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Global Trends in Poliomyelitis Research: A Bibliometric Analysis from 1857–2019

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ABSTRACT

The evolution of poliomyelitis (polio) research, an acute viral infection predominantly affecting children and ranging from mild illness to disabling paralysis, was systematically evaluated through a bibliometric analysis of publications from 1857 to 2019. Six thousand one hundred thirty-nine polio-related publications were extracted from the Web of Science and Scopus databases, employing 'Polio' as the keyword. Publications were predominantly in article format (71.16%), with English-language documents constituting 30% of the dataset. The analysis, executed using EndNote, Microsoft Excel, R (Biblioshiny), and VOSviewer, identified 2014 as the peak year of polio literature output, featuring 340 publications. A shift from single to collaborative authorship was observed, with multiple authorship patterns emerging more prominently. This trend highlights a transition towards interdisciplinary collaboration in the field. Despite the dominance of articles, a diverse array of sixteen document types was catalogued. The journal 'Vaccine' was the pivotal publication venue, representing a nexus for polio-related discourse. The institutional analysis placed the World Health Organization at the epicenter of polio research, with universities and private research entities following suit. The geographical spread of contributions was vast, covering 114 regions. Nonetheless, a significant proportion of the literature (33.5%) remained uncited, suggesting an untapped potential for research impact. Citation analysis yielded an average citation rate of 9.52%, and co-citation analysis unveiled a network of 4,758 references despite incomplete citation data in several records. Visualization maps elucidated recurrent thematic terms such as 'polio', 'children', 'eradication', 'vaccine', and 'virus', indicating the focal points of scholarly communication. This study not only delineates the historiography of polio research but also underscores the necessity for enhanced dissemination and integration of findings to fortify the global health response to poliomyelitis.

1. INTRODUCTION

Highly contagious, poliomyelitis (polio) is transmitted predominantly via the fecal-oral route, primarily in areas afflicted by epidemics, where polioviruses may infect entire human populations. The disease's latency—from initial exposure to symptom onset—usually spans six to twenty days, with a broader range of three to thirty-five days possible. Following infection, viral particles are shed in feces for several weeks. Transmission occurs primarily through ingesting contaminated food or water, with secondary transmission via the oral-oral route. The infectious period extends from seven to ten days post-symptom onset, but the virus can be excreted and potentially transmitted as long as it remains in the feces. Factors such as immune deficiency and malnutrition increase susceptibility to infection and can also exacerbate the severity, potentially leading to paralysis.

Globally, two types of vaccines are instrumental in the fight against polio. Both are designed to confer immunity and interrupt person-to-person transmission of the virus, thereby protecting individuals and the wider community. The pioneering vaccine, featuring an attenuated strain of the virus, was developed by microbiologist Hilary Koprowski and first administered to a child in 1950. Subsequently, Jonas Salk introduced an inactivated poliovirus vaccine at the University of Pittsburgh in 1952, followed by Albert Sabin's development of a live oral vaccine. After three doses, over 95% of recipients achieve protection from all three poliovirus types. Notably, pictorial evidence of polio dates back to prehistoric times.

Paralytic polio outbreaks, unknown before the 20th century, began to surface in Europe and the United States around 1900. The first documented outbreak occurred in Louisiana in 1841,

with a fifty-year hiatus until a subsequent report of 26 cases in Boston in 1893. The widespread adoption of polio vaccines in the 1950s precipitated a marked decrease in incidence across many industrialized nations. In 1988, the World Health Organization (WHO), UNICEF, and The Rotary Foundation launched a concerted global effort to eradicate polio, which achieved a 99% reduction in cases—from an estimated 350,000 in 1988 to 483 by 2001. Currently, the incidence fluctuates between 1,000 to 2,000 cases annually. As of the WHO's 2015 Annual Report, polio remains endemic in Pakistan and Afghanistan, with sporadic re-emergence in other nations, including developed ones.

The present study employs a bibliometric approach to analyze a corpus of 6,139 polio-related publications from 1857 to 2019, extracted from the Scopus and Web of Science databases using 'Polio' as the search term. Employing analytical tools such as EndNote, Microsoft Excel, R (Biblioshiny), and VOSviewer, the research delineates the trajectory of polio literature, examining document types, language distribution, author collaboration patterns, journal activity, and contributions by country and institution, along with citation and co-citation analyses to identify prevailing terms in the discourse.

This paper is structured as follows: Section 2 presents a detailed literature review, while the methodology is delineated in Section 3. Section 4 discusses the experiments and findings, and the paper concludes with Section 5, which also provides future research directions.

2. LITERATURE REVIEW

A lot of bibliometric analysis research was done in the field of medical sciences. Here, we review some related literature related to medical sciences, such as the analysis of critical issues in healthcare integrity. Pandey et al. [1] analyze essential healthcare integrity matters. They report that managing data integrity is a difficult task for the researcher. Therefore, this study makes a scientometrics analysis of the research publications in healthcare data integrity. This paper highlights the data integrity issues in healthcare and provides a literature review of the previous findings. Moreover, they discuss the methodology and issues and give a road map to future researchers by giving them various ideas. The concluding part of the paper presents an objective and sensitivity analysis for finding the difficulties in the studies while informing about the feasible solutions.

Esmaeilpour-Bandboni et al. [2] conducted a bibliometric analysis aimed at performing analysis of Radiology, Nuclear Medicine, and Medical Imaging articles written by Iranian researchers, published in journals and extracted from WoS and Scopus databases from 2001 to 2016. Three thousand three hundred thirty-five documents were retrieved. HistCite, Microsoft Excel, and VOSviewer were used to analyze the data. The study analyzes that Iran's contribution was meagre in both databases, i.e., WoS (0.32%) and Scopus (0.52%). The Tehran University of Medical Sciences was the database's most contributing institution. According to these findings, the study concludes that Iran may contribute with the USA, Japan, and Germany to increase the publication count. On the other hand, our research is not limited to a particular country and covers more than 150 years of Polio research.

In recent years, bibliometric analysis has been widely administered to analyze and evaluate scientific research publications on other viral diseases. We discuss the literature review on some diseases and viruses such as COVID-19, Coronavirus, Celiac disease, Poliovirus, Echinococcosis disease, Alzheimer's disease, Leishmaniasis disease, Rotavirus, cancer disease and Zika virus. Colavizza et al. [3] analyzed the COVID-19 Open Research Dataset (CORD-19) of publications on COVID-19 and coronavirus research. They compare the CORD-19 account with the Web of Science database. On one hand, the indication is that CORD-19 extends beyond COVID-19 and coronavirus studies. On the other hand, it might not encompass a significant portion of the literature solely dedicated to COVID-19 and coronaviruses, suggesting a potential omission in the dataset. They thoroughly analyzed CORD-19 in different ways. They generated a map of interconnected terms sourced from COVID-19 publications. A topic modeling analysis indicated that CORD-19 publications connect to medical research encompassing various viruses, including COVID-19 and coronaviruses. Predominant themes within CORD-19 include studies on public health, epidemics, molecular biology, and a spectrum of viruses like coronaviruses and influenza. Using Altmetric data, 46,996 publications were explored on CORD-19. They found that 4,096 publications belong to the year 2020. They selected social media engagements concerning CORD-19 publications, focusing on platforms like Altmetric, including blogs, Twitter, news media, policy documents, and citations in Wikipedia. Notably, Twitter dominated the interactions, comprising over 95% of all social media interactions. News mentions accounted for 3.6% of the engagement, followed by blog citations at 0.6%, highlighting their relative importance in this context. Our research also focuses on a virus. However, the number of publications is much lesser.

Hossain [4] discussed in his work that the coronavirus (COVID-19) disease is the primary health concern due to its infective and global distribution. He performed the bibliometric analysis to evaluate the current scientific literature to find the development of knowledge on coronavirus. A total of 422 records were extracted, with 1,652 authors. One thousand five hundred eighty-one documents had multiple-authored documents. Moreover, 2.47 citations were received on average for each document. The author, E. Mahase, had the highest number of publications (n=13). It also includes information about the top 10 journals which publish articles on COVID-19. British Medical Journal was the top journal with 47 articles. We believe the data could be more extensive according to the state-of-the-art bibliometric analysis of COVID-19. Even the number of publications considered in our research is more than ten times.

