Heliyon 10 (2024) e25431

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Review article

An overview of air pollution research in Chile: Bibliometric analysis and scoping review, challenger and future directions

Loreto Villacura, Luis Felipe Sánchez, Francisco Catalán, Richard Toro A, Manuel A. Leiva G [*]

Departamento de Química, Facultad de Ciencias, Universidad de Chile, Las Palmeras 3425, Ñuñoa, Santiago 7800003, Chile

A R T I C L E I N F O

Keywords:
Air pollution
Chile
Bibliometric analysis
Review
Research trend
Future directions

A B S T R A C T

This study provides a comprehensive overview and bibliometric analysis of air pollution research in Chile from 1980 to 2022. The analysis reveals a significant increase in scientific production, a 9.2 annual growth rate, and an H-index of 60. The research spans 33 countries and is influenced by environmental sciences, meteorology, and atmospheric sciences journals. The top ten authors account for 33.49 % of all publications, with local institutions contributing more than 35 %. The University of Chile and the Pontifical Catholic University of Chile are significant contributors. The most cited articles focus on health impacts and various pollutant sources, emphasizing air pollution as a critical public health concern. The study also emphasizes environmental science, meteorology, and atmospheric science, focusing on topics such as air pollution and health, pollutants, models, sources and chemistry, and social sciences. The findings are affirmed through rigorous discussion and review, providing a roadmap for future research, guiding decision-making processes, and expanding the knowledge frontier in the field.

1. Introduction

In recent decades, air pollution has persistently emerged as a critical environmental issue with far-reaching implications for public health and the economy worldwide [1]. Most of the world's population, approximately 99 %, is currently exposed to air pollution levels that exceed the guidelines set by the World Health Organization (WHO) [2]. The significant health effects associated with air pollution have been highlighted by a large body of epidemiologic research [3], including an increased risk of lung cancer [4], heart disease [5], bronchitis, and other cardiopulmonary diseases [6]. Moreover, air pollution significantly impacts crop yields and the environment, resulting in detrimental effects on biodiversity and ecosystems [7–9]. In 2019, the deaths and illnesses caused by air pollution had an estimated economic impact of USD $8.1 trillion, equivalent to 6.1 % of global GDP. This highlights the urgent need for comprehensive strategies to mitigate air pollution and reduce its associated health risks [10,11].

In Chile, the urban environment poses significant challenges in maintaining air quality, as nearly 90 % of the population resides in areas where fine particle levels systematically exceed the National Air Quality Standard Thresholds [12]. In response to this challenge, Chile has implemented an extensive air quality monitoring program. The initial network, established in 1988, was located in the Santiago Metropolitan Area. Today, the program has expanded to cover urban areas with populations exceeding 100,000 inhabitants. These efforts have revealed high levels of exposure to atmospheric pollutants among the population [13]. In fact, the country is home

* Corresponding author.
E-mail address: manleiva@uchile.cl (M.A. Leiva G).

https://doi.org/10.1016/j.heliyon.2024.e25431
Received 24 September 2023; Received in revised form 18 January 2024; Accepted 26 January 2024
Available online 27 January 2024
2405-8440/

to eight of the 15 most polluted cities in Latin America and the Caribbean [14]. The implications of air pollution extend beyond health concerns, as it also has a substantial economic impact on the nation. Annually, air pollution results in approximately 127,000 emergency room visits and 4000 premature deaths [15], leading to an estimated loss of USD $451 to 856 million in productivity [16]. These statistics underscore the need for strong science-based approaches to effectively understand ongoing atmospheric changes and their impacts, both in Chile and worldwide. The academic community is actively engaged in addressing the challenge of air pollution, and scientific research is critical to formulating strategies to mitigate the harmful effects of air pollution [17]. Key research areas typically include the characterization of emission sources, atmospheric transport and dynamics, chemical transformations leading to pollutant accumulation, dose–response relationships in biological effects, risk assessments, economic and social aspects, policies, accountability, and the effectiveness of control measures for protecting human health and ecosystems.

To date, systematic assessments have not identified specific areas of development and research needs in the field of atmospheric science and air pollution in Chile. However, bibliometric analyses provide an efficient approach to scrutinize scientific production, allow visualization of research trends, and the analysis of the state of the art and evolution of a discipline or research area [18] identifies knowledge gaps and defines its future research directions [19]. The performance and impact of authors, countries and journals can be assessed [19]. Several studies have used this methodology, for example, to study research trends in the monitoring and management of air quality [20], airborne microorganisms [21], and the impact of air pollution on human health [22]. Bibliometric indicators were used to review the literature on particulate matter (PM) and its possible association with atherosclerosis [23] and to analyze current research patterns on atmospheric aerosols worldwide [24]. Such studies are valuable to researchers, decision makers and the public because they can provide information on current trends and the state of research on air pollution, inform the formulation of new research proposals, identify knowledge gaps that require attention, guide research funding, evaluate intervention results, and provide reliable information to the public. This study seeks to fill existing gaps in the existing body of knowledge, recognizing the indispensable role of in-depth scientific analysis in air pollution research in Chile while identifying new areas of interest. Importantly, this investigation represents a pioneering effort, marking the first application of bibliometric analysis and scoping review methodologies in these research fields. Using these methodologies, the study offers an objective depiction of the current state of the art in the field. Additionally, it evaluates the progress of the nation in addressing environmental challenges, acting as a barometer of progress. Furthermore, this research fills a crucial gap in Chilean air pollution studies, examining the potential of enhanced research initiatives to translate into more effective policies and interventions. These advances are not only vital for Chile but also contribute to global efforts to mitigate air pollution, highlighting the broader relevance and impact of the study.

