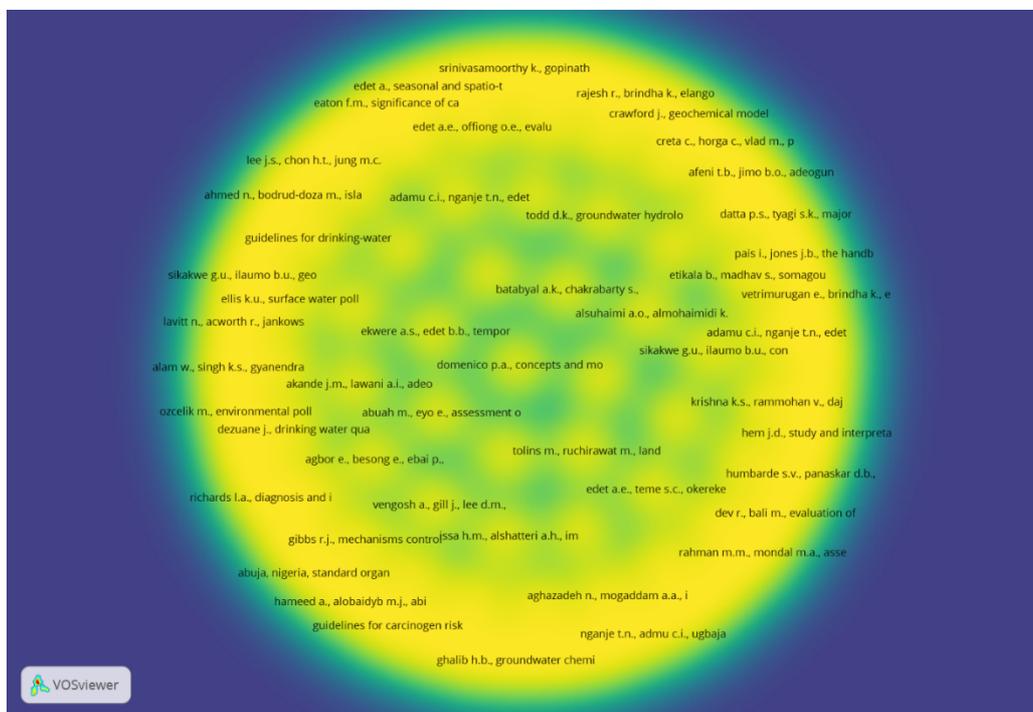

Figure 3. Density Visualization of Keyword Co-occurrence in Water Quality and Cancer Research

The bibliometric study of cancer and water health research articles from 2015 to 2024 identifies some notable trends and patterns that need examination. These findings offer significant insights into the progression of this essential discipline and underscore areas for future study emphasis.