Demir and Comba [5] explain in their work that Celiac disease (CD) is an immune disease in which people cannot eat gluten because it can destroy the small intestine. They analyze the publications on celiac disease and find the related trends about this disease, such as top articles, journals, and countries. The data were downloaded from the Web of Science database between 1980 and 2018. It was found that 13,306 articles related to celiac disease were downloaded. The most popular research area on CD was gastroenterology hepatology (2,703, 41.3%). They also analyze the publications during the next ten years, from 2019 to 2028. The Journal of Pediatric Gastroenterology and Nutrition was regarded as the most active journal. They also made the co-citation analysis and term analysis just like our research.

The aim of the paper by Ravi and Jeyshankaris [6] is to

make a scientometrics analysis of polio research papers in India. The data were downloaded from the WoS database for this purpose. The study period was quite limited (1994–2018). They found that India published 488 records on Polio; all publications are in English, and publishing was done in different journals. The study tells us that India published most of its publications (44) in 2017. The document type was also analyzed. It was found that from 488 records, 317 are articles, whereas letters, proceeding papers, reviews, and meeting abstracts are also present. While considering the global citations, it was found that 20% of records did not receive any global citations. In local citations, about half, i.e., 49.5%, did not get any single local citation, while only one record had more than 100 citations. Of 488 papers, 76 have single-authored documents, and 73 have joint authors. The most productive author is T. J. John, who has 41 publications. The journals contributing to this Polio research are 19. By contrast, our research is not limited to a particular country and contains much more papers. Furthermore, we used WoS and Scopus to retrieve the publications.

Ma et al. [7] stated that both humans and animals are affected by Echinococcosis disease caused by the larval stage of Echinococcus. Scientists tried to minimize this viral disease, but many cases have been reported in the last twenty years. Echinococcus, which is a pandemic, is found in sheep, cattle, and dogs. The humans were affected directly or indirectly by eating foodstuff or drinking water contaminated with Echinococcosis. This virus causes cysts in organs such as the liver and lungs. The relevant data were retrieved from the Web of Science database, and hot topics and trends about this disease were evaluated. The data were visualized using citeSpace software. A total of 7,775 articles were downloaded. The period between 2008 and 2017 was found to be a fast development period. France was considered the most represented country in this research area (n=582/7,688). The University of Zurich was at the top. More than 22,445 authors contributed to this research, with P. S. Craig appearing in 171 publications. They also analyzed the citations and co-citations. The top cited author was J. Eckert (1,508 citations).

Dong et al. [8] made a bibliometric analysis of Alzheimer's disease worldwide, particularly in China. The WoS and PubMed databases were selected for search with data from 1988 to 2017. One hundred eighty-one thousand one hundred sixteen articles were downloaded and analyzed. According to this research, 30.93% were global publications, and 95.31% were from China. A total of 8,935 journals participated in the publication of this disease. The Neurobiology of Aging journal published the most articles, with 5,206 publications. Many organizations worked together and sponsored 11,809 articles.

Ram [9] contributed to the bibliometric analysis of Leishmaniasis disease. According to WHO, Leishmaniasis is one of the neglected diseases in the world, which has become more challenging for the medical sciences. The disease has spread to 98 countries, which is alarming. It is caused by the bite of phlebotomine sandflies on humans, dogs, foxes, and rats. For this analysis, 39,302 articles on Leishmaniasis are fetched from the Scopus database. The time duration is selected from 1968 to 2017 (50 years). Comparing the global publications on Leishmaniasis with India, 2008–2017 seems to be the most productive years for both. In the case of India, it is 60.34% and globally, it is 44.64%. The USA is the most productive country for Leishmaniasis research, with 7,609 papers (19.36%). Similarly, India was ranked fifth with 3,395 papers. Hirsch Index (h-index) is also calculated. The USA has the highest h-index (211) and citation rate (3,17,646 citations). The citation rate per paper is 1.75. Indian Institute of Chemical Biology, Kolkata, has 566 articles published on Leishmaniasis and remains at the top. The most active journal in this research is PLOS Neglected Tropical Diseases, with 86 publications and 2.54% of the share in total papers published. Regarding international collaboration, India has the most collaborated research with the USA (339 articles; 10% share). There were six articles which received more than 500 citations.

Koster et al. [10] reported that Rotavirus is the leading cause of diarrheal disease. Every child in the world is affected by this disease at least once by the age of five. A scientific analysis was made to identify the quantity and quality of research articles on Rotavirus. From 1900 to 2013, 5,906 publications were published in 138 countries. The USA authored 2,037 articles, accounting for 34.5% of all publications. They also made a gender analysis of authors, finding that most of the authors are women and from Brazil. They also made the cooperation and subject analysis.

Singh [11] studied the Zika virus, which is transmitted through the bite of mosquitoes and was initially found in monkeys. Later 1952, it was found in humans in Uganda, America, and Africa. It mainly affects pregnant women, leading to severe congenital disabilities like microcephaly. After applying a filter to data, 567 documents remained. Lotka's law was used to analyze the authors' productivity, and Broadford's law was used to find the distribution pattern of articles. The authorship distribution did not align with Lotka's law, indicated by a value of n = 2, suggesting an irregular pattern. However, the distribution of articles across journals closely adhered to Bradford's law of scattering. This confirms the presence of a select few core journals that significantly contribute to Zika virus research.

Basu et al. [12] discussed the cancer disease and conducted a scientometric analysis on herbal medicine for cancer treatment. Cancer is increasing health problems worldwide, especially with an increase in city life, population, and changes in lifestyle and environment. According to WHO, it is the second major cause of death worldwide. The data were downloaded from Medline, Scopus, and Web of Science databases, while most of the data belonged to WoS and was consequently used for analysis. Seventeen thousand authors belonged to 135 countries and 3,900 different institutions. The data were published in 1,290 different journals and got 82,879 citations. The data were divided into periods, followed by the analysis of period-wise publication growth.

Missen et al. [13] analyzed Pakistan's social science and science disciplines. Two thousand publications were examined, which belong to 50 authors of different disciplines. This analysis has three levels: Research, domain, and field level. They discussed single and multiple authors of articles, readability scoring, title format, publication rate, gender-wise contribution of researchers, and contribution of PhD students in research publications. This analysis found that more research is being conducted on the science discipline than the social science discipline. It was also discovered that the readability scores of authors changed with time, while the readability score of science articles was higher than the social science ones.

Fuzzy logic resolved many problems in the research areas and various applications, like mobile computing, for data analysis and cloud computing [14]. Researchers have tried to make many changes in fuzzy logic within the last few decades. For analyzing fuzzy logic, 410 research publications were

downloaded from the Web of Science (WoS) database. This research answers various questions related to essential concepts of hesitant fuzzy sets. Furthermore, it determines co-authorship patterns, research areas of hesitant fuzzy sets, contributions of countries with various research contributions, co-citation patterns, and the bibliographic coupling for the institution in this field.

Yang et al. [15] performed an analysis on hepatocellular carcinoma (HCC) using magnetic resonance imaging (MRI). With the development of MRI, many articles have been published. A total of 835 articles on MRI were published from 2008 to 2017. Journal of Magnetic Resonance Imaging has the most publications (79 or 9.46%). South Korea is the most active contributor to MRI publications, with 199 publications (21.82%). In the top 10 co-cited authors, J. Bruix is considered first in rank with 398 citations. Forty-seven of the most common keywords were found, with microvascular invasion being the most popular during the last three years. Therefore, publications on HCC MRI continuously increased from 2008 to 2017.