2. Materials and methods

The study was conducted within the ambit of the 2020 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Scoping Reviews) extension guidelines [25]. This methodology, ensures comprehensive reporting of methods and results of scoping reviews, facilitating an evaluation of their trustworthiness, applicability, and integrity of research. Detailed methodological information is available in the OSF (Open Science Framework) registry at the provided link (https://osf.io/ywhrz/). In the OSF repository, the next documentation was provided: The PRISMA-ScR Checklist; the Scoping Review Protocol; Database of Selected Articles; and the Results from the Scoping Review. Above, we provide a brief description of the materials and methodology used in this study.

2.1. *Steps of bibliometric analysis*

To conduct this bibliometric study on air pollution research in Chile, the following methodological steps were meticulously followed, as illustrated in Supplementary Material Fig. S1, based on the preferred reporting items for scooping reviews [25]. The methodology proceeds as follows: i) definition of the field of study; ii) selection of the database and search strategy; iii) refinement of search and/or eligibility criteria; iv) quantitative and qualitative analysis and selection of analysis tools; and v) visualization and interpretation of results (see OSF registry at https://osf.io/ywhrz/for more details). A brief methodological description of each step is provided below.

Step 1. **Definition of the field of study**. The focal field of study was the scientific production of research on air pollution in Chile, using the widest possible scope to understand the state of this research. This definition guided the search strategy and database selection.

Step 2. **Database selection and search strategy**. The database chosen to obtain articles in the focal field of study was the Web of Science (WoS) Core Collection [26]. This database was selected for its comprehensiveness, as it integrates data from the Expanded Science Citation Index (SCI-Expanded), Social Sciences Citation Index (SSCI), Arts & Humanities Citation Index (AHCI), and Emerging Sources Citation Index (ESCI). It offers several advantages over other databases, including indexed citations, comprehensive author and affiliation indexing, rapid and preliminary data analysis capabilities, compatibility with various citation management software, and widespread use in bibliometric research.

The search strategy in WoS involved the selection of specific keywords (Table S1 in the Supplementary Material). These keywords were determined collaboratively by the authors. The search criteria and Boolean logical operators were used during the search process, which consisted of six phases (Table S2 in the Supplementary Material). The first phase involved searching for the key titles of documents using various keywords associated with the field of study. Phases 2 and 3 involved searching document types using keywords associated with the field of study and the focal country, Chile, respectively. Phase 4 integrated the searches from Phases 1 and 2 using the OR Boolean operator. Phase 5 combined the results of Phases 4 and 3 using the AND Boolean operator. Finally, in Phase 6, these combined search queries were filtered by excluding certain components (e.g., excluding the year 2022). To maintain a consistent approach, the search was limited to English-language articles only. As most databases are in the English language, this may have the potential to increase the efficiency of the review process and the assurance of accessibility. However, it is possible that this approach may have resulted in a language bias; we acknowledge this as a possible limitation of the study in section 3.8 below. The research process flow chart is presented in Fig. 1.

Step 3. **Refinement of search criteria and/or eligibility criteria.** Bibliographic searches often yield false positives, whereby documents that do not meet the requirements of the field of study may be included in their results; duplicates may also be present, and there may be insufficient or unavailable information (such as abstracts or full-text articles not available for review). Therefore, we needed to refine our search. Specifically, we use the Web-based collaborative systematic review software application SWIFT Active-Screenner (SCIOME LLC, Research Triangle Park, NC 27709, USA) [27]. This system enables the identification of duplicates and facilitates the systematic review and refinement of a search carried out in WoS. Thus, each document was carefully examined by the three reviewers (LV, LFS and FC); for a document to be considered eligible, the three reviewers needed to agree. Amid any disagreement, a review conflict emerged, and the eligibility of the focal document was discussed by a panel comprising all reviewers and a fourth reviewer (ML). Furthermore, in this review stage, normalized keywords were assigned to each document based on the specific characteristics of the study using SWIFT ActiveScreenner [27]. These normalized keywords included authors' affiliation characteristics, study objectives, study characteristics, effects or impacts of results, evaluation methods, contaminants or variables, spatial-temporal resolution, national-level spatial coverage, and pollutant emission citations (Table S3 in the Supplementary Material).

Fig. 1a (see Results section) shows the flowchart that was implemented in the present study and the main results obtained in selecting the final collection of articles. We included studies from January 1, 1980, to December 31, 2022, that focused on air pollution research in Chile. As a starting point for our analysis, we chose the first article that was indexed in the database. This article was published in 1983. Our search yielded 812 documents in total at the beginning. However, we excluded 167 articles through a refinement phase that involved a careful review of the eligibility criteria. Subsequently, during the quantitative and qualitative analysis phase, we thoroughly examined the remaining articles. Ultimately, a total collection of articles had 645 articles (see OSF registry at https://osf.io/ywhrz/).

Step 4. **Quantitative and qualitative analysis.** Finally, we conducted a comprehensive analysis on various aspects, such as keywords, titles, authors, cocited authors, journal sources, keywords, authors' affiliations, and their countries or regions. This quantitative analysis produced a comprehensive overview of the characteristics of the publication field, highlighting its patterns, collaborations, and key contributors. Moreover, it allowed us to identify the most prevalent and influential topics and researchers in the field.

