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Research Article

Global COVID-19 and Environmental Sciences Research: A Scientometric Analysis of Highly-Cited Publications

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ABSTRACT

The COVID-19 pandemic increased exponentially across the global, it has threatened the human lives and uprooted the economy of various countries, besides having a major impact on the environment. The global disruption caused by the COVID-19 has brought about several effects on the environment and climate. Hence a scientometric study of the highly cited global publications in impact on COVID-19 and Environment has been conducted to identify the emerging research trends in this field. The data downloaded Global publications on this topic from the Web of Science database using a well-defined research strategy, which was based on using "keyword" and "Title' search tags of Web of Science database. The search was subsequently restricted to "Covid-19" and "Environmental Science" subject and limited to 29 years in "global" yielded 2,903 records. The 2,903 publications were published on 'Covid-19 and Environmental Science' as searched in web of science database and these have received 126 papers have 1,444 citations from 1≤100 citations, average citation per paper 254.6 from the data spans 1992-2023, covering 126 publications published across 85 different sources, including journals, books, and proceedings. Despite an annual growth rate of 0%, indicating stable but non-expanding research output, the dataset has an impressive average citation per document age is 15.6 years, suggesting that many highly cited papers were published years ago and continue the depth of engagement with existing literature. Regarding document contents, there are 697 keywords plus and 431 authors keywords, demonstrating diverse research themes and indexing strategies. Authorship analysis reveals contributions form 602 authors, with 27 single-authored documents, indicating that most research in this field is collaborative. The average number of co-authors per document is 4.98, with an international co-authorship rate of 29.375, reflecting strong global collaborations. The results of the present study are focused on the evaluation of the Global contribution, focusing on global issues using quantitative and qualitative methods. Such a study has allowed us to visualize the research trends that emerged during the COVID-19 pandemic and will facilitate the researchers to identify significant hotspots and the latest trends in the field.

Keywords: COVID-19, Environmental Science, Global publications, Highly Cited Papers, Scientometrics.

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INTRODUCTION

The COVID-19 pandemic has had a profound impact on human health, economies, and societal structures worldwide. Emerging as a global crisis in late 2019, the disease caused by the novel coronavirus SARS-CoV-2 has led to unprecedented challenges across sectors (Wang *et al*., 2025). While initial research primarily focused on medical and epidemiological aspects, the pandemic's environmental consequences have gained significant attention from the scientific community (Lindawati and Meiryani, 2024). The interplay between COVID-19 and environmental sciences has sparked numerous studies investigating the pandemic's effects on air quality, climate change, water pollution, biodiversity, and sustainable development. Environmental factors play a crucial role in the transmission and mitigation of infectious diseases. Studies have examined how air pollution exacerbates COVID-19 severity, how lockdown measures temporarily improved air and water quality, and how changes in human activity impacted ecosystems. Furthermore, research has explored sustainable strategies for managing biomedical waste, developing eco-friendly disinfectants, and addressing long-term environmental policy challenges in a post-pandemic world. Given the interdisciplinary nature of this field, there is a growing need to assess the global

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research trends in COVID-19 and environmental sciences (Arya *et al.*, 2024; Sethi *et al.*, 2014).

Scientometric analysis serves as a powerful tool to assess the growth, trends, and influence of research output in a given field. By analysing citation patterns, publication trends, and collaboration networks, scientometric studies provide valuable insights into the evolution of scientific knowledge (Geng *et al.*, 2025). In the context of COVID-19 and environmental sciences, a scientometric approach helps identify the most influential studies, key contributors, leading institutions, and emerging research themes that have shaped the discourse in this interdisciplinary domain. This study aims to conduct a comprehensive scientometric analysis of highly cited publications related to COVID-19 and environmental sciences. By examining publication trends, citation impact, and keyword analysis, this research seeks to uncover the intellectual structure of the field and highlight significant contributions. Additionally, it explores collaboration patterns among researchers and institutions to understand the global research network driving advancements in this area. The findings of this study will provide researchers, policymakers, and funding agencies with valuable insights into the current state of research, identify gaps for future studies, and guide evidence-based decision-making. By mapping the scientific landscape of COVID-19 and environmental sciences research, this study contributes to a deeper understanding of how environmental factors interact with pandemic-related challenges and informs strategies for future environmental and public health preparedness (Gupta *et al.*, 2024).

RELATED LITERATURE

Over the past five years, numerous studies have explored the intricate relationship between the COVID-19 pandemic and environmental factors. Only a few bibliometric studies have been undertaken on this topic. Among such studies (Gupta *et al.*, 2024), tracked the current host spots and research trends on COVID-19 in the environmental field. Below is a curated list of recent literature reviews that provide comprehensive insights into this dynamic interplay (Pratama *et al.*, 2024), discusses the impact of environmental factors on the COVID-19 pandemic, highlighting how closely health and the environment are linked 3. reviews and analyses the literature on the impact of the COVID-19 pandemic on the environment and, conversely, how environmental pollution may influence the spread and severity of COVID-19. It examines the observed and hypothesised environmental impacts of the COVID-19 pandemic, considering both short-term effects during lockdowns and potential long-term consequences (Aboagye *et al.*, 2023). Review study highlights the complex and bi-directional impact that the COVID-19 pandemic has had on environmental health, discussing both positive and negative effects and also review systematically examines the effect of COVID-19 lockdowns on pollutant concentrations in China by synthesising reported evidence, following PRISMA guidelines. India's research output on COVID-19 and environmental sciences, analysing publication trends, prominent authors, and collaborative patterns. The findings highlight India's contributions to global research in this domain. 6A bibliometric study assesses the influence of COVID-19 social lockdowns on air pollution, identifying emerging issues and discussing future perspectives (Wang *et al.*, 2025). Focuses on the influence of COVID-19 on scientific productivity concerning water variables, including wastewater and renewable water resources. It examines how the pandemic has shaped research in water-related environmental studies. 8 explores the effects of the COVID-19 pandemic on environmental sustainability, emphasising changes in greenhouse gas emissions and solid waste generation. The bibliometric analysis sheds light on the pandemic's environmental implications (Lindawati and Meiryani, 2024). Presents an extensive scientometric analysis of research production related to COVID-19 and the dissemination of misinformation, both globally and within specific countries. It offers insights into the challenges of information spread during the pandemic.

These studies collectively enhance our understanding of the multifaceted relationship between COVID-19 and environmental sciences, providing valuable perspectives for future research and policy formulation.

METHODOLOGY

Bibliometric tools and analysis

This analysis employs diverse tools to process and enhance the data and create visual representations. Microsoft Excel 2019 (v16.0) is used for primary data cleansing, filtering, and statistical analysis tools. Various scientometric software packages are also utilised to facilitate data visualisation and mapping. These software packages encompassed a range of functions.

Biblioshiny (v4.1.3) (Van and Waltman, 2010)

This tool was developed by visualises citation networks, maps research trends, and analyses publication metrics. These bibliographic tools were used to identify key research themes, track citation patterns, and evaluate trends in this study.