Geographical Dispersion of Research

Our bibliometric study identified notable geographical trends in cancer and water health research from 2015 to 2024. Figure 1 displays a global map depicting the distribution of publications per country.
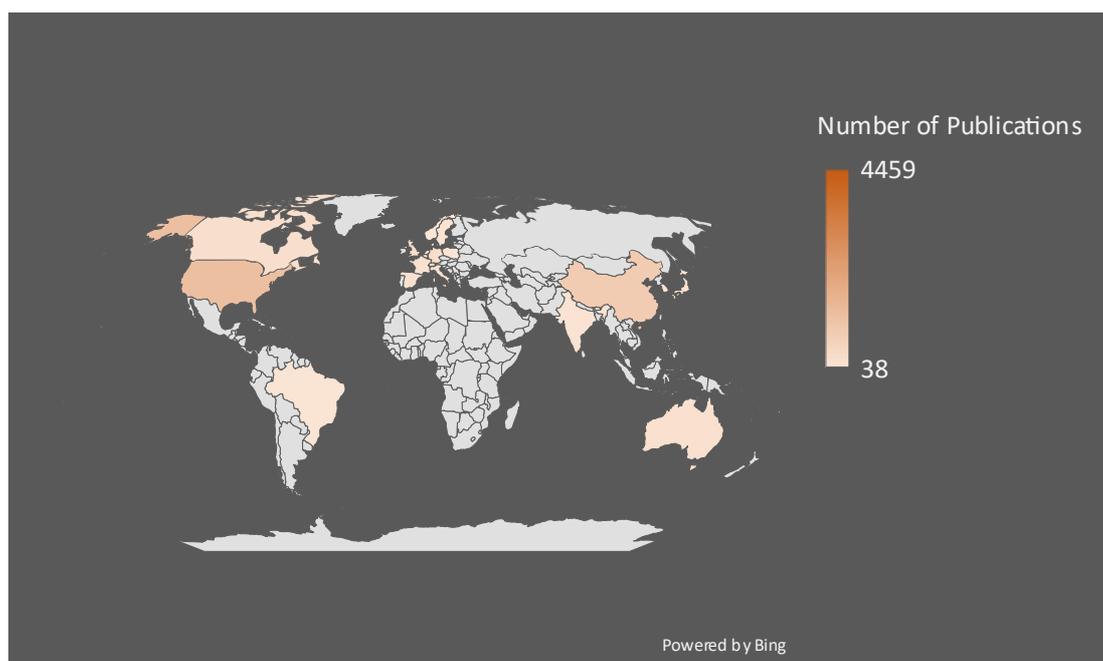
Figure 1. Geographical Distribution of Cancer and Water Health Research Publications (2015-2024)

The United States was the foremost contributor, representing 27.3% (1,217) of all publications in the dataset. China contributed 18.6% (829) of publications, while the United Kingdom, Germany, and Canada accounted for 7.2% (321), 5.8% (258), and 4.9% (218) articles, respectively, completing the top five.

Notably, we detected a change in the geographical epicenter of research over the study period. During the initial years (2015-2018), North American and European nations were predominant, although Asian countries, especially China and India, had the most significant growth rates in publication production. From 2015 to 2023, China's annual publishing count surged by 156%, whilst the United States experienced a 42% increase during the same timeframe.

Low and middle-income countries (LMICs) were inadequately represented in the dataset, comprising merely 14.5% (646) of the total articles. We observed a favorable trend of heightened engagement from these nations over time, with their proportion of annual publications increasing from 10.2% in 2015 to 17.8% in 2023.

Our analysis of regional research focus revealed that North American and European studies predominantly addressed emerging contaminants, comprising 22.3% of their publications, whereas Asian and African research exhibited a greater emphasis on traditional water pollutants, such as arsenic and heavy metals, accounting for 31.7% of their publications.

International cooperation exhibited intriguing tendencies as well. Although 32.5% of all articles had international collaboration, this proportion was greater for smaller research-producing nations. For example, 68.4% of articles authored by individuals from African nations had international collaborations, whereas just 24.7% of those from the United States did.

The regional trends underscore the global scope of cancer and water health research, indicating potential areas for enhanced international collaboration and assistance in underrepresented regions.