2.2. *Software tool to construct and visualize bibliometric networks*

In the construction and visualization of bibliometric networks, we employed various tools and software to perform bibliometric analysis. The widely used VOSviewer software version 1.6.18 [28] was utilized to analyze the data and visualize the results. The full count method was used in VOSviewer to construct bibliometric networks, as it is one of the most commonly used bibliometric analysis methods [29]. Therefore, these tools facilitated the quantitative and qualitative analysis of focal articles, allowing us to extract

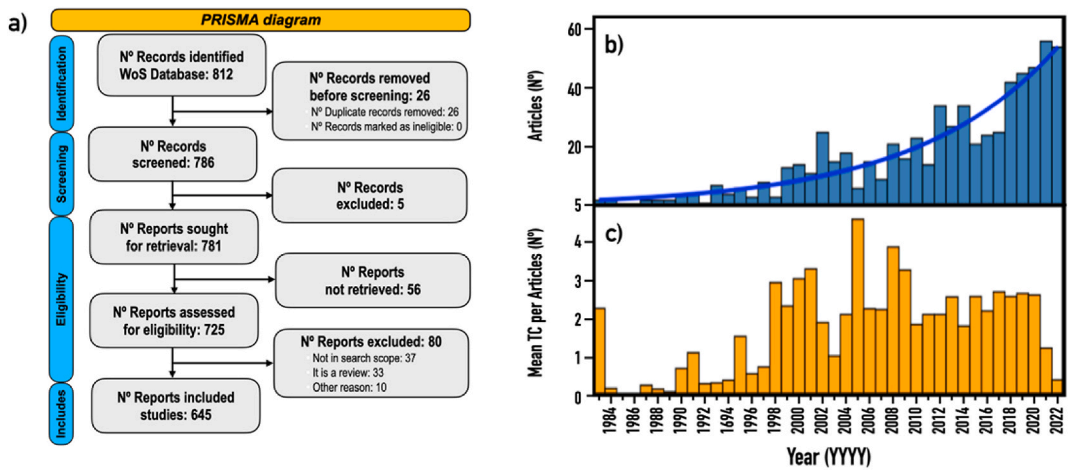

Fig. 1. a) The research flow chart illustrating the search for articles in the WoS database and the main results obtained for the bibliometric analysis of air pollution research in Chile and the annual scientific production of publications related to air pollution research in Chile from 1980 to 2022: b) number of articles per year (articles, No.) and c) average number of citations per year (MeanTCperYear, No.).

valuable insights and trends from the dataset. MS-Excel Mac v.16.59 [30] was used for tabulation purposes, as well as the open-source software package R [31] in addition to other R packages. These include the Comprehensive Science Mapping Analysis package: R-Bibliometrix version 3.2.1 [32], which was accessed through Biblioshiny [33]; to manage and visualize data effectively, we used Cartogram version 0.3.0 [34] for creating cartograms; ggplot 3.4.2 [35] for data visualization; igraph version 3.4.2 [36] for network analysis and visualization; metagear version 0.7 [37] for comprehensive research synthesis tools applicable to systematic reviews and meta-analysis; SP version 2.1-1 [38] for spatial data handling; Magick version 2.8.1 [39] for advanced graphics and image processing; and rnaturalearth version 0.3.4 [40] for accessing world map data from Natural Earth. This suite of tools allowed for a thorough and sophisticated analysis, ensuring the reliability and clarity of the findings of our study.