VOSviewer (v1.6.18) (Eck and Waltman, 2017)

The visualisation software developed by the Centre for Social and Technology Studies at Leiden University was used to analyse data and create visual maps of co-authorship networks and author keywords. The collaboration criterion for including authors was a minimum of co-authorship with at least one other author. Centrality, a measure of node influence based on collaboration frequency, was used to assess the prominence of each author in the network. This tool encompasses a comprehensive set of bibliometric methods for analysis, making it a valuable resource for our study. In co-citation networks, two items appear together

in the Bibliography of a third citing item. Co-occurrence networks represent relationships between items based on their frequency of appearance together in publications (Ahmed *et al.*, 2022; Sab *et al.*, 2022; Eck and Waltman, 2017). Visualisations use nodes and links of various colours, with node size reflecting citation of occurrence count and link strength quantified by the Total Link Strength (TLS) parameter (Ahmed and Sab, 2025; Sab *et al.*, 2021). Our present study utilised the detailed flow diagram provided in Figure 1.

OBJECTIVES OF THE STUDY

This scientometric study aims to analyse the global research landscape on COVID-19 and Environmental Sciences using bibliometric methods. The specific objectives are:

- To examine the global publication trends in COVID-19 and environmental sciences research, including annual growth, distribution, and productivity.
- To identify the most influential countries, institutions, and authors contributing to research on the impact of COVID-19 on the environment.
- To analyze the top-cited publications and leading journals in this field, highlighting their impact and significance.
- To explore the major research themes and keyword trends emerging from the literature, identifying the key focus areas of scientific inquiry.
- To study international research collaborations by mapping co-authorship networks among authors, institutions, and countries.
- To evaluate the citation impact and h-index of publications to determine their scholarly influence.
- To assess how research focus evolved during different phases of the pandemic, examining shifts in themes and priorities over time.
- To provide insights for future research directions and policy implications by identifying gaps and potential areas for further investigation.

DATA COLLECTION AND METHODS

From previous bibliometric studies on medical topics, the Web of Science database was selected as the main data source for the present study, as it is the largest database for medical literature and provides the maximum number of useful metrics for a bibliometric study. A search strategy was developed to identify, retrieve, and download relevant literature in the Web of Science database on 16, February 2025 based on keyword tags, with the search strategy shown below. The literature search included keywords such as "COVID-19 and Environmental Science" keyword tag and joined by Boolean operators, as shown in the search strategy. A time span of 29 years was set, and thus only literature published from 1992 to 2023 was included. Publications related to "COVID-19 and Environmental Science" research were identified globally from the Web of Science (WoS) citation database on February 16, 2025, using a search strategy based on Keywords like "COVID-19 and Environmental Science" The Boolean search string was used, i.e., TITLE=("Covid-19" or "2019 novel coronavirus" or "coronavirus 2019" or "coronavirus disease 2019" or "2019-novel CoV" or "2019 ncov" or covid 2019 or covid19 or "corona virus 2019" or ncov-2019 or ncov2019 or "nCoV 2019" or 2019-ncov or Covid-19 or "Severe acute respiratory syndrome coronavirus 2" or "SARS-CoV-2" or "Covid 19" or "2019 novel coronavirus" or "coronavirus 2019" or "coronavirus disease 2019" or "2019-novel CoV" or "2019 ncov" or covid 2019 or covid19 or "corona virus 2019" or ncov-2019 or ncov2019 or "nCoV 2019" or 2019-ncov or Covid-19 or "Severe acute respiratory syndrome coronavirus 2" or "SARS-CoV-2" AND "Environmental Science") conversing literature from 1992 - 2023, the search yielded 2,903 records. These records were sorted by the citations they received since their publication. We set a cut-off of 100 citations, resulting in 126 Highly Cited papers (HCPs) for detailed analysis. Information on Publication year, citation count, funding sources, title, author, journal, country, institution, research area, and strategic keywords were collected from these HCPs. These HCPs were considered as those who received 100 or more citations. The most productive authors and institutions were those that contributed a maximum than the average number of publications, and the most impactful authors and institutions were those that had registered Citations Per Paper (CPP). Data was imported from the Web of Science (WoS) database into Microsoft Excel, VOSviewer and R Software for further analysis (Adya, and Inamadar, 2025). VOSviewer was used to visualise the collaboration network maps of countries, organizations, authors, journals, and keywords using co-authorship, co-citation, and keywords using co-occurrence analysis. Specifically, a co-citation network means that two items appear in a co-occurrence network, representing that the relationship of items is built according to the quantity of publications where they occur together. In co-authorship networks, nodes represent authors, organisations, or countries, which are connected when they share the authorship of a paper. The visualisation maps mainly consist of nodes and links with different colours (Ahmed and Das, 2024; Madhu *et al.*, 2025). Nodes in the visualisation map represented the analysed elements such as authors, journals, and keywords, and the size of the nodes indicated the number of citations or occurrences. The links between nodes reflected the relationship of co-citation or co-occurrence. An important parameter, Total Link Strength (TLS), was used to quantitatively evaluate the strength of links.

RESULTS

Annual citation trends

Table 1 presents a longitudinal analysis of citation metrics from 1992 to 2023, showcasing the evolution of citations over the years. The key parameters include Mean Total Citations per Article (MeanTCperArt), the Number of articles (N), Mean Total Citations per Year (MeanTCperYear), and Citable Years.

In the early years, particularly in 1992 and 2001, the MeanTCperArt values were significantly high, at 409.00 and 527.20, respectively, indicating highly cited publications. However, MeanTCperYear remained moderate (12.03 in 1992 and 21.09 in 2001) due to the long citable lifespan of these papers. Over time, there was a fluctuation in citations, with noticeable peaks in 2011 (MeanTCperArt: 483.17, MeanTCper Year: 32.21) and 2014 (MeanTCperArt: 299.00, MeanTCperYear: 24.92), indicating the presence of influential papers in these years.

From 2016 onwards, the citation pattern suggests an increase in citation impact per year, with MeanTCperYear peaking at 64.10 in 2021 and maintaining high values in 2022 (37.62) and 2023 (56.67). Despite having fewer citable years, these recent papers are receiving a higher annual citation rate, suggesting a growing relevance and immediate recognition in the research community. Overall, the trend indicates that while older papers have accumulated more citations over extended periods, recent papers exhibit higher annual citation rates, likely due to increased research visibility, digital dissemination, and evolving citation patterns.

Publication and citation trends

Figure 1 illustrates the growth of publications and citations related to "Global COVID-19 and Environmental Sciences Research: A Scientometric Analysis of Highly-Cited Publications." The x-axis represents the years from 1992 to 2025, while the y-axis on the left denotes the number of publications, and the y-axis on the right corresponds to the number of citations. The bars (light purple) indicate the number of publications per year, and the dark blue line represents the cumulative citations over time. From 1992 to around 2010, the research output remained relatively low, with only a few publications each year. A noticeable increase in the number of publications began in the early 2000s, peaking around 2008, suggesting growing interest in the intersection of environmental sciences and related topics. After some fluctuations, a significant rise in publications occurred between 2010 and 2018, demonstrating increased research attention in this domain. The highest number of publications was recorded around 2008, followed by another peak in 2017 and 2019.

Regarding citations, the trend remained relatively flat until approximately 2005, after which a gradual increase can be observed. The growth in citations became more prominent after 2010, aligning with the rise in publications. A sharp surge in citations is noticeable between 2016 and 2022, reaching a peak around 2021, indicating the heightened relevance of these studies during the COVID-19 pandemic. However, post-2022, there is a decline in both publications and citations, possibly due to a shift in research focus or saturation in the field.