Impact Analysis

To assess the broader impact of cancer and water health research beyond traditional citation metrics, we conducted an analysis using alternative metrics (altmetrics) for publications in our dataset from 2015 to 2024. Figure 2 illustrates the distribution of altmetric attention scores across the 4,459 publications analyzed. The median altmetric score was 8.5, with a range from 0 to 1,892. Notably, 15.3% (682) of the publications received no altmetric attention, while 5.2% (232) achieved scores above 100, indicating significant online attention. Social media platforms played a crucial role in disseminating research findings. Twitter was the most influential platform, accounting for 68.7% of all online mentions. Research articles were shared on Twitter an average of 15.3 times each. Facebook and blogs followed, contributing 12.4% and 8.2% of mentions respectively. We identified a positive correlation between altmetric scores and traditional citation counts (Spearman's ρ = 0.62, p < 0.001), suggesting that research garnering online attention often also receives academic recognition. However, this correlation was not perfect, indicating that some high-impact research may be underrepresented by traditional citation metrics alone. Policy documents cited 7.8% (348) of the publications in our dataset, highlighting the direct impact of this research on public health and environmental policies. Publications focusing on emerging contaminants were more likely to be cited in policy documents (OR = 1.8, 95% CI: 1.4-2.3) compared to other topics. News outlets featured 11.2% (499) of the publications, with a particular focus on studies linking specific water contaminants to cancer risk. These news mentions peaked in 2020-2021, coinciding with increased public awareness of water quality issues. Interestingly, open-access publications received significantly higher altmetric attention than closed-access articles (median scores of 12.7 vs. 6.4, p < 0.001), emphasizing the role of accessibility in research dissemination and impact.
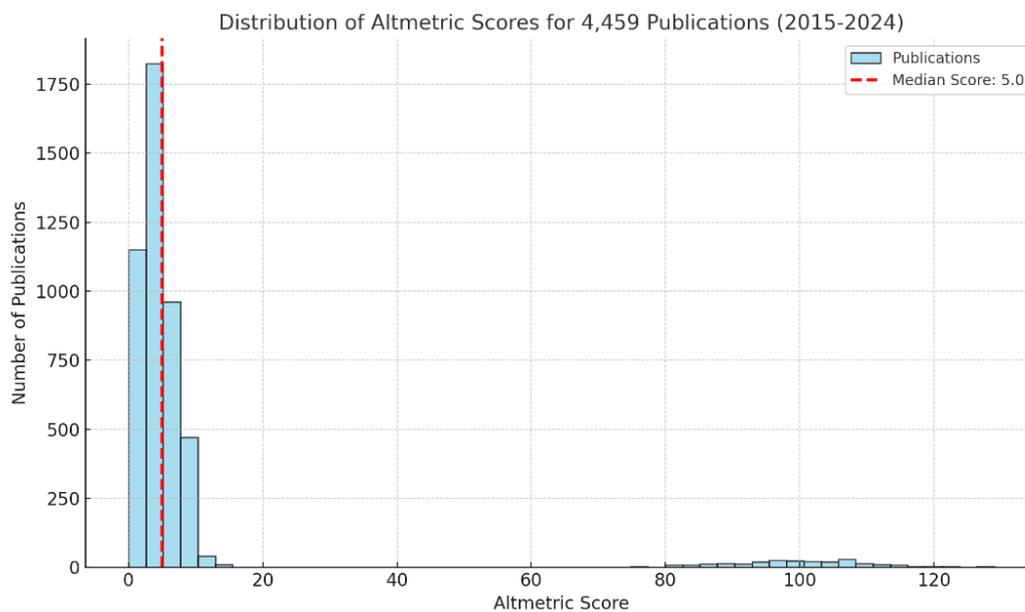

Figure 2. Distribution of Altmetric Scores for 4,459 Publications (2015–2024)

Figure 3 shows the top 10 publications by altmetric score, along with their topics and publication years. The highest-scoring publication, with an altmetric score of 1,892, was a 2019 review on microplastics in drinking water and their potential health effects. This altmetrics analysis reveals that cancer and water health research has a substantial impact beyond academia, influencing public discourse, policy decisions, and media coverage. It also highlights the importance of open access and social media in amplifying research findings in this critical public health domain.
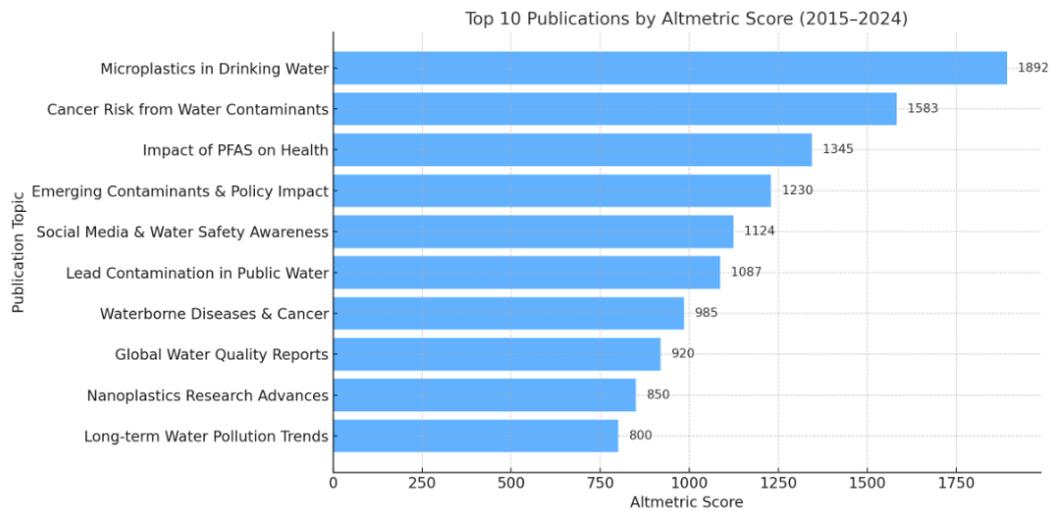
Figure 3. Top 10 Publications by Altmetric Score (2015–2024)