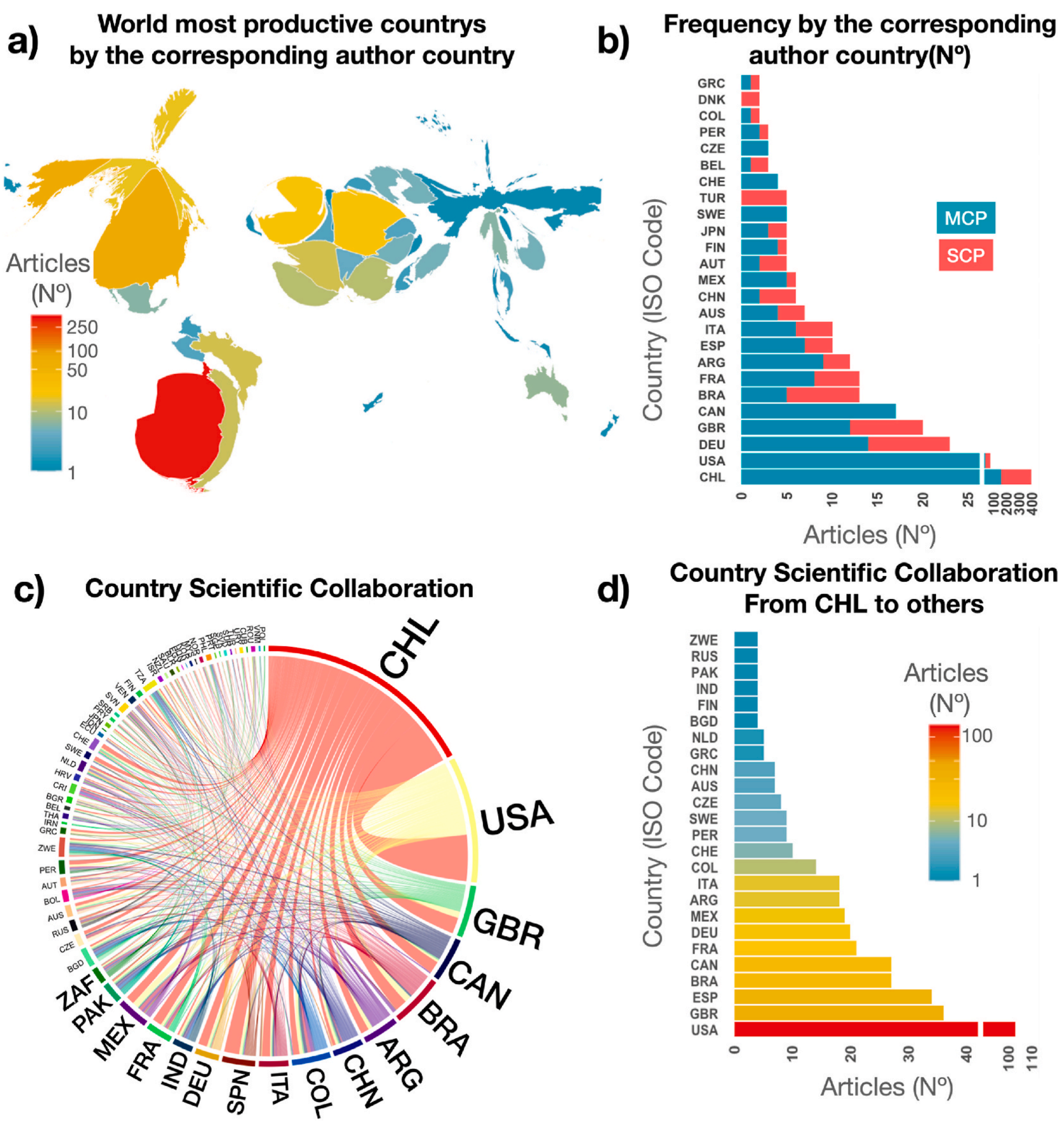

Fig. 2. Representations of geographical trends in air pollution research in Chile from 1980 to 2022: a) cartogram depicting the geographical distribution of articles based on country affiliation of focal author(s); b) frequency of publications per country by corresponding author, indicating the number of articles with authors from a single country (SCP) and authors from multiple countries (MCP) in different colors; c) origin-destination diagram, representing the number of authors from the focal country (origin) and from the collaborating countries (destination); d) Top 25 countries collaborating with Chile, expressed as the number of articles published in collaboration with authors from other countries. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

3. Results and discussion

3.1. Evolution of scientific production over time

The frequency of publication of scientific articles over time plays a crucial role in understanding the research landscape within a specific field [41]. Fig. 1b illustrates the temporal evolution of published articles on air pollution research in Chile from 1980 to 2022, with a total of 645 published articles. In particular, 1992 recorded the lowest number of publications ($n = 1$) when excluding inactive publication years (i.e., 1980 through 1982, 1985, and 1986). In contrast, 2021 saw its peak with 46 published papers. The mean number of publications per year, along with its corresponding 95 % confidence interval (CI95 %), is 15.4 (CI95 %: 10.7 to 20.1). Furthermore, the average number of publications per decade is 1.25 (95 % CI: 0.37–2.1) for the 1980s, 5.2 (95 % CI: 2.8–7.6) for the 1990s, 15.0 (95 % CI: 11–19.0) for the 2000s, and 28.8 (95 % CI: 21.9–35.7) for the 2010s.

The distribution of publications within the exhibits of the collection and the distinct patterns specifically indicates that publications in the 1980s represent 1.66 % of the total. This percentage increased to 8.64 % in the 1990s and increased further to 24.9 % in the 2000s. Publications during the 2010s constitute a substantial proportion, 47.8 % of the entire collection. This striking increase reflects a growth of more than 28 times the initial phase in the 1980s.

The number of publications demonstrates an exponential growth trend from 1983 to 2022, with an annual increase of 9.2 (95 % CI: 7.4 to 11; $R2 = 0.846$) publications. This growth reached its peak in 2019, accounting for 9.3 % of all publications. Furthermore, the annual citation distribution curve indicates a progressive increase in the number of citations, from 0.29 citations in 1983 to 6.04 citations in 2021 (Fig. 1c). The number of citations per article also exhibits a progressive increase in each decade, ranging from 0.31 (CI95 %: 0.00 to 0.82) and 1.1 (CI95 %: 0.46 to 1.8) in the 1980s and 1990s to 2.9 (CI95 %: 2.1 to 3.7) and 2.6 (CI95 %: 2.3 to 3.0) in the 2000s and 2010s, respectively (a summary diagram of the search performed in this bibliometric study is provided in the Supplementary Material, Fig. S2).

The H-index [42] of the collection of articles is equal to 60. This means that 60 articles, approximately 10 % of the total, have been cited at least 60 times. The H-index is widely used as a numerical indicator of the productivity and influence of a given collection of related articles. Therefore, these results indicate the high quality of the published articles and the high level of academic attention that has been given to this field.

3.2. Geographical trends

Fig. 2a shows the global distribution of articles based on the institutional affiliations of the authors by country. Such cartographic representations scale each country's size according to the number of articles penned by individuals associated with institutions within that nation [43]. This analysis shows that research on air pollution in Chile has engaged authors from 33 countries on five continents, signifying a pronounced international collaboration. Given the research methodology and search criteria tailored to Chile, it was anticipated that a substantial portion of the articles would originate from authors linked to Chilean institutions. In fact, this assumption is validated since 60 % of the articles originate in Chile. Remarkably, 40 % of the articles in the dataset are of international origin without any Chilean affiliation, highlighting the global intrigue in the topic. The United States (USA) followed with an approximate contribution of 11 % of the articles, followed by Germany (GER) at 3.5 %, the United Kingdom (GBR) at 3.3 %, Canada (CAN) at 2.8 %, Brazil (BRA) at 2.0 %, France (FRA) and Argentina (ARG) each at 1.8 %, Spain (SPN) at 1.7 %, and Italy (ITA) at 2.5 %. In contrast, several regions, including most African nations (except South Africa) and specific countries in the Middle East, Central Asia, and Southeast Asia, have made minimal or no contributions to this body of research.