Senel and Demir [16] made a bibliometric analysis of the articles about religion and health between 1975 and 2016. Fields like religion and fitness have become growing areas of study, but only a few bibliometric studies have been made in these fields. The WoS database found two thousand six hundred eighty-three research articles. The original articles were 1,655, making 62.1% of the total, whereas the remaining are letters, books, and proceeding papers. With 1,665 (62.45%) publications, the USA has the highest chunk of publications. Cornell University was found at the top with 73 papers. Two thousand nine hundred seventy-three keywords were considered for use (n = 253, 250, 97, 71, and 41 times).

Chandra [17] explained in his article the scientometrics techniques used to study the evolution of entrepreneurship between 1990 and 2013. He used a combination of topic mapping, author citation analysis, and co-citation analysis. Moreover, he also made a visualization graph to show the hot and trending topics. Prakash and Arumugam [18] analyze the growth of literature related to biotechnology in India between 2002 and 2016. The Scopus database is used to analyze Indian contributions to biotechnology literature. The study analyzes the performance based on many parameters such as literature publishing trends, authorship and co-authorship patterns, collaboration patterns, top journals by the scientists and according to the number of citations. The number of articles published from 2002–2016 is 5,514. The trend is going upward according to the number of published papers.

Kullenberg and Kasperowski [19] stated that citizen science involves the public in research to improve scientific knowledge. This study obtained two data sets (N=1,935, N=633) from the WoS database. The results reveal that there were three main points. First, the citizens used different methodologies for collecting and classifying data. Second, the citizens are involved in collecting the geographical data. Third includes public participation related to environmental and health issues.

In another paper, Moraes et al. [20] showed that Mercury (Hg) has a hazardous effect on humans and wildlife. Because of its high toxic capacity in food, mercury is classified as a persistent toxic substance (PTS). It is obtained from natural sources and enters the environment from anthropogenic sources. Amazon rain forests are relevant in this regard on a global scale. Scientometrics analysis was applied to find out about the latest trends of publications on mercury. The data were collected between 1991 to 2017.

Fang et al. [21] studied climate change and tourism interactions. This has been one of the most critical research areas in tourism during the last few years. For this analysis, 976 documents were extracted between 1990 to 2015. Later, they identified and visualized the collaboration network of the authors of these publications to find the emerging trends. They analyzed from their findings that publications in this area are constantly increasing. The most productive authors belong to the USA, Canada, and Europe. They find out the most trending topics about climate, such as tourist behavior and response toward the environment.

The extensive analysis of diverse fields showcases the breadth of bibliometric research conducted across numerous scientific disciplines.

Various health-related studies demonstrated extensive bibliometric analysis: Esmaeilpour-Bandboni et al. [2] evaluated Iranian research contributions in Radiology, while Hossain [4] reviewed the current scientific literature on coronavirus. The research on specific diseases, such as Alzheimer's [8] and Leishmaniasis [9], highlighted global trends, top contributing countries, institutions, and prolific authors. Basu et al. [12] addressed cancer's impact and the scientometric evaluation of herbal medicine in its treatment, underscoring the increasing challenge of cancer as a global health issue.

Other analyses concentrated on neglected areas, like Colavizza et al. [3], who explored the COVID-19 Open Research Dataset (CORD-19), unraveling its broader scope beyond COVID-19 studies. Similarly, Chandra [17] scrutinized the evolution of entrepreneurship using scientometric techniques. Demir and Comba [5], also shed light on Celiac disease, emphasizing research trends, top articles, journals, countries, and co-citation analyses. Koster et al. [10] focused on Rotavirus, elucidating its significant impact on diarrheal diseases.

Multiple studies employed scientometric tools and databases, such as Web of Science, Scopus, and PubMed, to clarify publication patterns, collaborations, and citation analyses. These varied analyses collectively contribute to the expanding knowledge and comprehension of diverse scientific disciplines, guiding future research directions and informing decision-making processes across different fields of study.

3. METHODOLOGY

The present study uses a bibliometric method to analyze the literature on Polio. The idea is to analyze and measure the scientific literature related to Polio. Quantitative, qualitative, and computational methods are used by bibliometrics. The primary purpose of this study is to map institutional productivity and the institutional ranking by research area and journal rank while identifying the countries and authors who cooperated the most. This method is beneficial for visualizing consequential patterns and trends in a vast body of literature and scientific data. It allows the researchers to make literature-related inventions that are challenging through any other analysis. The research methodology comprised data collection, tools and techniques, and bibliometric techniques.

The selection of WoS and Scopus databases as search engines was based on their widespread recognition and established prominence in the analysis of scientific literature [22]. Furthermore, they are well-known index databases for

the scientific literature. However, the reason for selecting these databases for data extraction is the large dataset involved, and many previous analyses were also based on these databases. Following strict selection criteria, we collect the world's most prominent scientific and technical journals from both databases. This ensures a high quality of retrieved papers on Polio. The data were downloaded from Scopus and WoS databases using the keywords 'Polio' or 'Poliomyelitis'.

The keywords 'Polio' or 'Poliomyelitis' are prevalent in this research field, ensuring comprehensive coverage of related areas. Employing these keywords in the search process across the title, abstract, and keywords sections of documents was crucial. The literature search spanned from 2007 to June 2019 in the WoS database and from 1857 to 2019 in the Scopus database to capture all relevant articles for the study.

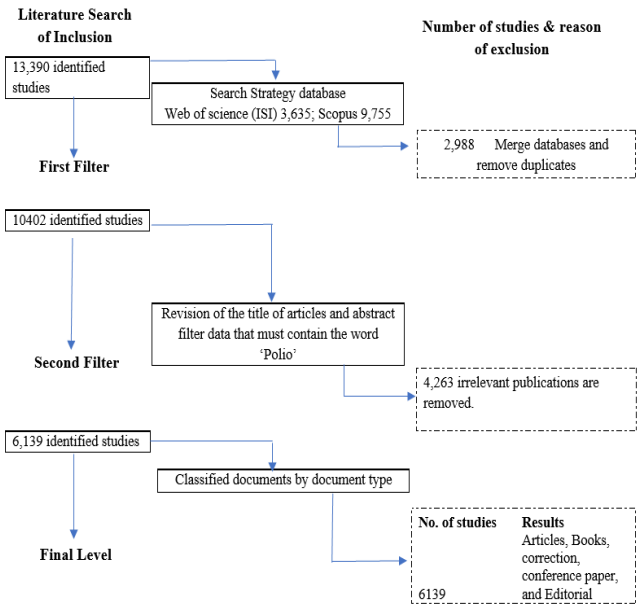

Figure 1. Selection process of the studies for exclusion in the review

The year 2020 was excluded to improve the results' accuracy. If the most recent (incomplete) year had been included, getting the same number of documents might not be possible if the analysis is repeated. The reason is that several journal issues are released and uploaded to databases after several months of publication to be online. The search results are saved in BibTeX format, and the cited reference information is included. The selection criteria for inclusion are shown in Figure 1.

In total, 13390 publications on Polio were obtained, 3,635 from the Web of Science database and 9,755 from the Scopus database. The data of these two databases was merged, resulting in 2,988 duplicates. After removing all the duplicates, 10,402 publications remained. A revisit of the title and abstract was done in order to ensure that the data must contain the word Polio. However, after revision, we found that much data was unrelated to our research work, and data related to different diseases and viruses other than Polio was also present.

Therefore, we applied a filter on the title and extracted only Polio-related data, or applied a filter on the title and extracted data that must contain the word Polio or Poliomyelitis. After filtering the data, it was discovered that 4,263 publications are irrelevant. After excluding all the irrelevant data, 6,139 publications remained. This data contains articles, book chapters, proceeding papers, letters, and notes. It is observed that these articles were written in many different languages, such as English, French, Spanish, German, Portuguese, Japanese, and Chinese (Complete details about document types and languages of articles are described in the Experiments section). Table 1 shows a detailed summary of the general results. Involvement from 114 regions, 30 languages, and contributions from 4,306 institutions demonstrate a widespread and diverse global engagement in Polio research, underscoring its international significance. This research uses quantitative analysis, graphs, and network models to visualize our findings efficiently. The flow chart of this study is shown in Figure 2. The selected research papers are analyzed using the current acclaimed bibliometric mapping tools, such as VOSviewer and R-studio.