Overall, the analysis suggests that research on COVID-19 and environmental sciences experienced a substantial increase in output and impact, particularly during the pandemic, with citations following a delayed but significant upward trend. The recent decline in 2024-2025 might reflect a stabilization phase as global research priorities evolve.

Most Productive and impactful countries

Top 20 Most Collaborative Countries in Global COVID-19 and Environmental Sciences Research. The United States (USA) leads the global collaboration in COVID-19 and environmental sciences research,

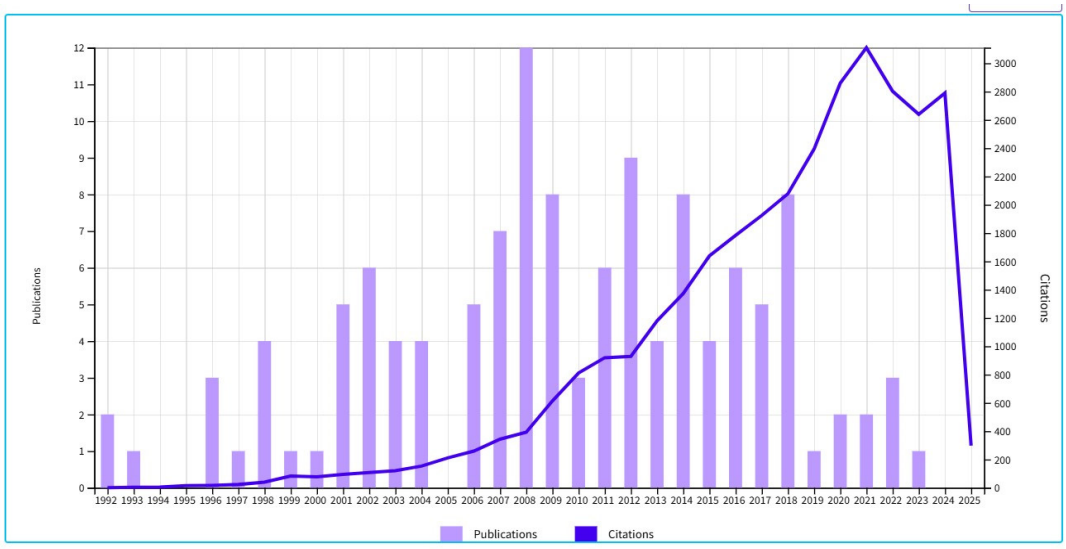

Figure 1: Global COVID-19 and Environmental Sciences Research Growth of publications and citations.

Table 1: Top Most productive and impactful countries.

Sl. No.	Countries/Regions	TP	% of 126	TC	CPP	h-index	TLS
1.	USA	85	67.46	21,781	256.25	85	72
2.	England	16	12.698	3,845	240.31	16	31
3.	Australia	14	11.111	3,326	237.57	14	14
4.	Canada	12	9.524	3,024	252	12	31
5.	Netherlands	11	8.73	1,802	163.82	11	30
6.	Germany	8	6.349	1,298	162.25	8	29
7.	Spain	8	6.349	1,397	174.63	8	38
8.	Belgium	6	4.762	2,302	383.67	6	24
9.	Peoples R China	6	4.762	1,768	294.67	6	10
10.	Sweden	6	4.762	1,241	206.83	6	14
11.	Denmark	5	3.968	2,151	430.2	5	16
12.	France	4	3.175	840	210	4	13
13.	Italy	4	3.175	600	150	4	13
14.	Norway	4	3.175	845	211.25	4	19
15.	Austria	3	2.381	517	172.33	3	11
16.	Finland	3	2.381	640	213.33	3	8
17.	South Africa	3	2.381	583	194.33	3	14
18.	Czech Republic	2	1.587	583	194.33	3	9
19.	Ireland	2	1.587	429	214.5	2	10
20.	Israel	2	1.587	412	206	2	5

contributing 85 records (67.46% of the total 126 publications). It has the highest total citations (21,781), Citation Per Publication (CPP) of 256.25, and an h-index of 85, highlighting its research impact and influence. Additionally, it has the highest Total Link Strength (TLS) of 72, indicating extensive collaboration networks. England follows with 16 publications (12.69%), 3,845 citations, and a CPP of 240.31. It shares a strong collaborative network with a TLS of 31, showing high research connectivity. Australia (14 records, 11.11%) and Canada (12 records, 9.52%) also exhibit high research influence with CPP values of 237.57 and 252, respectively. Canada has a notable TLS of 31, suggesting strong international collaborations. European nations, including the Netherlands (11 records, 8.73%), Germany (8 records, 6.35%), and Spain (8 records, 6.35%), show significant research contributions with substantial citation impacts. Spain has the highest TLS of 38 among European nations, indicating active research networking. Belgium (6 records, 4.76%) has an exceptional CPP of 383.67, suggesting its publications are highly influential. Denmark (5 records, 3.97%) leads in citation impact with a CPP of 430.2, despite a lower record count. China (6 records, 4.76%) also holds a strong position with a CPP of 294.67, but it has a relatively lower TLS (10), indicating fewer collaborative ties.

Other significant contributors include Sweden, France, Italy, Norway, and Austria, with varying research outputs and citation performances. Finland (CPP 213.33), South Africa (CPP 194.33), Czech Republic (CPP 194.33), Ireland (CPP 214.5), and Israel (CPP 206) contribute to research diversification but show lower publication counts and collaboration strengths.

Table 1 illustrates the dominance of the USA, England, Australia, and Canada in shaping high-impact research in COVID-19 and environmental sciences. European countries maintain a strong presence, particularly in collaborative research, while China and other emerging players are gaining influence in this field.

Figure 2 visually represents international research collaborations, where the size of each node (Country) indicates its research output and the connecting lines reflect the strength of co-authorship links. In this network, the USA is the dominant research hub, exhibiting the largest node and strong connections with several countries, including Canada, England, Germany, Australia, and the Netherlands, European countries, such as France, Sweden, and Italy, form a well-connected cluster, highlighting regional collaborations. Similarly, Australia and China maintain active collaborations, particularly in research regional collaborations. Similarly, Australia and China maintain a well-connected cluster, highlighting regional collaborations, Similarly, Australia and China maintain active collaborations, particularly in research-intensive fields. Multiple colours suggest different collaborative clusters, indicating regional or disciplinary research focus areas.

Leading Subjects

Table 2 indicates that the analysis of highly cited research on COVID-19 and environmental science reveals a strong emphasis on interdisciplinary subjects, with Environmental Sciences and Ecology leading as the dominant research area. This field accounts for 56 publications (44.44% of 126) and 16,684 Total Citations (TC), achieving an Average Citation per Publication (ACP) of 297.93. This indicates the significant role of environmental research in understanding COVID-19's ecological impacts and public health implications.

Science and Technology Other Topics follows with 16 papers (12.70%) and 4,002 TC, demonstrating a broad interest in technological innovations related to pandemic response, with an ACP of 250.13. Similarly, Public Environmental and Occupational Health (12 papers, 9.52%) shows a substantial impact with 2,579 TC and an ACP of 214.92, highlighting research on workplace safety, pollution, and disease transmission during COVID-19.