Fig. 2b provides information on the top 25 countries with the highest number of articles based on the affiliation of the focal author's country. This figure differentiates articles with authors from a single country (SCP), representing intracountry publications, and articles with authors from multiple countries (MCP), representing intercountry collaborations [44]. The MCP ratio was calculated as the total number of articles (TC) divided by the total number of articles with authors from different countries (MCP). These results reveal that the MCP ratio is highest for CAN at 1.00, ARG at 0.73, SPN at 0.70, FRA at 0.64, GBR at 0.60, DEU at 0.57, ITA at 0.56, USA at 0.49, BRA at 0.42, and CHL at 0.38. Consequently, these results indicate that international collaboration is present in nearly 40 % of Chile's articles. In general, this bibliometric analysis demonstrated global participation and collaboration in air pollution research in Chile, where Chilean researchers lead in terms of productivity. It also highlighted opportunities for further international collaboration and the need for increased research contributions from underrepresented regions.

A common approach to visualizing collaboration within a country concerns the origin-destination diagram [45]. In this study, this diagram represents the number of authors from the focal country (origin) and the number of authors from the collaborating countries (destination), as shown in Fig. 2c (and Fig. S3 in the Supplementary Material). These findings reveal a high level of collaboration among authors affiliated with institutions in 63 different countries (refer to Fig. 2c). As expected, most collaborative articles involving CHL are evident, as their authors are from 55 countries. Fig. 2d presents the frequency of authors collaborating with the top 25 countries; Chilean researchers exhibit the highest collaboration rate with their international counterparts (refer to Fig. 2d). This is followed, in descending order, by collaboration with authors from the USA, GBR, SPN, BRA, CAN, FRA, DEU, MEX, ARG and ITA.

The results show that the collaborations between Chilean researchers and their counterparts in developed countries outnumber those with researchers in underdeveloped or developing countries. African collaborations are notably absent (Fig. 2c). This trend warrants further investigation and potentially points to disparities in the level of research developed in these regions. Furthermore, the global importance of Chile's air pollution issues is underscored by its extensive international collaborations, including more than 55 countries. This broad collaboration reflects the global recognition of air pollution as a public health priority.

3.3. Analysis of core sources

The frequency of articles published in each journal serves as an indicator of the current state of a field of research and reflects researchers' choices regarding where to publish their studies [46]. Therefore, this bibliometric analysis revealed that a total of 255 different journals have published articles in the field of air pollution research in Chile (Fig. 4a). However, most publications are concentrated in a few sources. Specifically, 160 journals published only one article, 9 journals published between 2 and 5 articles, and 14 journals published more than 10 articles.

To identify the core sources, Bradford's law was applied [47]. This law allows the division of sources into three zones based on the distribution of the number of articles, where the number of journals in the core and subsequent zones constitutes a ratio of 1 (zone 1): n (zone 2): n2 (zone 3). Such analysis reveals the preferred journals among researchers and provides information on the most prominent journals within the focal knowledge domain. Therefore, the relevant findings indicate the presence of 10 core journals with 222 publications, 52 s-tier journals with 211 publications, and 185 third-tier journals with 212 publications (Fig. 3b). As the journals in the core zone align closely with the top 10 most productive journals, they are the preferred publishing outlets among the authors in this study.

The top 10 journals preferred by these authors are ranked in Table 1 based on the number of articles published in each journal. Additionally, the impact factor (JIF) of the journal, the H index associated with the study collection, the editorial office, and the thematic category in which the journal is indexed are indicated. The top 10 journals have an average of 22 published articles (95 % confidence interval ranging from 7.97 to 33.96) and a median of 14.50 articles.

Among these journals, ATMOS ENVIRON stands out as the most popular journal in this field, with a total of 12.40 % of published articles (80 articles, JIF = 5.755). It is followed by SCI TOTAL ENVIRON (24 articles, JIF = 10.754), ATMOS CHEM PHYS (22 articles, JIF = 7.197), and J AIR WASTE MANAGE (22 articles, JIF = 7.197).

Regarding the H-index, the top 10 journals have an average of 13 (95 % confidence interval ranging from 7.0 to 19) and a median of 11. This means that approximately 1.5 % of the articles published in this group of journals have been cited 11 times or more. The journal with the highest H-index is ATMOS ENVIRON (H-index = 34).

In general, the editorial offices of these journals are in European countries and the United States. The top 10 journals are mainly indexed in two areas: environmental sciences, meteorology, and atmospheric sciences. Six of the 10 journals in the top 10 are ranked in the first quartile of the categories in which a given journal is indexed.

It is also important to highlight the relevance of the JIF in the choice of journal for publication. These journals not only have high impact factors but also have published numerous articles on air pollution, making them attractive to researchers in this field due to the potential interest they may generate among the international research community.

3.4. Most relevant authors and cocitation network

Lotka's law was employed to assess the author's productivity in the field of air pollution research in Chile. This law characterizes the distribution of authors based on their productivity and is represented by the following equation: number of authors = C x (number