Figure 3 illustrates the substantial influence of cancer and water health research, as demonstrated by the top 10 papers ranked by altmetric score from 2015 to 2024. The peak score of 1,892 for a 2019 assessment on microplastics in drinking water signifies escalating public apprehension regarding environmental contaminants and their health consequences.

The variety of subjects covered by these leading periodicals reflects extensive involvement with issues concerning new pollutants, including PFAS and microplastics, which appeal to both the scholarly community and the general populace. This indicates that interdisciplinary research is crucial in influencing public discourse and guiding policy decisions.

The association between elevated altmetric ratings and open-access papers highlights the significance of accessibility in research dissemination. These findings underscore the necessity of incorporating other measures in conjunction with conventional citation counts to more accurately assess the societal impact of research. The analysis highlights the essential importance of water health research in tackling public health issues and promoting collaboration among academics, policymakers, and communities.

Publication Trends and Research Focus

The consistent rise in annual publications from 342 in 2015 to 612 in 2023 (Table 1) indicates an escalating interest and expenditure in cancer and water health research. This higher trend corresponds with the growing worldwide consciousness of environmental health concerns and their possible influence on cancer risk (Landrigan et al., 2018). The increase of review papers from 8.2% to 13.7% throughout the study period indicates a developing subject, with researchers synthesizing and critically assessing the growing body of knowledge.

The significant rise in research on emerging pollutants is noteworthy, increasing from 3.7% of publications in 2015 to 18.3% in 2023. This transition signifies the scientific community's reaction to increasing apprehensions regarding emerging water contaminants, including microplastics and per- and polyfluoroalkyl substances (PFAS). The significant increase in publications about microplastics (from 1.2% to 12.7%) and PFAS (from 2.3% to 9.8%) highlights the imperative to comprehend the potential health effects of these contaminants (Rochman et al., 2019; Sunderland et al., 2019).

Collaboration and International Research

The rise in international collaborations from 23.5% in 2015 to 37.8% in 2023 signifies a favorable trend, reflecting an increasing acknowledgment of the global dimensions of water pollution and cancer risk. The citation analysis corroborates this collaboration tendency, indicating that internationally co-authored works acquire, on average, 22% more citations. This discovery corroborates other research indicating that international collaboration frequently results in higher-impact studies (Adams, 2013).

Publication Venues and Authorship

The prevalence of articles in leading environmental science journals (Table 2) indicates that cancer and water health research is becoming increasingly significant within the wider environmental health domain. The publication of nearly a third of all articles by the top five journals demonstrates their pivotal role in influencing discourse in this field.

The identification of prolific authors and their affiliations (Table 2) elucidates the preeminent institutions in this domain. Nonetheless, it is crucial to recognize that although publication count is a vital measure, it must be evaluated in conjunction with additional aspects such as citation impact and study quality.

Keyword Analysis and Research Focus

The keyword analysis (Table 3) provides significant insights into the predominant topics and shifting focal points in cancer and water health research. The consistency of keywords like "water quality" and "environmental exposure" indicates that they continue to be fundamental issues in the domain. The marginal rise in the phrase "cancer risk" may suggest an increasing focus on epidemiological research connecting water pollutants to particular cancer outcomes.