Table 1. Summary of general results

Criteria	Quantity
Time Span	1857–2019
Document type	16
Languages	30
Documents	6,139
Authors	4,572
Source Journals	1,725
Regions	114
Institutions	4,306
Cited References	58,438
Term Analysis	10,416
Documents per Author	0.506

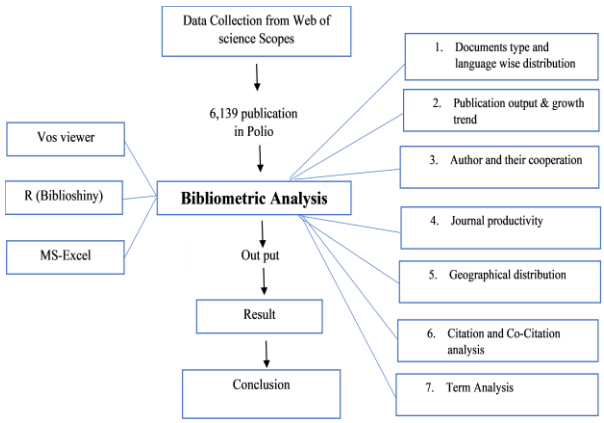

Figure 2. Research process of Polio research

3.1 Tools and techniques

Several bibliometric analysis tools exist, each with strengths and abilities [23]. Therefore, after thoroughly examining each tool, we find that the appropriate use of various tools for various types of analysis is essential. Therefore, we take an overview of tools like VOSviewer, Gephi, HistCite, Citespace, Bibexcel, and Rtools. However, we find VOSviewer and Rtools more flexible and accurate than others.

3.1.1 VOSviewer

VOSviewer is a software that offers the main functionality required for visualizing, producing, and exploring bibliometric networks [24]. This idea of visualizing bibliometric networks received much attention during the early days of bibliometric research. Bibliometric network visualization has become a

powerful approach to analyzing bibliometric networks in a large variety, which can depict the relationship between authors and co-authors, find a relationship between countries and institutions or citation and co-citation networks, and also find the subject category and term analysis. With time, researchers have started to analyze large networks, thus requiring more advanced visualization tools [25]. The VOSviewer (version 1.6.15) was used in this research and is freely available. All the tabs that were used are described next:

VOSviewer displays graphs in three ways, but we use only network visualization and overlay visualization graphs in this research work.

(1) Network visualization: The network visualization graph represents the items by labels and circles by default. The item's weight determines the label's size and the item's circle. If the item's weight is more significant, its label and circle size are also larger. Some items whose labels are not displayed are also present; this is done to avoid overlapping of labels. Their cluster represents the color of an item. The lines between items demonstrate the links. By default, one thousand lines are drawn, representing the most vital links between different items. In this work, we make three network visualization graphs and find the cooperation of the authors, countries, and institutions. We also perform the term analysis.

(2) Overlay visualization: This visualization is the same as network visualization, except the items' colors differ. In the overlay visualization, the items can be colored differently. In the first case, the color of an item is determined by the score when the items are scored. Therefore, when the score is low, the color by default is blue, and when the score is higher, it ranges from green to yellow. If the items have no scores, then overlay visualization is not shown. In this research, we only make one overly visualization graph to find the new and old terms within the given period.

(3) Density visualization: In this type of visualization graph [24], the items are also represented similarly to the network and overlay visualization. Each point of the item in density visualization is represented by a color that indicates the density. By default, it ranges from blue to green and green to yellow.

The weights of the neighboring items are higher when the items of the neighborhood are higher in point and the color of the point is yellow. On the other hand, the weights of the neighboring items are smaller when the neighbourhood items are lower in point, and the point color is blue.

3.1.2 R (Biblioshiny)

R-Studio is an integrated development environment (IDE) tailored for the R language, specifically designed for statistical computation and graphics [26]. R-studio provides several packages such as Shiny, RMarkdown, flex-dashboard, Tidymodels, Sparklyr, Stringr, Reticulate, and Plumber. However, the Bibliometrix package of R-Studio was selected for bibliometric analysis in related research. Biblioshiny is the interface of bibliometrix [27].

It has many features that are very helpful to carry out deep bibliometric analysis. The interface of biblioshiny is well managed and divided according to the workflow [28]. A main menu presents all data summaries, such as year span, total authors, total citations, total references, and single-author and multi-author documents. The analysis options are divided into seven categories: Overview, Sources, Authors, Documents, Conceptual structures, Intellectual structure, and social structure. The graphs that have been generated can be exported to several file formats; maps can be exported to Pajek and then further analyzed in VOSviewer.

Similarly, the tables can be copied, downloaded, or saved as Excel, CSV, PDF or printed. Later, the file of Scopus and Web of Science literature in BibTeX format was uploaded on the Biblioshiny interface. As per the study's objectives, the Excel files were downloaded and used for further data analysis and for making tables and graphs, as described in the next section.

3.2 Linear forecasting

Forecasting is also performed in this research work. Forecasting is the technique that helps us predict the future. Linear forecasting is applied to the yearly publication growth of polio articles, and we forecast the number of publications during the next four years. Linear forecasting is a type of time series forecasting. The linear forecasting function is categorized and calculated under the statistical function of Microsoft Excel. It predicts a future value by using linear regression.

3.3 SCImago Journal Rank (SJR)

SJR measures the scientific impact of scholarly journals that count both the importance or prestige of the journals, from where the citations come from and the citations received by a journal. A journal's SCImago Journal Rank shows a numeric value that indicates the average number of weighted citations received during a selected year, during the previous three years per document published in the journal. The higher the value of SJR, the greater the prestige of the journal [29]. SJR does not only rank journals but countries as well. It can tell the citations of that journal, H-index, place of publication, editor name, subject category to which certain journal belongs, scope, citations per document, and documents cited. All of the aforementioned fields are shown in graph format as well.

In this study, the analysis of the top active journals is conducted along with finding the SJR of 2019 and the subject category related to those journals. This analysis helps us to find out which journal belongs to which specific areas of research [30] ("SJR: Scimago Journal and Country Rank", 2020).

An academic journal's Impact Factor (IF) is a bibliometric index representing the average citations received annually. Its calculation involves aggregating the total citations garnered by articles over the last two years and dividing this by the total number of articles published within that period or a specific timeframe [31]. Across academic disciplines, the IF helps in assessing the significance of publications or academic contributions, typically considering journals with higher IF as more influential. The formula to compute the IF for the year 2018 is expressed in Eq. (1).

$$IF_{2018} = \frac{Citations(2017) + Citations(2016)}{Publications(2017) + Publications(2016)} \quad (1)$$

These metrics filter out top journals in a particular domain wherever they are needed.

4. EXPERIMENTS AND RESULTS

A comprehensive dataset spanning 162 years (1857 to 2019) regarding polio research publications was collected from the Web of Science and Scopus databases, comprising 6,139

records. This extensive dataset was analyzed using tools such as R-studio, Microsoft Excel, and VOSviewer to gain insights and visualize trends within the data.

4.1 Distribution of document type and languages in polio research

Table 2 shows the document types of world contributions to polio research. Most of the research papers on Polio are articles (4,369, 71.16%), followed by reviews (411), letters (344) and editorials (179). Therefore, journal articles stand out as researchers' most favored mode of research communication.