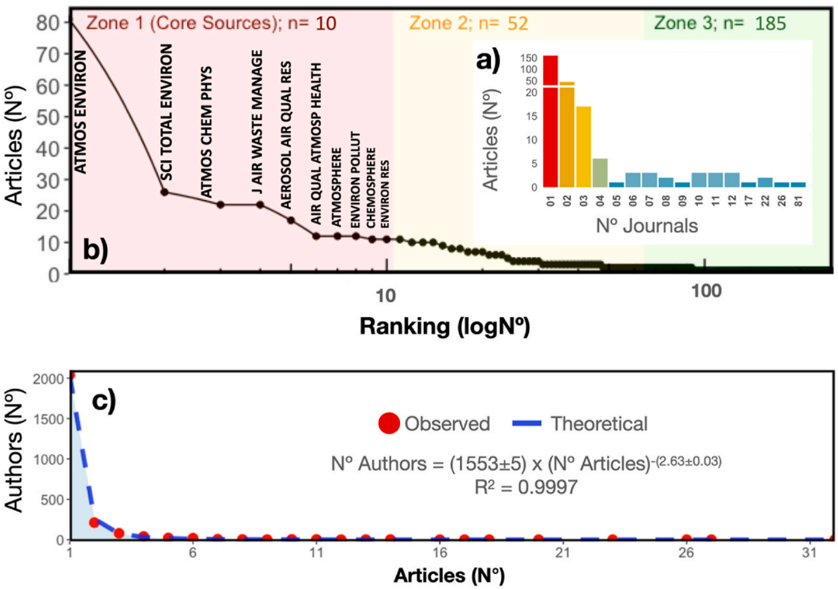

Fig. 3. The main sources of air pollution research in Chile from 1980 to 2022: a) frequency of articles in each journal; b) Bradford's law applied to the article database, where sources (journals) are divided into three zones based on their distribution of the number of articles (N°), and the number of journals (n) in the core and subsequent zones is proportional to a ratio of 1 (Zone 1): n (Zone 2): n^2 (Zone 3); c) adjusted data for Lotka's law.

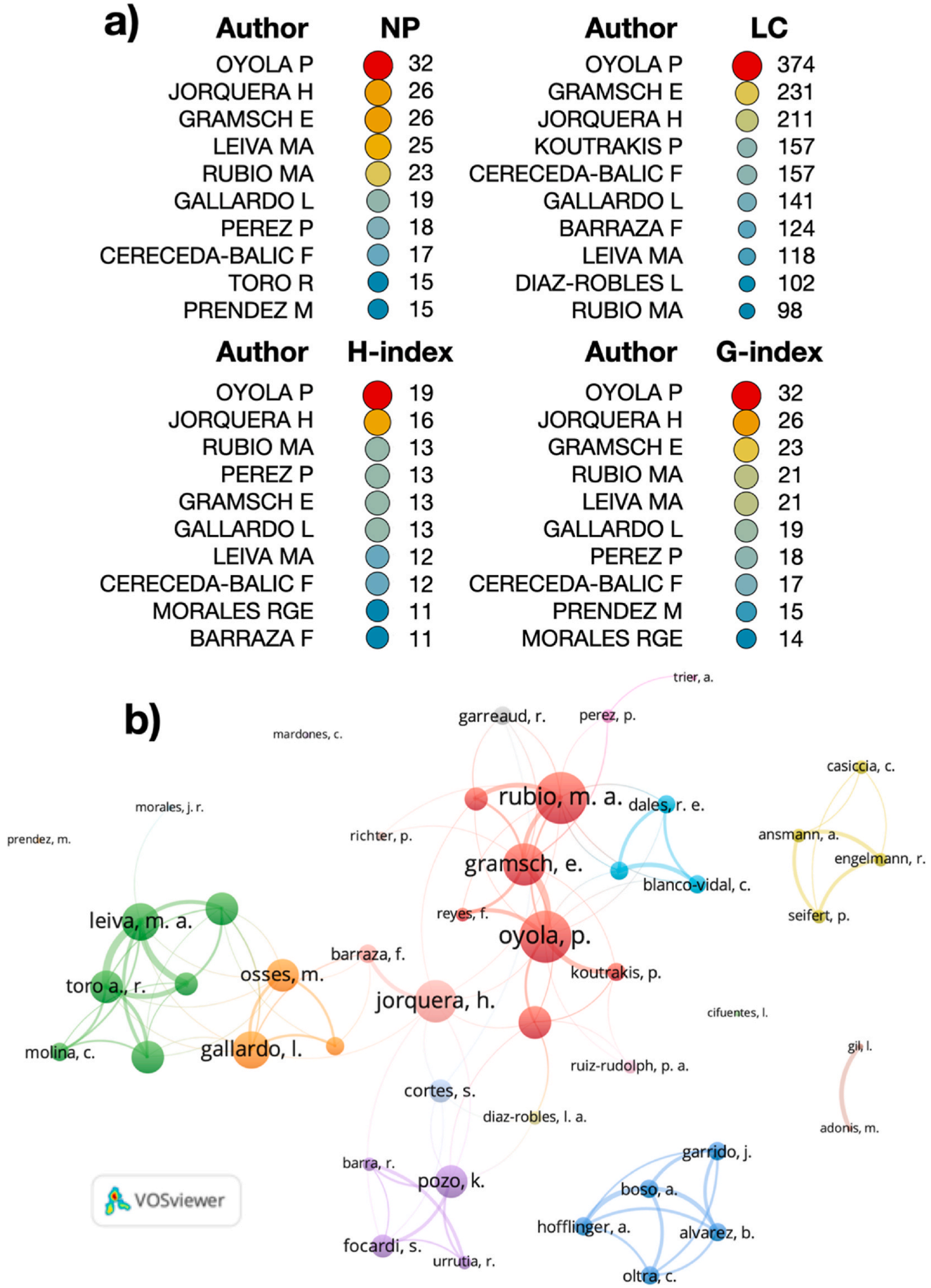

Fig. 4. a) Ranking of the most relevant authors in air pollution research in Chile during 1980–2022 according to their number of published articles (NP), total citations (TC), and H-index and g-index; b) coauthorship network of the top 50 most productive authors.

of articles)$^{-2}$, where C is an arbitrary constant [48]. The fitted data for Lotka's law are displayed in Fig. 4c and demonstrate a strong fit with an R-squared value of 0.9997. This confirms the validity of Lotka's law, since a total of 2038 authors contributed to the focal articles. Among these authors, 77.5 % contributed one article each, 11.6 % contributed two articles each, and 4.40 % contributed three

Table 1
Top 10 most relevant sources, number of published articles (NP), percentage of total (N° NP %NP), journal impact factor (JIF), H-index (H-index), editorial office country or region, and journal indexing category in WoS database.