Highly technical fields such as Engineering (9 papers, 7.14%) and Toxicology (11 papers, 8.73%) also make notable contributions, with ACP values of 335.78 and 220.36, respectively. Engineering research has focused on innovations in medical devices, ventilation systems, and pandemic infrastructure, while toxicology explores the health effects of environmental contaminants on virus susceptibility.

Other key disciplines include Geography (7 papers, 5.56%), emphasizing spatial analysis of disease spread (ACP: 226.43), and Physics (6 papers, 4.76%), contributing modelling approaches to COVID-19 dynamics (ACP: 227.33). Biodiversity Conservation (3 papers, 2.38%) stands out with a high ACP of 335.33, underscoring research on wildlife interactions and zoonotic diseases.

Additionally, Materials Science (ACP: 220.5) and Geology (ACP: 319.75) have played roles in environmental monitoring and contamination studies. Astronomy and Astrophysics (ACP: 305), though seemingly unrelated, may involve satellite-based monitoring of environmental changes.

Overall, the data highlights a multidisciplinary approach to COVID-19 and environmental science research, with leading contributions from environmental health, engineering, toxicology, and computational sciences. The high citation impact in these fields reflects their crucial role in pandemic preparedness, response strategies, and understanding long-term environmental consequences.

Most Productive and impactful Institutions

Table 3 shows that the most productive and impactful organization, the University of California System is the leading institution in global COVID-19 and environmental sciences research, contributing 21 publications (16.67%) out of 126 highly-cited papers. It has the highest Total Citations (TC) of 4,650 and a Citation Per Publication (CPP) of 221.43. Additionally, it exhibits a strong h-index of 21 and the highest Total Link Strength (TLS) of 25, indicating extensive collaborative networks. Following this, the United States Department of Energy (DOE) holds a significant position with 9 papers (7.14%), 2,132 citations, and the highest CPP of 236.89 among top organizations, signifying a strong impact. The National Institutes of Health (NIH USA) contributed 8 papers (6.35%), with 1,810 citations and a CPP of 226.25, showcasing its major influence in this field. The NIH National Institute of Environmental Health Sciences (NIEHS)

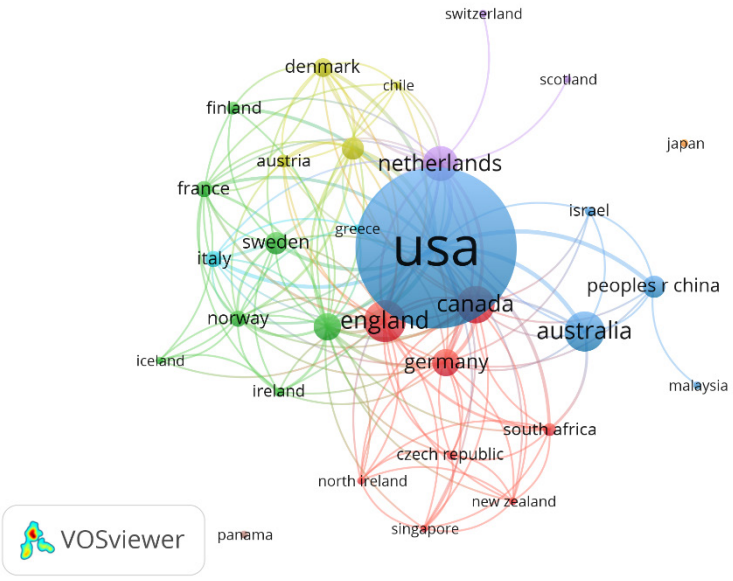

Figure 2: Bibliometric map based on the network of co-authorship relations among the top 20.

Table 2: Most productive research areas in Global COVID-19 and Environmental Science.

Sl. No.	Research Areas	TP	% of 126	TC	ACP
1.	Environmental Sciences Ecology	56	44.444	16,684	297.93
2.	Science Technology Other Topics	16	12.698	4,002	250.13
3.	Public Environmental Occupational Health	12	9.524	2,579	214.92
4.	Toxicology	11	8.73	2,424	220.36
5.	Engineering	9	7.143	3,022	335.78
6.	Chemistry	8	6.349	1,698	212.25
7.	Geography	7	5.556	1,585	226.43
8.	Computer Science	6	4.762	1,271	211.83
9.	Instruments Instrumentation	6	4.762	1,045	174.17
10.	Physics	6	4.762	1,364	227.33
11.	Spectroscopy	5	3.968	851	170.2
12.	Water Resources	5	3.968	1,205	241
13.	Biochemistry Molecular Biology	4	3.175	663	165.75
14.	Business Economics	4	3.175	823	205.75
15.	Geology	4	3.175	1,279	319.75
16.	Materials Science	4	3.175	882	220.5
17.	Astronomy Astrophysics	3	2.381	915	305
18.	Biodiversity Conservation	3	2.381	1,006	335.33
19.	Evolutionary Biology	3	2.381	490	163.33
20.	Genetics Heredity	3	2.381	480	163.21

and the University of California Berkeley both contributed 7 papers (5.56%) each, with TC values of 1,556 and 1,209, respectively. NIEHS has a slightly higher CPP (222.29) than Berkeley (172.71), reflecting its stronger research impact. Several universities, including the University of Michigan (292.5 CPP), the University of Wisconsin-Madison (248.5 CPP), and the University of Wisconsin System (248.5 CPP), each contributed 6 papers (4.76%) with substantial citation counts, making them key players in the field. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) from Australia has 5 papers (3.97%), but with a lower CPP (149) compared to other top institutions. Among environmental and governmental organizations, the United States Environmental Protection Agency (EPA) also stands out with 5 papers (3.97%), a high CPP of 254.6, and an h-index of 5, indicating its important role in the environmental aspects of COVID-19 research.

The Arizona State University (303.5 CPP) and Colorado State University (309 CPP), each with 4 papers (3.18%), demonstrate significant research contributions with high citation impact. Overall, the analysis highlights the University of California System, NIH, DOE, and major U.S. universities as the dominant contributors in this field. Institutions from Europe (University of London, Helmholtz Association) and Australia (CSIRO) also contribute significantly, though with lower record counts. The high TLS values for institutions like the University of California System (25), DOE (8), and NIH NIEHS (9) indicate strong global research collaboration networks.

Figure 3 shows the organizational collaboration map visually represents search partnerships between institutions worldwide. Each node represents an organization, with its size indicating research productivity and collaboration intensity. The connecting lines depict co-authorship relationships, where stronger and more frequent collaborations result in thicker lines. In this network, major research institutions such as the University of California, Berkeley, University of Michigan, Colorado State University, NIEHS (National Institute of Environmental Health Sciences), and Nature Conservancy emerge as central interconnected clusters with other universities and research organizations. These institutions form interconnected clusters with other universities and research organizations, such as Cornell University, Clark University, CSIRO, and Rutgers State University. Distinct coloured clusters indicate different research domains or geographical partnerships, highlighting regional and thematic collaboration partners. For instance, university domains or geographical partnerships, highlighting regional and thematic collaboration patterns. For instance, universities from North America, Europe, and Australia exhibit strong interconnections, emphasizing global research cooperation. Smaller nodes and peripheral organizations suggest emerging or specialized research contributions.