Table 2. Distribution of document types in Polio research

Document Types	No. of Records	Percentage
Article	4,369	71.16
Article in press	18	0.29
Article, proceedings paper	3	0.04
Book	87	1.41
Conference paper	87	1.41
Correction	12	0.19
Editorial	179	2.91
Erratum	27	0.43
Letter	344	5.60
Meeting abstract	117	1.90
News item	79	1.28
Note	312	5.08
Poetry	2	0.03
Reprint	2	0.03
Review	411	6.69
Short survey	90	1.46

Table 3. Language-wise distribution in Polio research

Language	No. of records	Percentage
English	5,266	85.77
German	224	3.64
Spanish	125	2.03
French	91	1.48
Chinese	63	1.02
Italian	61	0.99
Japanese	57	0.92
Swedish	39	0.63
Polish	34	0.55
Dutch	31	0.50
Portuguese	24	0.39
Russian	24	0.39
Danish	21	0.34
Romanian	18	0.29
Czech	10	0.16
Norwegian	10	0.16
Turkish	8	0.13
Finnish	5	0.08
Hungarian	5	0.08
Hebrew	4	0.06
Polyglot	3	0.04
Slovak	3	0.04
Bulgarian	2	0.03
Croatian	2	0.03
Greek	2	0.03
Korean	2	0.03
Serbian	2	0.03
Arabic	1	0.01
Bosnian	1	0.01
Thai	1	0.01

Table 3 indicates the language-wise literature output on Polio. Among the 6,139 papers, 85.77% were published in English, showcasing the language's dominance in conveying Polio-related research. The total number of documents published in languages other than English is 873, around 14.23% of the total publications.

4.2 Publication output trends: Analyzing growth over time

The scientific documents underwent analysis by periods, as depicted in Figure 3. Publications showed an upward trend beginning in 1963. Over the past three decades, there was consistent growth in the average number of publications per period: 1990–1999 (95), 2000–2010 (147), and 2011–2017 (254). However, there was a decline in publications in 2018 and 2019 (n=191). Notably, the pinnacle of publications was observed in 2014, reaching its peak at 340. The annual growth rate is 5.34%. The prediction of publication volume was accomplished through a statistical function utilizing linear regression to forecast future values. The forecast for the upcoming four years (including 2020) stands at 148, 149, 151, and 153 publications respectively. This cumulative growth underscores the escalating significance of subject-related publications, showing an exponential increase over the years.

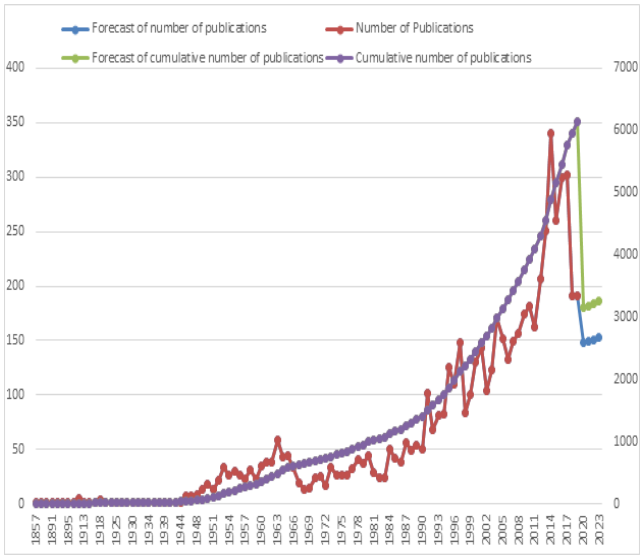

Figure 3. Number and accumulation of publications per year in Polio research

4.3 Authors and their cooperation

Twelve thousand one hundred twenty-four different authors wrote the 5,781 publications. Three hundred fifty-eight publications are without an author name. Most authors (71.3%; n=8,290) are associated with a single publication, while 14.6% (n=1,775) are credited in two, 5.2% in three, 2.5% in four, and 6.2% in five or more. Table 4 highlights the top ten most prolific authors based on their total number of publications. The analysis of key authors in Polio research reveals a blend of significant contributors from various countries, notably Switzerland and the USA. Notably, R. Sutter emerges as both the most productive and cited author. The USA maintains a notable presence among top authors, with individuals like M. Pallansch, K. Thompson, and S. Cochi contributing significantly in volume and average citations per publication.

Table 4. Top 10 most-productive authors in Polio research

Authors	Country	Publications	Citations	Avg. Citations	Pub. as the 1st Author
Sutter, R.	Switzerland	109	4042	37	11
Pallansch, M.	USA	93	3975	42.7	2
Thompson, K.	USA	72	1854	25.7	27
John, T.	India	61	792	12.9	36
Oberste, M.	USA	60	1254	20.9	2
Wassilak, S.	Europe	59	1571	26.6	5
Kew, O.	USA	54	3446	63.8	9
Cochi, S.	USA	52	1655	31.8	9
Aylward, R.	Switzerland	50	1511	30.2	10
Duintjer, T.R.	USA	47	1147	24.4	25

Table 5. Top 10 most-active journals in Polio research

Journal Title	Publ.	SJR 2019	Impact Factor 2019	Subject Category (SJR)
Vaccine	245	1.683	4.76	Biochemistry: Genetics and Molecular Biology, Molecular Medicine, Immunology and Microbiology: Immunology and Microbiology (miscellaneous), Medicine: Infectious Diseases, Public Health, Environmental and Occupational Health, Veterinary: Veterinary (misc.)
Journal of Infectious Diseases	188	2.946	4.71	Medicine: Immunology and Allergy Infectious Diseases
Indian Pediatrics	114	0.285	1.163	Medicine: Pediatrics, Perinatology and Child Health
Science	89	13.11	41.037	Arts and Humanities: History and Philosophy of Science, Multidisciplinary: Multidisciplinary
Bulletin of the World Health Organization	72	2.502	6.818	Medicine: Public Health, Environmental and Occupational Health
Archives of Physical Medicine and Rehabilitation	70	1.114	2.697	Health Professions: Physical Therapy, Sports Therapy and Rehabilitation, Sports Science Medicine: Rehabilitation
The Lancet	62	14.554	59.102	Medicine: Medicine (miscellaneous)
Deutsche Medizinische Wochenschrift	61	0.176	0.15	Medicine: Medicine (miscellaneous)
British Medical Journal	59	2.049	27.604	Medicine: Medicine (miscellaneous)
Nature	59	14.047	43.07	Multidisciplinary: Multidisciplinary

The average number of publications per author is 0.506. The author's name is missing in 5.8% (n=358/6,139) of the publications. Sixty-three publications do not have a specific authorship. 29.3% (n=1,801) of the publications have single authorship. Out of the publications analyzed, 14.2% (n=874) involved two authors, 12.2% (n=749) had three authors, 9.2% (n=565) had four authors, 6.9% (n=423) had five authors, and 21.3% (n=1,306) had six or more authors, with a maximum of 15 authors per publication. The authors' collaborative patterns in publishing were examined using VOSviewer, as shown in Figure 4. The size of the circles indicates the publication volume, while the curved connections represent collaborative ties. The colors denote distinct collaboration clusters within the network, identifying 27 author clusters.

4.4 Journals publishing on Polio research

Out of the 6,139 published articles, they were distributed across 1,725 journals. Among these journals, 1,011 (58.6%) were responsible for publishing only one article each. 283 (16.4%) journals published two articles. One hundred nine (6.3%) published three articles. Similarly, 227 (13.1%) journals published four to ten articles. Among the journals, 95 (5.5%) contributed significantly by publishing 11 or more articles, with publication counts ranging from 11 to 245. Table 5 outlines details regarding the top 10 most active journals. These ten journals accounted for 16.5% of all publications (n=1019 out of 6,139). According to the Scimago Journal Ranking (SJR), the primary sub-area category for these most recurring journals falls under Medicine: Infectious Diseases. Journals like "Vaccine" and "Journal of Infectious Diseases" demonstrate strong relevance to Polio research, focusing on Immunology, Infectious Diseases, and Pediatrics. Other influential journals such as "Science," "The Lancet," and "Nature" cover broader multidisciplinary areas, indicating their significant influence beyond specific medical domains. These results reflect a comprehensive landscape, from specialized medical publications to multidisciplinary platforms, emphasizing the diverse avenues for Polio-related research dissemination and impact.

Figure 5 demonstrates the publication frequency for the top five most influential journals over the years. There has been a noticeable rise in publications during the past decade. The substantial volume of publications in both ‘Vaccine’ and ‘Journal of Infectious Diseases’ can be attributed to including conference proceedings and editorials.