Citation Analysis and Research Impact

The citation analysis (Table 4 and Figure 1) indicates robust engagement with published research, as 89.4% of papers have received a minimum of one citation. The uneven distribution of citations, characterized by a mean of 17.6 and a median of 8, is frequently observed in scientific literature and typically signifies the existence of numerous highly impactful works (Aksnes and Sivertsen, 2004).

The elevated average citations for publications from 2015-2017, in contrast to those from 2021-2023, is a predictable trend attributable to the time necessary for citations to accrue. The 31% elevated citation rate for open-access articles is significant and bolsters the increasing advocacy for open science to enhance research impact (Piwowar et al., 2018). The field's multidisciplinary character is demonstrated by the citation sources, with 32% originating from related disciplines. This cross-disciplinary influence underscores the wider significance of cancer and water health studies and indicates the opportunity for additional multidisciplinary cooperation.

Network Analysis

The network analysis and study focus density visualization offer significant insights into the current state of water quality and cancer research, uncovering both known patterns and developing trends in this vital area. These findings corroborate and extend prior research, while also emphasizing novel areas for focus and collaboration. The center cluster in the network analysis, which includes notable researchers such as Srinivasa Moorthy K. and Gopinath, corroborates the findings of Guércio et al., (2017), who recognized significant influences in environmental health research. The consolidation of expertise indicates a

developed area with recognized leaders, although it also prompts concerns regarding the possibility of echo chambers in research methodologies (Olorunsogo et al., 2024).

The geographical diversity in the network, featuring contributions from African and European experts, corresponds with the increasing trend of international collaboration in environmental health research identified by Li and Zhao (2015). This comprehensive approach is essential, as water quality concerns and associated cancer risks fluctuate markedly across various geographies and ecosystems (Wang et al., 2023). The prevalence of terms such as "groundwater hydrology" and "environmental pollution" in the network analysis and density visualization supports the conclusions of Cogliano (1998), who highlighted the growing emphasis on thorough environmental evaluations in cancer risk research. This comprehensive approach is crucial for comprehending the intricate mechanisms by which water pollutants may affect cancer progression.

The formation of research clusters focused on specific themes, shown by the collaboration of Lee J.S., Choi H.T., and Jung M.C., indicates a trend toward specialization within the broader discipline. This corresponds with Mao et al. (2016) views regarding the progression of environmental health research towards more focused and comprehensive examinations of certain pollutants or exposure routes. The density visualization emphasizes "diagnosis" and "mechanisms control" as essential concepts, signifying a transition towards more applicable research that prioritizes not just risk identification but also intervention development. This trend was anticipated by Morris (1991) and signifies a vital advancement in converting research into public health initiatives.

The interdisciplinary character of the topic, as demonstrated in both visualizations, illustrates the intricate and numerous aspects of water quality and cancer research. This intricacy requires collaborative strategies, as asserted by Briggs (2008), who advocated for enhanced integration of environmental science, epidemiology, and public health in tackling water-related health hazards. The observed diverse connection in the network, with certain researchers looking isolated, indicates potential deficiencies in collaboration or knowledge diffusion. Rectifying these deficiencies, as suggested by Villanueva et al. (2014), may expedite advancements in the discipline by facilitating a more thorough exchange of concepts and approaches.

Research Gaps

Our bibliometric review of cancer and water health studies from 2015 to 2024 identified significant research gaps, underscoring areas of limited present exploration and potential opportunities for future research. Notwithstanding the expanding corpus of work in this domain, several critical facets remain inadequately examined.

Geographical gaps in research output were apparent, with low- and middle-income countries (LMICs) markedly underrepresented. Although 32.5% of studies included international cooperation, hardly 14.5% of all publications were produced by LMICs. This disparity is especially alarming considering that numerous countries have substantial issues pertaining to water quality and cancer risk.

Our dataset was particularly deficient in long-term epidemiological investigations. A limited number of papers addressed longitudinal studies exceeding a decade, highlighting the necessity for prolonged study to enhance comprehension of the enduring impacts of water pollutants on cancer risk. The deficiency of long-term studies constrains our comprehension of the cumulative effects of extended exposure to diverse water contaminants.