JOURNAL ABBRV.	NP (%NP)	JIF	H-INDEX	COUNTRY	CATEGORY	POSITION
ATMOS ENVIRON	80 (12.40 %)	5.755	34	NLD	ENVIRON SCI	69/325 Q1
					METEOR ATMOS SCI	27/108 Q1
SCI TOTAL ENVIRON	24 (3.72 %)	10.754	18	NLD	ENVIRON SCI	26/279 Q1
ATMOS CHEM PHYS	22 (3.41 %)	7.197	11	DEU	ENVIRON SCI	50/279 Q1
					METEOR ATMOS SCI	12/94 Q1
J AIR WASTE MANAGE	22 (3.41 %)	2.636	14	USA	ENGIN, ENVIRON	42/54 Q4
					ENVIRON SCI	196/279 Q3
					METEOR ATMOS SCI	64/94 Q3
AEROSOL AIR QUAL RES	17 (2.64 %)	4.530	10	TWN	ENVIRON SCI	115/325 Q2
ENVIRON POLLUT	12 (1.86 %)	9.988	11	GRB	ENVIRON SCI	28/279 Q1
ATMOSPHERE	12 (1.86 %)	4.530	4	CHE	ENVIRON SCI	178/325 Q3
					METEOR ATMOS SCI	68/108 Q3
CHEMOSPHERE	11 (1.71 %)	8.943	4	GRB	ENVIRON SCI	33/279 Q1
ENVIRON RES	11 (1.71 %)	8.431	8	USA	ENVIRON SCI	19/325 Q1
					PUB ENVIRON OCCUP HEALTH	26/392 Q1
AIR QUAL ATMOS HEALTH	11 (1.71 %)	5.804	7	NLD	ENVIRON SCI	74/279 Q2

articles each. Notably, the top ten authors who contributed at least 10 articles each, in accordance with Lotka's law, can be considered recurrent authors.

Fig. 4a presents the 10 most productive authors, ranked in descending order according to their number of published articles (NP), followed by their H-index. When multiple authors share the same H-index (Hirsch, 2005), further sorting was performed using the G-index [49]. This figure also displays the bibliometric indicator Local Citations (LC), which represents the number of times an author or document within the collection has been cited by other documents therein. Remarkably, the top 10 authors formed a consistent core across all parameters (NP, LC, H-index, and G-index). These authors account for 33.49 % of the total number of publications. On average, this group of researchers has published 22 articles (mean: 21.6) with a 95 % confidence interval ranging from 18.09 to 25.11. In terms of local citations, the top 10 authors have received citations ranging from 374 to 98. Furthermore, at least eight authors from this group are ranked in the top 10 based on both the H-index and the G-index. The mean and median H-index (G-index) for this group of scientists was 13.3 (20.3), with a 95 % confidence interval for the mean ranging from 11.78 (16.69) to 14.81 (23.90). Women make up 30 % of the participating researchers, considering all bibliometric indicators.

Fig. 4b illustrates a map of the coauthorship network of highly productive authors, representing the collaborative relationships among them. In this visualization, each author is depicted as a node in the network; the coauthored publications are represented by the links or edges connecting these nodes [50]. The size of the node corresponds to the number of papers authored by everyone, and the thickness of the lines represents the intensity of coauthorship. The map also reveals the presence of multiple clusters where authors with significant coauthorship connections are grouped together.

Specifically, this map includes authors who have contributed more than 7 articles to the collection. These results indicate the existence of seven distinct clusters with regular member collaboration. Among these clusters, two stand out prominently in terms of their number of authors. The red cluster depicted in Fig. 4b consists of seven authors, with Oyola and Gramsh being the most prolific collaborators. The green cluster comprises six authors, with Leiva and Toro being the most active collaborators. Additionally, these clusters are aligned with authors who are affiliated with similar research groups and highly productive academic institutions. This finding suggests a tendency toward cohesive collaboration within these groups, fostering productive partnerships and knowledge exchange in the field of air pollution research in Chile.

Fig. 5. Ranking of the most relevant institutions in air pollution research in Chile from 1980 to 2022 based on the number of published articles (NP) according to author affiliation.

3.5. Characteristics of institutional contributions

Fig. 5 illustrates the 10 best-performing institutions based on their number of publications in the field of air pollution research in Chile. Our bibliometric analysis revealed the participation of 683 institutions in this research area during 1980–2022. Analyzing this distribution of institutions provided valuable information on the research capacity in this field.

The top 10 institutions thus collectively contribute more than 35 % of the publications. All these institutions are in Chile, reflecting the scope of our bibliographic analysis. The University of Chile is the leader, accounting for a significant 11.64 % of focal articles. The Pontifical Catholic University of Chile is closely followed, with a participation rate of 5.57 %. Furthermore, Ctr Climate and Resilience Research, an affiliated research center of the University of Chile, occupies a prominent position.

Thus, these results unquestionably highlight the substantial contributions of universities, particularly public state universities, in the field of air pollution research in Chile. In particular, the presence of these top 10 public academic institutions can be attributed not to significant government financial support, which remains limited, but to the dedication, commitment, and enthusiasm of individual researchers and institutional policies.

Therefore, this analysis has elucidated the research landscape, illuminating the crucial role of universities in driving research on air pollution in Chile. Despite financial constraints, these institutions continue to demonstrate their determination to pursue research excellence through self-financing and the dedication of their researchers.