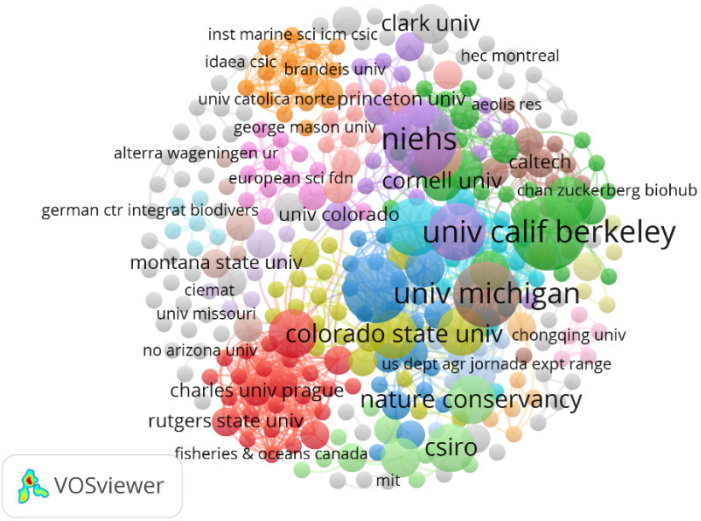

Figure 3: Biblopmetric map based on the network of co-authorship relations among the top 60 institutions.

Most productive and impactful authors

Figure 4 visualizes co-authorship relationships among researchers, with nodes representing authors and edges indicating collaborations. Larger nodes signify higher publications or citation counts, while different colours represent distinct clusters of closely collaborating researchers. In this network, central authors like "Woodruff, Tracey J." and "peters, Debra P.C." have strong co-authorship ties, suggesting influential roles in their respective research fields. The spread of smaller nodes and isolated authors indicates varying levels of collaboration intensity within the scholarly community.

Table 4 shows that the most productive authors in highly cited research on COVID-19 and environmental sciences are predominantly affiliated with leading research institutions in the USA, Australia, and Europe. Among them, Macdowell AA, Padmore HA (Lawrence Berkeley National Laboratory, USA), and Woodruff TJ (University of California San Francisco, USA) are the top contributors, each with 3 publications (2.38%). Woodruff TJ leads in Total Citations (TC) with 665 and has the highest Citation Per Publication (CPP) of 221.67 among these three. Padmore HA has the highest Total Link Strength (TLS) of 34, indicating extensive collaborative networks. Several authors contributed 2 highly cited publications (1.59%), with significant citation counts. Angela H. Arthington (Griffith University, Australia) has a CPP of 237, while Ballard HL (University of California Davis) has the highest impact with 875 total citations and a CPP of 437.5, showing strong influence in this field. Heap AD and Li J (Australia) have the highest citation impact (596.5 CPP), highlighting their research significance. Other notable authors include Poff NL (University of Canberra, Australia) with 897 citations (448.5 CPP) and Palmer MA (University of Maryland College Park) with 453 citations (226.5 CPP), both demonstrating strong research impact. In terms of international representation, Manceau A (European Synchrotron Radiation Facility, France), Navarro S (CSIC - Centro de Astrobiologia, Spain), and Hobday AJ (CSIRO, Australia) show strong contributions with high collaboration strength (TLS up to 38). Overall, Lawrence Berkeley National Laboratory, the University of California System, and Australian institutions dominate in authorship. The analysis highlights the crucial role of American, Australian, and European researchers in advancing the intersection of COVID-19 and environmental sciences research, with many authors engaging in extensive international collaborations.

Most productive and impactful journals

Table 5 indicates that the most productive journals in highly cited research on COVID-19 and environmental science reflect a strong interdisciplinary focus, covering environmental health, policy, ecology, and public health. Environmental Health Perspectives emerges as the most productive journal, contributing 10 publications (7.94% of 126) with 2,315 Total Citations (TC) and a Citation Per Publication (CPP) of 231.5. This highlights its critical role in research at the intersection of environmental health and COVID-19. Environmental Science Policy and Science of the Total Environment follow, each publishing 4 papers (3.18%). While Environmental Science Policy has 1,427 TC and a high CPP of 356.75, emphasizing its policy influence, Science of the Total Environment has an outstanding CPP of 424.67, showcasing its strong research impact. High-impact journals like Nature and Science contributed 4 papers each, but their CPPs (122.5 and 220.25, respectively) suggest a broader citation distribution. Biological Conservation (3 papers) and Environmental Modelling Software (3 papers) have high CPPs (335.33 and 305), indicating strong influence in biodiversity conservation and environmental modelling. Significantly, Global

Environmental Change**:** Human and Policy Dimensions and Science Technology and Human Values exhibit exceptional impact despite fewer publications. Global Environmental Change has 890 citations from 2 papers, making its CPP 445, reflecting significant influence in policy research. Science Technology and Human Values stands out with 1,248 citations from just 2 papers, achieving the highest CPP of 624, emphasizing the technological and social science dimensions of COVID-19 research.

These findings highlight the interdisciplinary nature of COVID-19 research in environmental science, with major contributions from environmental health, policy-making, sustainability, and social sciences. The high CPP values of certain journals further demonstrate the strong research impact of select publications, particularly those bridging science, policy, and public health.

Figure 5 illustrates the network of academic journals contributing to research in environmental science and related fields. Each node represents a journal, with its size indicating the volume of publications or citations associated with it. The links between nodes show co-citation relationships highlighting the interconnectedness of journals in disseminating scientific knowledge. The map reveals that Environmental Health Perspectives is the most influential journal, playing a central role in the network with strong connections to other key sources such as the science of the Total Environment. These journals form distinct clusters representing various environmental science subfields, including conservation biology, policy-making, sustainability, and ecological economics. Clusters with defined colours signify thematic groupings. For example, nature and Advanced Energy materials likely represent high-impact interdisciplinary sources, while Marine Pollution Bulletin and Environmental Science-Nano focus on specialized environmental issues. Additionally, journals like Social Studies of Science and Geoforum suggest an interaction between environmental research and social sciences.

Highly cited papers

Table 6 shows that the top 25 highly cited papers in COVID-19 and environmental science highlights key trends in scholarly impact. Turner (2007) leads with 1,444 citations and a normalized citation of 4.30, marking it as highly influential. Zhong (2001) demonstrates rapid impact with the highest citation rate of 103.40 per year. Papers by McKinley (2010) and Komarek (2008) also strong citation influence. Topics range from environmental monitoring, policy and conservation to climate change and sustainability.

Table 3: Top 20 most Productive and impactful Institutions.