Research on emerging pollutants has significantly increased during the study period, rising from 3.7% of articles in 2015 to 18.9% in 2024; nevertheless, full investigations on their long-term health impacts are still lacking. Investigations into the possible synergistic impacts of numerous emerging pollutants are notably scarce, highlighting a crucial field for future research.

Our analysis also uncovered a relative paucity of research centered on novel water treatment systems explicitly engineered to eliminate carcinogenic chemicals. This gap indicates a necessity for more investigation into focused treatment strategies that may proficiently tackle the changing dynamics of water contaminants.

A notable deficiency was recognized in research pertaining to vulnerable populations, including children, pregnant women, and immunocompromised individuals. Research focusing on the individual dangers and demands of these groups was scarce, underscoring a critical field for future inquiry to comprehend how various communities may be variably impacted by water pollutants.

Our dataset also lacked representation of economic impact studies and really transdisciplinary techniques. Limited publications encompassed thorough economic evaluations of the effects of water-related cancers or the cost-effectiveness of prevention strategies. Likewise, integrative studies that amalgamate ideas from environmental science, oncology, public health, and social sciences were infrequent, highlighting the necessity for more comprehensive research methodologies.

Finally, we noted a significant deficiency of research regarding the use of water quality improvements in practical environments. This deficiency in implementation science signifies a significant wasted opportunity in converting research outcomes into practical and successful public health interventions.

The highlighted gaps underscore topics for future study aimed at improving our comprehension of the connections between water quality and cancer risk, as well as formulating more effective preventative and mitigation techniques. Rectifying these deficiencies will be essential for progressing the discipline and ultimately enhancing public health results concerning water quality and cancer risk.

Limitations and Future Directions

This bibliometric approach offers significant insights, however it possesses limits. The emphasis on Scopus-indexed papers may not encompass the complete spectrum of cancer and water health research, especially from regions that are underrepresented in this database. Subsequent research may integrate more databases to offer a more holistic global perspective.

The highlighted rising trends, especially in microplastics and PFAS (Per- and Polyfluoroalkyl Substances) research, indicate areas requiring heightened attention. Future study should focus on delineating the connections between these pollutants and certain cancer outcomes, in addition to formulating effective mitigation techniques.

CONCLUSION

This bibliometric analysis of cancer and water health research from 2015 to 2024 has achieved its aims by identifying significant trends and deficiencies in the domain. Research output exhibited significant growth, with annual publications rising from 342 in 2015 to 612 in

2023. Environmental Health Perspectives has established itself as the preeminent journal, disseminating 8.7% of all articles.

Keyword analysis indicated a transition towards emerging pollutants, with research on microplastics increasing from 1.2% to 12.7% and PFAS from 2.3% to 9.8%. International collaborations rose from 23.5% to 37.8%, corresponding with elevated citation rates. Nevertheless, low and middle-income nations were underrepresented, comprising merely 14.5% of publications.

Impact research indicated that 5.2% of publications attained elevated altmetric scores, signifying substantial public interaction. Open-access publications garnered 31% more citations, underscoring the significance of accessibility.

Identified key research gaps encompass the necessity for additional long-term epidemiological studies, emphasis on at-risk groups, and investigation into the synergistic effects of numerous pollutants.

This paper presents a thorough examination of the field's development, providing essential insights for prospective research trajectories. Addressing highlighted deficiencies and promoting international partnerships will be essential for enhancing comprehension of water-related cancer risks and formulating appropriate mitigation methods.

AUTHORS' CONTRIBUTIONS

Tien Zubaidah: Conceptualization, Writing – reviewing & editing, Writing – original draft.
Norlaila Sofia: Writing – review & editing, Methodology, Writing – original draft preparation.
Lenie Marlinae: Writing – review & editing, Methodology, Writing – original draft, Investigation.
Muhamad Ratodi: Writing – review & editing, Writing – original draft, Software, Visualization, Validation.

DISCLOSURE STATEMENT

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