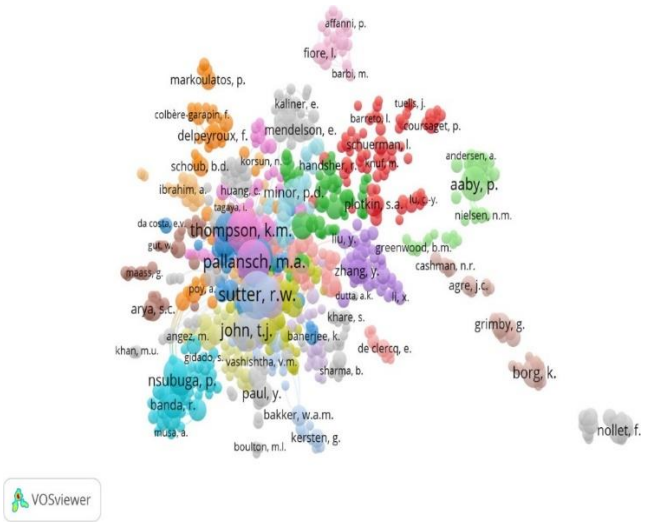

Figure 4. Author cooperation network in Polio research

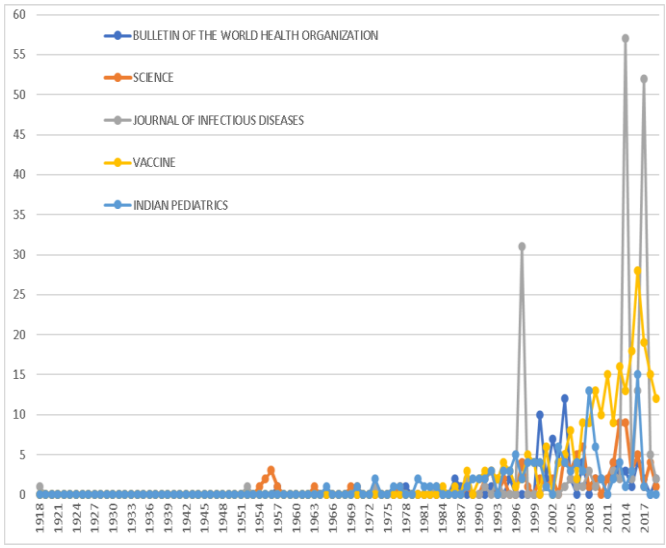

Figure 5. Frequency of publications across years in the top five most influential journals

4.5 Geographical and institutional distribution, along with collaborative partnerships

Each publication underwent assignment to a country based on the available information within the author affiliations and addresses documented in WoS and Scopus databases. A total of 1,522 publications lacked any identifiable affiliation. Approximately 75.2% of the publications were associated with a specific region or country. Publications potentially linked to multiple countries or institutions were assigned multiple affiliations or authorships, considering all affiliations based on country or institution.

The body of publications regarding Polio originated from 114 distinct regions worldwide. Among these, 31 are in Europe, 32 are in Asia, 33 are in Africa, and 15 are in the Americas. Figure 6 provides a visual representation of the global distribution showcasing the contribution of these countries and territories.

A breakdown reveals that 67 countries or territories (58.8%) contributed fewer than ten publications, while 28 (24.6%) produced between 11 and 50 publications. Furthermore, 11 (9.6%) contributed between 51 and 150 publications. Notably, the USA emerged as the leading producer of publications in this domain.

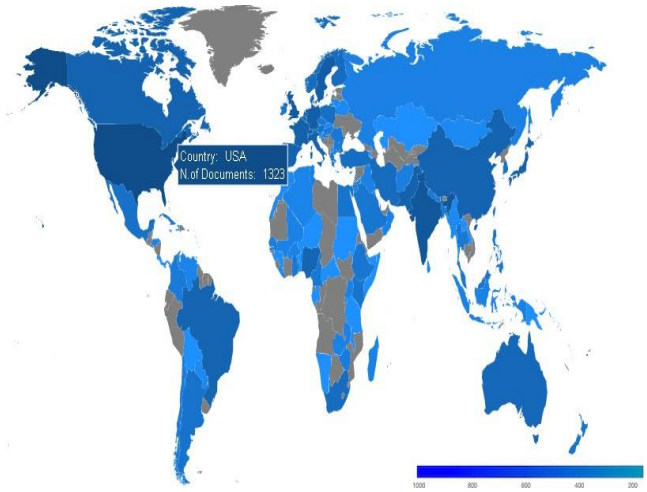

Figure 6. Distribution of publications across countries or territories in Polio research

Figure 7 showcases the top 10 countries and territories with the most publications. There was no publication in the journal from 1857 to 2017. Therefore, these years were skipped from the graph. Economically developed countries significantly contribute to scientific and academic advancements. The top 10 most productive countries in polio publications include the USA, India, United Kingdom, Sweden, Germany, France, Netherlands, Switzerland, Italy, and Pakistan. Information from countries and territories' affiliations of the authors is present in 6,417 publications.

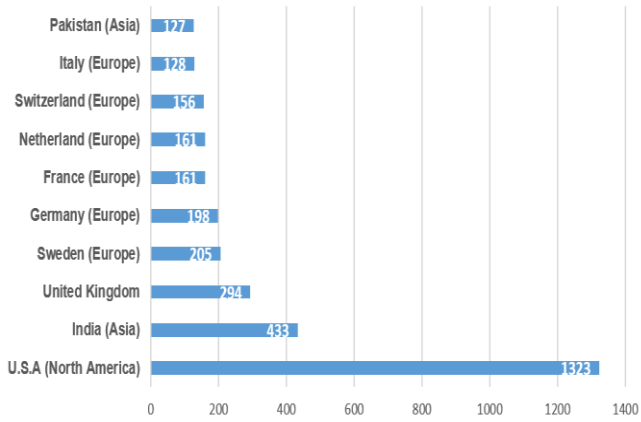

Figure 7. Countries and territories leading in publication productivity: Top 10 Rankings

Figure 8 depicts the collaboration network among countries and territories in Polio research created using VOSviewer. The network explicitly highlights countries with five or more publications, excluding those not interconnected. Circle sizes correspond to publication volumes, while connections signify collaborative efforts between countries. The analysis identifies thirteen primary clusters, with the USA forming the central group, followed by the UK (peach-colored cluster) and a third cluster involving Ethiopia and Cuba (red-colored cluster). The fourth cluster relates to Japan and Brazil (green). The fifth cluster relates to France (blue group). The sixth cluster relates

to the Netherlands and Bangladesh (yellow group). The seventh cluster relates to India (purple group). The eighth cluster relates to Sweden (sky-blue group). The ninth cluster relates to Pakistan (orange group).

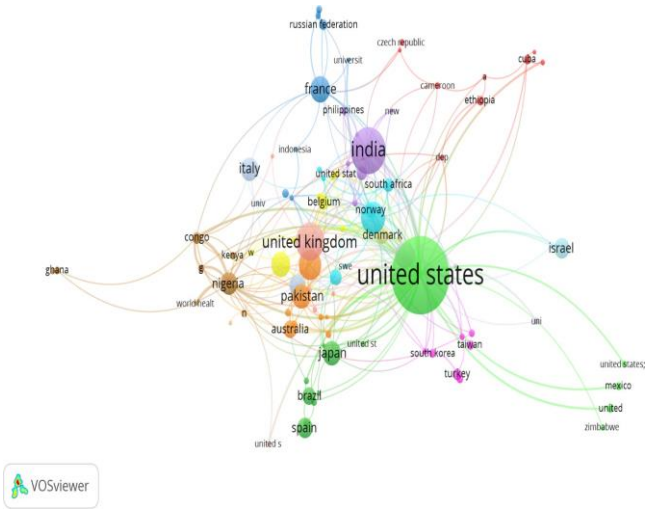

Figure 8. Cooperation network between countries and regions

The tenth cluster relates to Turkey (pink group). The eleventh cluster relates to Italy (grey group). The twelfth cluster relates to Switzerland (light purple group). In our analysis of country cooperation in publications, we found that the UK collaborates significantly with Western European countries. Similarly, Germany's collaborations extend notably to African nations. Notably, Nigeria is the sole African country displaying strong connections with the USA and the UK. Pakistan has connections with the USA, Saudi Arabia, Australia, Germany, and Nigeria. The United States is a central hub in these relationships, while Japan is associated with neighboring Asian countries.