Sl. No.	Affiliations	TP	% of 126	TC	CPP	h Index	TLS
1.	University of California System	21	16.667	4,650	221.43	21	25
2.	United States Department of Energy DOE	9	7.143	2,132	236.89	9	8
3.	National Institutes of Health NIH USA	8	6.349	1,810	226.25	8	6
4.	NIH National Institute of Environmental Health Sciences NIEHS	7	5.556	1,556	222.29	7	9
5.	University of California, Berkeley	7	5.556	1,209	172.71	7	9
6.	University of Michigan	6	4.762	1,755	292.5	8	4
7.	University of Michigan System	6	4.762	1,755	292.5	6	3
8.	University of Wisconsin Madison	6	4.762	1,491	248.5	6	7
9.	University of Wisconsin System	6	4.762	1,491	248.5	6	8
10.	Commonwealth Scientific Industrial Research Organisation CSIRO	5	3.968	745	149	5	4
11.	Consejo Superior De Investigations Cientificas CSIC	5	3.968	854	170.8	5	3
12.	United States Environmental Protection Agency	5	3.968	1,273	254.6	5	6
13.	University of California Davis	5	3.968	1,275	255	5	7
14.	University of London	5	3.968	718	143.6	5	6
15.	Arizona State University	4	3.175	1,214	303.5	4	10
16.	Arizona State University Tempe	4	3.175	1,214	303.5	4	2
17.	Colorado State University	4	3.175	1,236	309	4	6
18.	Cornell University	4	3.175	912	228	4	5
19.	Helmholtz Association	4	3.175	699	174.75	4	7
20.	Johns Hopkins University	4	3.175	537	134.25	4	8

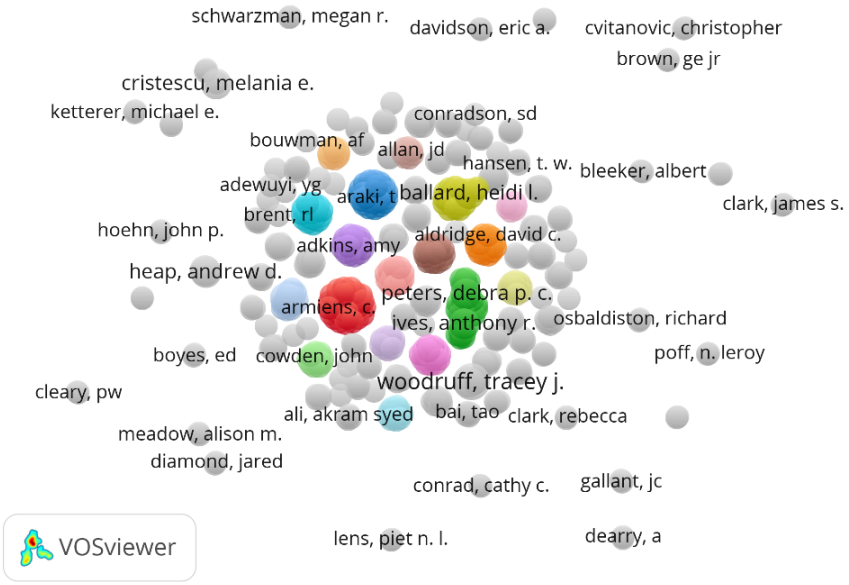

Figure 4: Collaboration Network Visualization of Authors.

Table 4: Bibliometric profile of the top 20 most productive and impactful authors.

Sl. No.	Authors	Affiliations	TP	% of 126	TC	CPP	h index	TLS
1.	Macdowell AA	Lawrence Berkeley National Laboratory, USA	3	2.381	547	182.33	3	5
2.	Padmore HA	Lawrence Berkeley National Laboratory, USA	3	2.381	547	182.33	3	34
3.	Woodruff TJ	University of California San Francisco, USA	3	2.381	665	221.67	3	24
4.	Angela H. Arthington	Griffith University	2	1.587	474	237	2	24
5.	Ballard HL	University of California Davis	2	1.587	875	437.5	2	23
6.	Celestre RS	Lawrence Berkeley National Laboratory	2	1.587	308	154	2	12
7.	Cristescu ME	McGill University	2	1.587	334	167	2	16
8.	Cvitanovic C	University of New South Wales Sydney	2	1.587	363	181.5	2	8
9.	GÃ³mez-elvira J	Instituto Nacional de Técnica Aeroespacial, INTA	2	1.587	366	183	2	5
10.	Heap AD	Symonston, Act, Australia	2	1.587	1,193	596.5	2	2
11.	Hobday AJ	Commonwealth Scientific and Industrial Research Organisation (CSIRO)	2	1.587	363	181.5	2	38
12.	Ives AR	University of Wisconsin Madison	2	1.587	240	120	2	2
13.	Li J	Anberra, Act, Australia	2	1.587	1,193	596.5	2	2
14.	Manceau A	European Synchrotron Radiation Facility, France	2	1.587	394	197	2	14
15.	Navarro S	CSIC - Centro de Astrobiologia (INTA)	2	1.587	366	183	2	38
16.	Palmer MA	University of Maryland College Park	2	1.587	453	226.5	2	36
17.	Peters DPC	United States Department of Agriculture (USDA)	2	1.587	255	127.5	2	14
18.	Poff NL	University of Canberra, Australia	2	1.587	897	448.5	2	21
19.	Sutton P	University of California San Francisco, USA	2	1.587	411	205.5	2	38
20.	Tamura N	Lawrence Berkeley National Laboratory	2	1.587	308	154	2	24

TP: Total publications, TC: Total Citations, CPP: Citation per paper, TLS: Total Link strength.

Table 5: Top 20 most productive and impactful journals.

Sl. No.	Publication Titles	TP	% of 126	TC	CPP	h Index	IF2023
1.	Environmental Health Perspectives	10	7.937	2,315	231.5	10	2.41
2.	Environmental Science Policy	4	3.175	1,427	356.75	4	1
3.	Nature	4	3.175	490	122.5	4	11.3
4.	Science	4	3.175	881	220.25	4	9.9
5.	Biological Conservation	3	2.381	1,006	335.33	3	1.32
6.	Ecological Economics	3	2.381	521	173.67	3	1.59
7.	Environmental Modelling Software	3	2.381	915	305	3	0.91
8.	Frontiers In Ecology and The Environment	3	2.381	708	236	3	1.88
9.	Science of The Total Environment	3	2.381	1,274	424.67	3	1.62
10.	Analytical And Bioanalytical Chemistry	2	1.587	432	216	2	0.96
11.	Applied Spectroscopy	2	1.587	371	185.5	2	0.96
12.	Environmental Management	2	1.587	347	173.5	2	0.55
13.	Environmental Science Technology	2	1.587	763	381.5	2	1.56
14.	Freshwater Biology	2	1.587	691	345.5	2	0.84
15.	Geoforum	2	1.587	265	132.5	2	1.34
16.	Global Environmental Change Human and Policy Dimensions	2	1.587	890	445	2	2.38
17.	Journal of Autoimmunity	2	1.587	377	188.5	2	1.88
18.	Journal of Environmental Management	2	1.587	353	176.5	2	1.49
19.	Review of Scientific Instruments	2	1.587	308	154	2	0.36
20.	Science Technology Human Values	2	1.587	1,248	624	2	1.02

Significant keywords

Table 7 illustrates that the keyword occurrences in highly cited publications on COVID-19 and environmental science reveal significant themes related to climate change, pollution, biodiversity, and public health risks.

"Climate Change" and "Exposure" emerge as the most frequently occurring keywords, each appearing 7 times, with Total Link Strengths (TLS) of 88 and 77, respectively. These high occurrences reflect the global concern about how climate change influences pandemic spread, vulnerability, and long-term environmental consequences. "Exposure" is particularly crucial in understanding how environmental pollutants and climate conditions affect virus transmission and human susceptibility.

"Conservation" (6 occurrences, TLS 76) and "Biodiversity" (5 occurrences, TLS 69) highlight the strong linkage between ecosystem health and disease outbreaks. Research suggests that habitat destruction and biodiversity loss increase the risk of zoonotic diseases like COVID-19. Similarly, "Ecosystems" (6 occurrences, TLS 52) and "Ecosystem Services" (3 occurrences, TLS 39) indicate the growing recognition of natural ecosystems' role in disease regulation and climate resilience.

Environmental concerns are prominent, with "Environment" (5 occurrences, TLS 66) and "Pollution" (4 occurrences, TLS 61) emphasizing how air and water pollution exacerbate COVID-19 severity and transmission. "Citizen Science" (5 occurrences, TLS 61) suggests an increased reliance on community-driven research for monitoring pandemic-related environmental changes.

Public health and risk assessment themes are evident with "Disease" (5 occurrences, TLS 58), "Risk Assessment" (4 occurrences, TLS 58), and "Uncertainty" (5 occurrences, TLS 49). These keywords reflect the scientific community's focus on pandemic modeling, risk evaluation, and decision-making under uncertain conditions. "Climate" (4 occurrences, TLS 51) and "Atmosphere" (3 occurrences, TLS 49) highlight the role of atmospheric conditions in pandemic response and virus survival. Sediment (3 occurrences, TLS 46), "Prediction" (3 occurrences, TLS 45), and "Monitoring" (3 occurrences, TLS 38) point to environmental tracking efforts related to wastewater surveillance for virus detection. "Public Participation" (4 occurrences, TLS 45) and "Recovery" (3 occurrences, TLS 44) emphasize community engagement and sustainable recovery strategies post-pandemic.

Finally, "Environmental Impact Assessment" (3 occurrences, TLS 37) underscores the importance of evaluating the pandemic's long-term environmental and policy implications. The keyword analysis reflects a multidisciplinary approach, integrating climate

science, ecology, public health, and environmental management to understand and mitigate COVID-19's global impact.

Figure 6 provides a visual representation of the most frequently occurring and interconnected research keywords in the dataset. Each node represents a keyword, with its size indicating the frequency of occurrence, while the links between nodes reflect co-occurrence relationships. Revealing thematic clusters. From this map climate change, ecosystems, and disease emerge as the most dominant themes suggesting strong research focuses on environmental changes and their biological and ecological impacts. These keywords form dense clusters with related terms such as adaption, air pollution, waste water, and endocrine disruptors, highlighting interdisciplinary research involving environmental science, public health, and policy. Also, the presence of terms like catalysis, contaminants, and disinfection by-products suggests significant attention to chemical and industrial influences on ecosystems and water quality. Similarly, agricultural land use, pesticides, and bioremediation indicate research efforts directed toward sustainable agricultural practices and pollution control. Additional clusters such as multiple-scattering calculation, speciation, and beliefs suggest broader research interests, including theoretical environmental modelling, evolutionary biology, and social aspects of climate change. The inclusion of atmospheric mercury and air temperature highlights concerns about air quality and climate dynamics.

DISCUSSION

The scientometric analysis of highly cited publications on COVID-19 and environmental sciences provides critical insights into the research landscape, highlighting key journals, research areas, and trending keywords. The study reveals that Environmental Health Perspectives is the most productive journal, publishing the highest number of influential studies in this domain. Other notable journals, such as Environmental Science Policy, Science of the Total Environment, and Nature, have also significantly contributed to advancing knowledge in this field. The high citation counts and impact factors of these journals underscore their pivotal role in shaping global environmental and health policies during the pandemic.

In terms of research areas, Environmental Sciences and Ecology (44.44%) dominate the field, indicating the strong intersection between the pandemic and ecological concerns. Other leading disciplines, including Science and Technology Studies, Public Health, Toxicology, Engineering, and Geography, demonstrate a multidisciplinary approach to studying the pandemic's impact on ecosystems, human health, and technology-driven solutions. The high Citation-Per-Paper (CPP) values in Engineering (335.78), Geology (319.75), and Astronomy and Astrophysics (305) suggest that scientific innovations and modelling techniques have been instrumental in understanding and mitigating the pandemic's environmental consequences.

Keyword analysis further reinforces the significance of climate change (TLS 88), exposure (TLS 77), conservation (TLS 76), and biodiversity (TLS 69) in COVID-19 research. The high occurrence of terms such as pollution, disease, risk assessment, and public participation underscores the need for sustainable policies to manage the pandemic's environmental aftermath. The presence of monitoring, environmental impact assessment, and prediction indicates the increasing role of data-driven approaches and technological interventions in tracking and mitigating environmental and health crises.

Overall, this study highlights the interdisciplinary nature of COVID-19 and environmental science research, emphasizing the

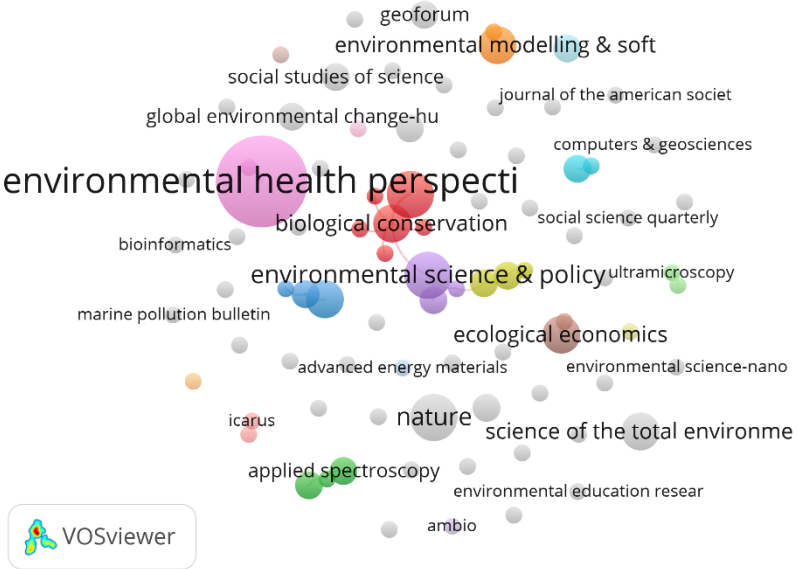

Figure 5: Network Visualization of Journals.

Table 6: Top 25 highly cited papers.