Four thousand three hundred six research institutions contributed to 4,617 publications for which affiliation data was available (with the possibility of multiple authors per publication or authors affiliated with multiple institutions). To ensure consistency, the names reported in the databases were standardized across different records in Scopus and WoS.

Of all the institutions involved, 71% (n=3,058) participated in just one publication, while 13.5% (n=580) were involved in two publications, and 13% (n=564) contributed to three publications. A smaller percentage, 1.6% (n=68), participated in 11 to 20 publications, and a mere 0.8% of institutions (36) were responsible for 20 or more publications. Table 6 outlines details regarding the top 10 most productive institutions. Most institutions belong to universities, private organizations, research centers, and institutes. Institutions like WHO and the Centers for Disease Control and Prevention (CDC) in the USA emerge as essential contributors, highlighting their noteworthy roles in global health and disease control.

Additionally, academic institutions such as Lund University and the University of Amsterdam display active engagement in Polio research, highlighting the academic community's dedication to understanding and fighting this disease. These diverse institutions underscore a cooperative, multidisciplinary approach towards addressing Polio globally. Figure 9 shows the cooperation network between institutions and territories in Polio research.

Table 6. Top 10 institutions with the highest productivity

Institution	Country	No. of Publications
World Health Organization	Switzerland	**371**
Centers for Disease Control and Prevention	USA	202
Bill and Melinda Gates Foundation	USA	64
National Center for Immunization and Respiratory Diseases	USA	64
Center for Global Health	USA	52
Statens Serum Institute	Denmark	50
Institute Pasteur	France	48
Lund University	Sweden	46
University of Amsterdam	Amsterdam	41
London School of Hygiene and Tropical Medicine	London	36

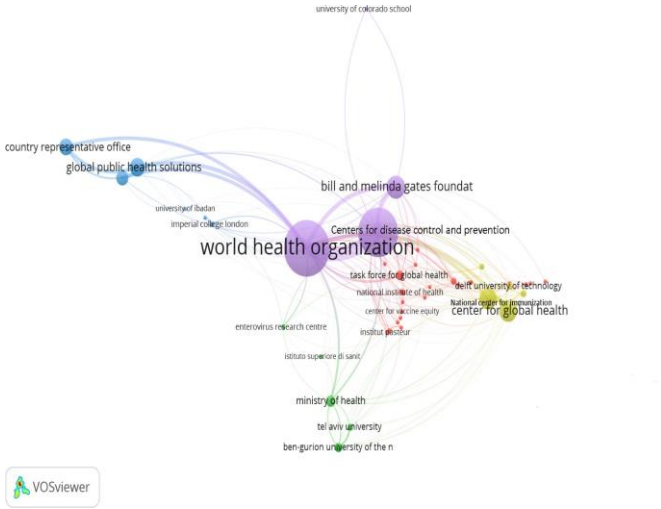

Figure 9. Collaboration network among institutions and regions

4.6 Citation analysis

This section delves into how these documents are referenced in other publications. The citation analysis helps identify how often a publication has been referenced. Out of the 6,139 publications, they were cited 58,438 times in other publications up to the data extraction point. This accounts for an average of 9.519 citations per publication.

33.5% (n=2,057) of the articles had not been cited. 11% (n=678) were cited only once. 6.9% (n=424) were cited twice. 24.7% (n=1,519) were cited between 3 to 10 times. 10.7% (n=655) were cited between 11 to 20 times. 9.6% (n=588) of publications had 21 to 50 citations. 2.6% (n=162) were cited between 51 to 100 times. 0.9% (n=56) were cited up to 454 times. The average citation of the top 10 articles was 285. Table 7 enumerates the top five frequently referenced publications. The primary authorship of nine publications aligns with the USA, followed by Europe. Notably, O. Kew is the sole author featured twice on this list. Regarding the primary topics categorized by Scimago Journal-SJR, four journals revolve around Medicine, while the others focus on Microbiology. Among the 6,139 journals studied (1,106 of which received more than one citation), 35.9% (n=619 out of 1,752) had no citations. Additionally, 9.9% (n=171) received a single citation, while 26.1% (n=451) fell within the range of

two to 10 citations. Furthermore, 18.2% (n=314) accrued citations ranging between 11 and 50. 6.2% of the journals have accumulated citations falling within 51 to 200. 3% (n=52) have between 200 and 1,000 citations, and 0.6% (n=10) have citations ranging from 1,001 to 3,415. Vaccine is the journal with the highest citations, with 5.9% (n=3,415/58,437) of the total citations. The Journal of Infectious Diseases and Archives of Physical Medicine and Rehabilitation collectively garnered 9% (n=5,301) of the total citations. This pattern suggests a strong correlation between the overall publication count and the most frequently referenced journals. Figure 10 depicts the top five journals referenced by other articles.

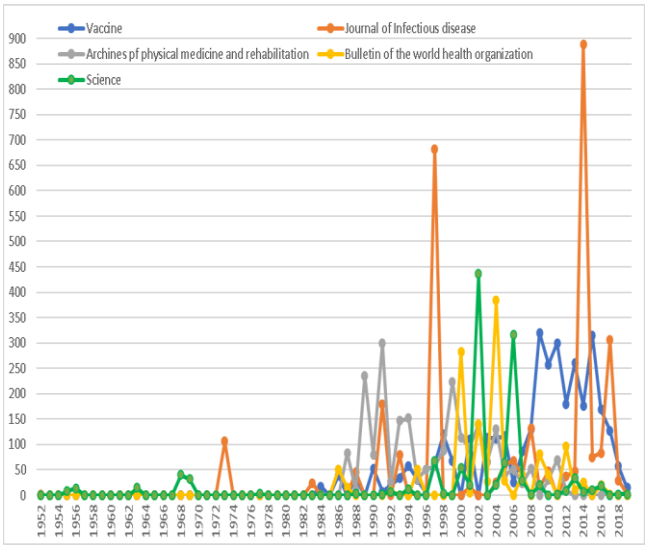

Figure 10. Journals with the highest references from other articles: Top five rankings

In total, 4,758 references were used for co-citation analysis. Many articles do not contain their cited references. The co-citation analysis serves to quantify interactions among publications, aiding in the analysis of their relationships. Specifically, we focus on the top 50 highly referenced articles. Figure 11 portrays the co-citation analysis created using VOSviewer. The nodes represent publications, and the edges represent co-citation relationships. Circle size indicates the extent of citation on the subject, while distance signifies the level of relationship. One can observe that most of the articles were written after 1990. The visual network reveals four distinct clusters, indicating topics or research areas. Notably, the red cluster pertains to Polio vaccination, while the green group is associated with conditions following polio. The yellow and blue groups are associated with vaccination, eradication, and symptoms, and O. Kew (2005) is highly co-cited.