Sl. No.	Paper	DOI	Total Citations	TC per Year	Normalized TC
1.	Turner BL, 2007, P Natl Acad Sci USA	10.1073/pnas.0704119104	1444	76.00	4.30
2.	Guston DH, 2001, Sci Technol Hum Val	10.1177/016224390102600401	937	37.48	1.78
3.	Adewuyi YG, 2001, Ind Eng Chem Res	10.1021/ie010096l	853	34.12	1.62
4.	Huang IB, 2011, Sci Total Environ	10.1016/j.scitotenv.2011.06.022	843	56.20	1.74
5.	Conrad CC, 2011, Environ Monit Assess	10.1007/s10661-010-1582-5	839	55.93	1.74
6.	Sarewitz D, 2004, Environ Sci Policy	10.1016/j.envsci.2004.06.001	834	37.91	2.42
7.	Mckinley Dc, 2017, Biol Conserv	10.1016/j.biocon.2016.05.015	673	74.78	2.55
8.	Komárek M, 2008, Environ Int	10.1016/j.envint.2007.10.005	666	37.00	2.86
9.	Li J, 2011, Ecol Inform	10.1016/j.ecoinf.2010.12.003	655	43.67	1.36
10.	Wynne B, 1992, Global Environ Chang	10.1016/0959-3780(92)90017-2	653	19.21	1.60
11.	Sauvé S, 2016, Environ Dev	10.1016/j.envdev.2015.09.002	585	58.50	2.01
12.	Poff NL, 2010, Freshwater Biol	10.1111/j.1365-2427.2009.02272.x	557	34.81	1.87
13.	Blum JD, 2014, Annu Rev Earth Pl Sc	10.1146/annurev-earth-050212-124107	549	45.75	1.84
14.	Li J, 2014, Environ Modell Softw	10.1016/j.envsoft.2013.12.008	538	44.83	1.80
15.	Zhong SF, 2021, Environ Sci Technol	10.1021/acs.est.1c01339	517	103.40	1.61
16.	Osbaldiston R, 2012, Environ Behav	10.1177/0013916511402673	487	34.79	2.12
17.	Hart JK, 2006, Earth-Sci Rev	10.1016/j.earscirev.2006.05.001	461	23.05	1.90
18.	Cao X, 2016, Adv Energy Mater	10.1002/aenm.201600665	442	44.20	1.52
19.	Kriebel D, 2001, Environ Health Persp	10.2307/3454986	431	17.24	0.82
20.	Kirchhoff CJ, 2013, Annu Rev Env Resour	10.1146/annurev-environ-022112-112828	364	28.00	1.49
21.	Poff NL, 2003, Front Ecol Environ	10.1890/1540-9295(2003)001[0298:RFAWWE]2.0.CO;2	340	14.78	1.71
22.	O'fallon LR, 2002, Environ Health Persp	10.1289/ehp.02110s2155	331	13.79	1.86
23.	Lenz M, 2009, Sci Total Environ	10.1016/j.scitotenv.2008.07.056	325	19.12	2.05
24.	Miller C, 2001, Sci Technol Hum Val	10.1177/016224390102600405	311	12.44	0.59

Sl. No.	Paper	DOI	Total Citations	TC per Year	Normalized TC
25.	Rooney AA, 2014, Environ Health Persp	10.1289/ehp.1307972	310	25.83	1.04

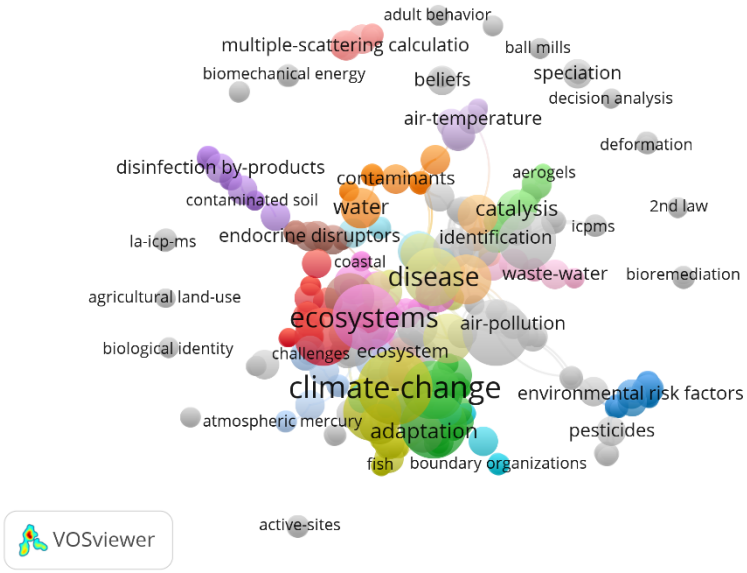

Figure 6: Co-occurrence map of the most significant keyword.

Table 7: Top 20 Most Significant Keywords.

Rank	Keyword	Occurrence	TLS
1	Climate Change	7	88
2	Exposure	7	77
3	Conservation	6	76
4	Biodiversity	5	69
5	Environment	5	66
6	Citizen Science	5	61
7	Pollution	4	61
8	Disease	5	58
9	Risk assessment	4	58
10	Ecosystems	6	52
11	Climate	4	51
12	Atmosphere	3	49
13	Uncertainty	5	49
14	Sediment	3	46
15	Prediction	3	45
16	Public Participation	4	45
17	Recovery	3	44
18	Ecosystem Services	3	39
19	Monitoring	3	38
20	Environmental impact assessment	3	37

need for collaborative efforts between ecologists, health experts, policymakers, and technologists. The findings suggest that future research should focus on long-term environmental recovery strategies, climate resilience, and public health preparedness to address future pandemics effectively. By integrating scientific advancements with sustainable development goals, this body of research contributes to a resilient and environmentally conscious post-pandemic world.

CONCLUSION

The scientometric analysis of highly-cited publications in Global COVID-19 and Environmental Sciences Research reveals significant trends in research productivity and scholarly impact over the past three decades. The findings demonstrate an evolving research landscape, particularly with a remarkable surge in publications and citations during the COVID-19 pandemic. From 1992 to the early 2000s, research in environmental sciences related to public health and pandemics remained relatively underexplored, with sporadic publications and limited citations. However, a gradual increase in research output was observed from the mid-2000s onward, reflecting growing awareness of environmental factors influencing public health. The first notable rise in publications occurred between 2008 and 2018, indicating increasing academic and policy-driven interest in the field. A significant shift emerged in 2020, coinciding with the COVID-19 pandemic. Research publications saw a sharp rise, likely fuelled by global urgency to understand the environmental implications of the pandemic, such as air pollution reduction, climate change impacts, and public health policies. This period also witnessed an exponential increase in citations, underscoring the relevance and impact of these studies in informing scientific discourse, policymaking, and mitigation strategies. The peak in citations around 2021 suggests that the findings from this body of research were extensively referenced and integrated into broader scientific and policy frameworks. Post-2022, a decline in both publications and citations is observed, likely due to a shift in research priorities as the global focus moved beyond immediate pandemic-related concerns. While the publication count dropped significantly in 2024-2025, the accumulated citations suggest a lasting influence of the highly-cited works produced during the pandemic. This decline could also indicate saturation in research on the direct environmental effects of COVID-19, leading scholars to explore new intersections or refine existing findings. The study highlights the dynamic evolution of research at the interface of COVID-19 and environmental sciences. The surge in research output during the pandemic underscores the scientific community's rapid response to global crises. The high citation impact reflects the critical role of environmental factors in understanding and mitigating pandemic effects. While recent trends suggest a decline in publication volume, the long-term scholarly and policy impact of this research remains significant. Future research may focus on the post-pandemic environmental recovery, sustainable health strategies, and the broader implications of pandemics on ecological resilience and climate action.

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ABBREVIATIONS

HCPs: Highly cited papers; **TP:** Total publications; **TC:** Total Citations; **CPP:** Citations per paper; **TLS:** Total link strength; **IF:** Impact Factor.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

CM: Collection of data, analysis of data, manuscript writing, and editing. TS: Conceptualisation, literature search, collection of data, analysis of data, and Correspondence. All authors read and approved the final manuscript.

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