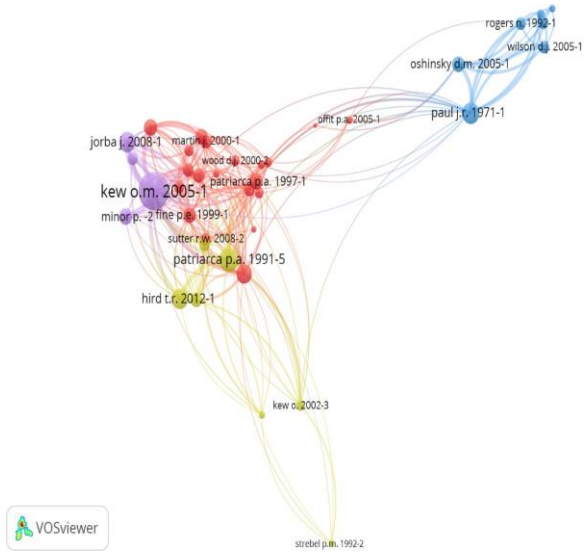

Figure 11. Analysis of co-citations among extensively referenced sources

Table 7. Most cited publications: Top 10 rankings

Title	References	Country	Institution	Journal-IF SJR (2018-2019)	Times Cited	Avg. Cit. per Year	Main Topic (Category SJR)
Vaccine derived polioviruses and the endgame strategy for global polio eradication	KEW O 2005	USA	National Center for Infectious Diseases	Annual Review of Microbiology (5.62-6.517)	**454**	28.38	Microbiology
Outbreak of poliomyelitis in Hispaniola associated with circulating type 1 vaccine derived poliovirus	KEW O 2002	USA	National Center for Infectious Diseases	Science (41.037-13.11)	423	22.26	History and Philosophy of Science
A long-term follow-up study of patients with post poliomyelitis neuromuscular symptoms	DALAKAS MC 1986	USA	National Institute of Neurological	New England Journal of Medicine (70.670-18.291)	291	8.31	Medicine (miscellaneous)
Lymphoblastic leukemias evidence for the involvement of the polio virus receptor cd 155 and nectin2 cd 112	PENDE D 2005	Europe	Istituto Nazionale per la Ricerca sul Cancro	Blood (16.601-5.416)	268	16.75	Biochemistry, Cell Biology, Immunology, Medicine
A protein covalently linked to poliovirus genome RNA	USA	LEE YF 1977	State University of New York	PNAS (9.58-5.165)	254	5.77	Multidisciplinary

4.7 Analysis of terms

The examination of terms present in the publications offers insights into primary subjects and evolving research directions. The terms frequently appearing together in different document parts are often considered related. This analysis measures the strength of the association using the frequency of the co-occurrence in titles, keywords, and abstracts. Terms occurring in at least ten publications were considered, resulting in the selection of 662 terms for inclusion in the network. The outcomes of this term analysis are depicted in Figure 12, where circles denote term occurrences, and the distance between them signifies their relation. The frequency of their co-occurrence indicates relationships among terms. The analysis identified six distinct clusters, notably highlighting a red cluster associated with Immunization (disease eradication, prevention, developing countries). Countries affected by Polio are also indicated (Afghanistan, Africa, Australia, Europe, India, and Pakistan). The green cluster is related to humans, post poliomyelitis syndrome, symptoms, females, children, and age groups. The blue cluster represents the poliomyelitis virus, polio virus, and virus antibody. The yellow cluster relates to the poliomyelitis vaccine, oral vaccination, and various circumstances. The purple cluster represents all the terms related to polio. The most frequent words are Polio, poliomyelitis, poliomyelitis vaccination, children, eradication, clinical condition, paralysis, and developing countries.

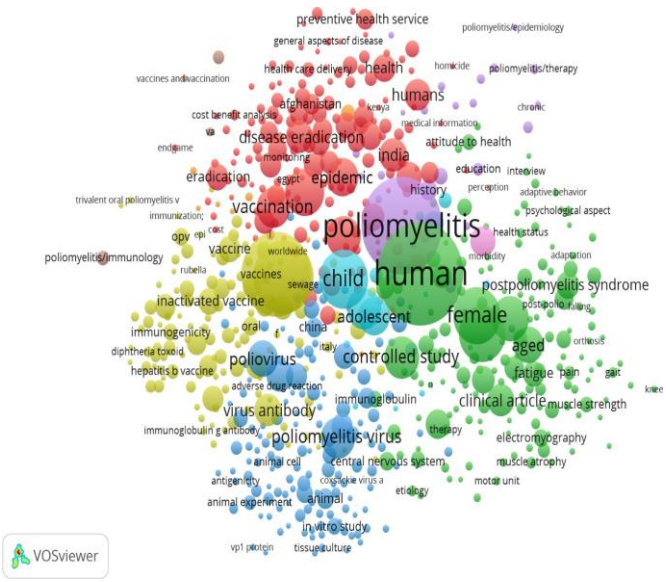

Figure 12. Terms analysis

Figure 13 depicts the temporal relationship among terms, showcasing the average publication period represented by the color of the terms. This average is computed from the collective publication years of all associated publications. The spectrum spans from 1990 to 2019, with yellow denoting newer terms and blue indicating older ones. The prominence of terms, delineated by the color range and circle size, highlights the prevalence of terms predominantly between 2000 and 2010. The clusters with more contemporary terms relate to Polio and the physical condition after Polio. The cluster associated with medical aspects pertains to the older terms. One can easily observe through the yellow cluster that the world is moving towards the completely eradicating the disease.

The WHO and CDC, USA, and academic powerhouses like Lund University and the University of Amsterdam collectively spearhead Polio research, showcasing a united, interdisciplinary effort toward eradicating global disease.

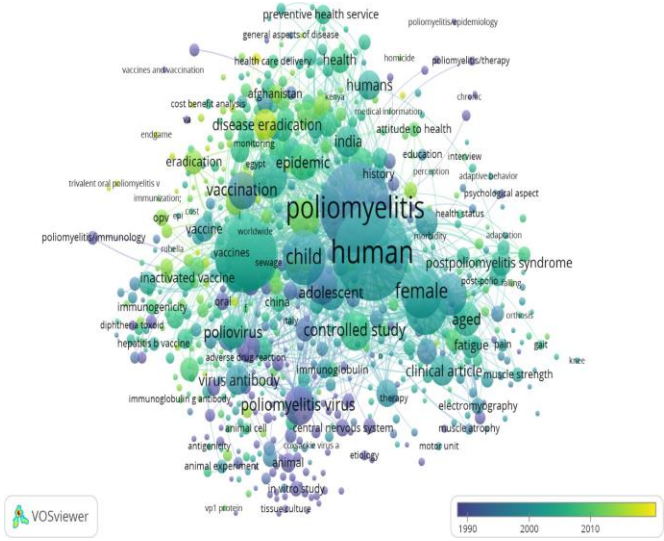

Figure 13. Analysis of Terms with Temporal Data

5. CONCLUSION

The present study examined the polio research output published from 1857 to 2019, merging Web of Science and Scopus databases. It is observed that the publications have had a steady growth in this field till 2014, which was also observed as a peak year for publications. However, after 2014, the number of publications decreased. In forecasting, it is also noticed that the number of publications declined in polio research. The primary reason for this decline is that according to WHO, the entire world except Pakistan and Afghanistan is polio-free. It was analyzed that 6,139 documents were published in Polio during 162 years. Twelve thousand one hundred twenty-four authors participated in publications in thirty languages, 1,725 journals, and sixteen document types. The most contributed country in polio publications is the USA. One hundred fourteen regions participated with 4,306 institutions. For the 6,139 publications, a total of 58,438 citations were received. The author of the most cited publication was O. Kew in 2005, and the most cited journal is 'Vaccine'. A total of 4,758 co-cited references were also found. In term analysis, the most repeated words are 'polio' and 'Poliomyelitis'.

In conclusion, these results provide an idea for future researchers of Polio to analyze the current scientific literature and fill the gaps in the field for further research. Furthermore, researchers in developing countries like Pakistan need to undertake research in polio and its related fields to make such developing countries polio-free. The current research underscores the importance of future investigations focusing on unexplored aspects, including the long-term effects of polio, addressing vaccine hesitancy, and exploring socio-economic impacts. Identifying and bridging gaps in cultural implications, demographic impacts, and post-eradication challenges remain critical. Encouraging global collaboration, particularly from regions that have eradicated polio, is vital for sustaining progress and redirecting research efforts toward public health initiatives. This study advocates for ongoing research in developing countries to sustain polio-free status. It suggests

adapting research strategies to support broader vaccination efforts or study other vaccine-preventable diseases, utilizing existing expertise and resources.

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