3.6. Top-cited documents

The articles most cited, according to the 98th percentile thereof, both locally (LC) and globally (GC), are presented in Table 2. LC represents the number of citations an article has received from other articles within the focal collection. GC represents the number of citations an article has received from indexed articles outside the focal collection. Importantly, LC and GC can be interpreted as measures of the relevance and influence of an article within the research field and its potential impact on other fields of study, respectively [51]. However, LC and GC do not necessarily indicate the quality of an article but rather its influence on and visibility within local or global research communities.

Consequently, we observed an average of 2.98 citations per article (95 % CI 0 to 20.2) throughout the entire collection of articles (Table 2), with a 98th percentile of 20 citations per article. A small proportion of articles (0.46 %) have generated 40 or more citations,

Table 2
Top-cited local and global articles by 98th percentile, digital object identifier (DOI), publication year, local citations (LC, N°) and global citations (GC, N°), and the percentage ratio between the latter (LC/GC, %).

Most Cited Documents (Reference)	Journal Abbreviations	Digital Object Identifier (DOI)	LC (N°)	GC (N°)	LC/GC (%)
LOCAL					
Kavouras et al., 2001a [52]	J AIR WASTE MANAGE	10.1080/10473289.2001.10464273	43	106	40.57
Gramsch et al., 2006 [53]	ATMOS ENVIRON	10.1016/j.atmosenv.2006.03.062	43	105	40.95
Koutrakis et al., 2005 [54]	J AIR WASTE MANAGE	10.1080/10473289.2005.10464627	38	70	54.29
Artaxo et al., 1999 [55]	NUCL INSTRUM METH B-a	10.1016/S0168-583X(98)01078-7	36	111	32.43
Ilabaca et al., 1999 [56]	J AIR WASTE MANAGE	10.1080/10473289.1999.10463879	29	78	37.18
Sanhueza et al., 2009 [57]	J AIR WASTE MANAGE	10.3155/1047–3289.December 59, 1481	27	77	35.06
Cakmak et al., 2007 [58]	ENVIRON HEALTH PERSP	10.1289/ehp.9567	24	70	34.29
Jorquera and Barraza, 2012 [59]	SCI TOTAL ENVIRON	10.1016/j.scitotenv.2012.07.049	24	46	52.17
Villalobos et al., 2015 [60]	SCI TOTAL ENVIRON	10.1016/j.scitotenv.2015.01.006	23	69	33.33
Ostro et al., 1990 [61]	ENVIRON HEALTH PERSP	10.2307/3434291	22	96	22.92
Romero et al., 1999 [62]	ATMOS ENVIRON	10.1016/S1352-2310(99)00145-4	21	95	22.11
Molina et al., 2017 [63]	AIR QUAL ATMOS HLTH	10.1007/s11869-017-0459-y	21	38	55.26
Gallardo et al., 2002 [64]	ATMOS ENVIRON	10.1016/S1352-2310(02)00285-6	20	38	52.63
Moreno et al., 2010 [65]	J AIR WASTE MANAGE	10.3155/1047–3289.December 60, 1410	20	23	86.96
Schmitz, 2005 [66]	ATMOS ENVIRON	10.1016/j.atmosenv.2004.12.033	19	45	42.22
Sanhueza et al., 2006 [67]	REV MED CHILE	10.4067/S0034-98872006000600012	19	35	54.29
Schueftan and González, 2013 [68]	ENERG POLICY	10.1016/j.enpol.2013.08.097	19	39	48.72
GLOBAL					
Kavouras et al., 2001b [69]	ENVIRON SCI TECHNOL	10.1021/es001540z	6	407	1.47
McMichael et al., 2008 [70]	INT J EPIDEMIOL	10.1093/ije/dyn086	0	404	0
Escobedo and Nowak, 2009 [71]	LANDSCAPE URBAN PLAN	10.1016/j.landurbplan.2008.10.021	4	292	1.37
Bollhöfer and Rosman, 2000 [72]	GEOCHIM COSMOCHIM AC	10.1016/S0016-7037(00)00436-1	3	267	1.12
Díaz-Robles et al., 2008 [73]	ATMOS ENVIRON	10.1016/j.atmosenv.2008.07.020	18	235	7.66
Simoneit et al., 2005 [74]	ENVIRON SCI TECHNOL	10.1021/es050767x	0	230	0
Schlitzer, 2002 [75]	DEEP-SEA RES PT II	10.1016/S0967-0645(02)00004-8	0	228	0
Pérez et al., 2000 [76]	ATMOS ENVIRON	10.1016/S1352-2310(99)00316-7	17	226	7.52
Pozo et al., 2004 [77]	ENVIRON SCI TECHNOL	10.1021/es049065i	11	216	5.09
Kavouras et al., 2001c [78]	ATMOS ENVIRON	10.1016/S1352-2310(99)00281-2	12	201	5.97
Bell et al., 2008 [79]	INT J EPIDEMIOL	10.1093/ije/dyn094	4	188	2.13
Escobedo et al., 2008 [80]	J ENVIRON MANAGE	10.1016/j.jenvman.2006.11.029	8	173	4.62
Cifuentes et al., 2000 [81]	J AIR WASTE MANAGE	10.1080/10473289.2000.10464167	0	154	0
Leiva et al., 2013 [82]	ENVIRON POLLUT	10.1016/j.envpol.2013.05.057	9	151	5.96

0.3 % between 30 and 39 citations, and 1.82 % between 20 and 29 citations. In contrast, approximately 48 % of the articles have not received any local citations; a similar proportion have received between 1 and 19 local citations. Articles that surpass the 98th percentile thus average 69 total citations, ranging from 23 to 111 citations.

The average local citation-global citation ratio (LC/GC) was approximately 45 %, with the top LC articles ranging from 22 % to 87 %. This suggests that these articles have garnered interest beyond the local sphere and attracted attention from researchers in related

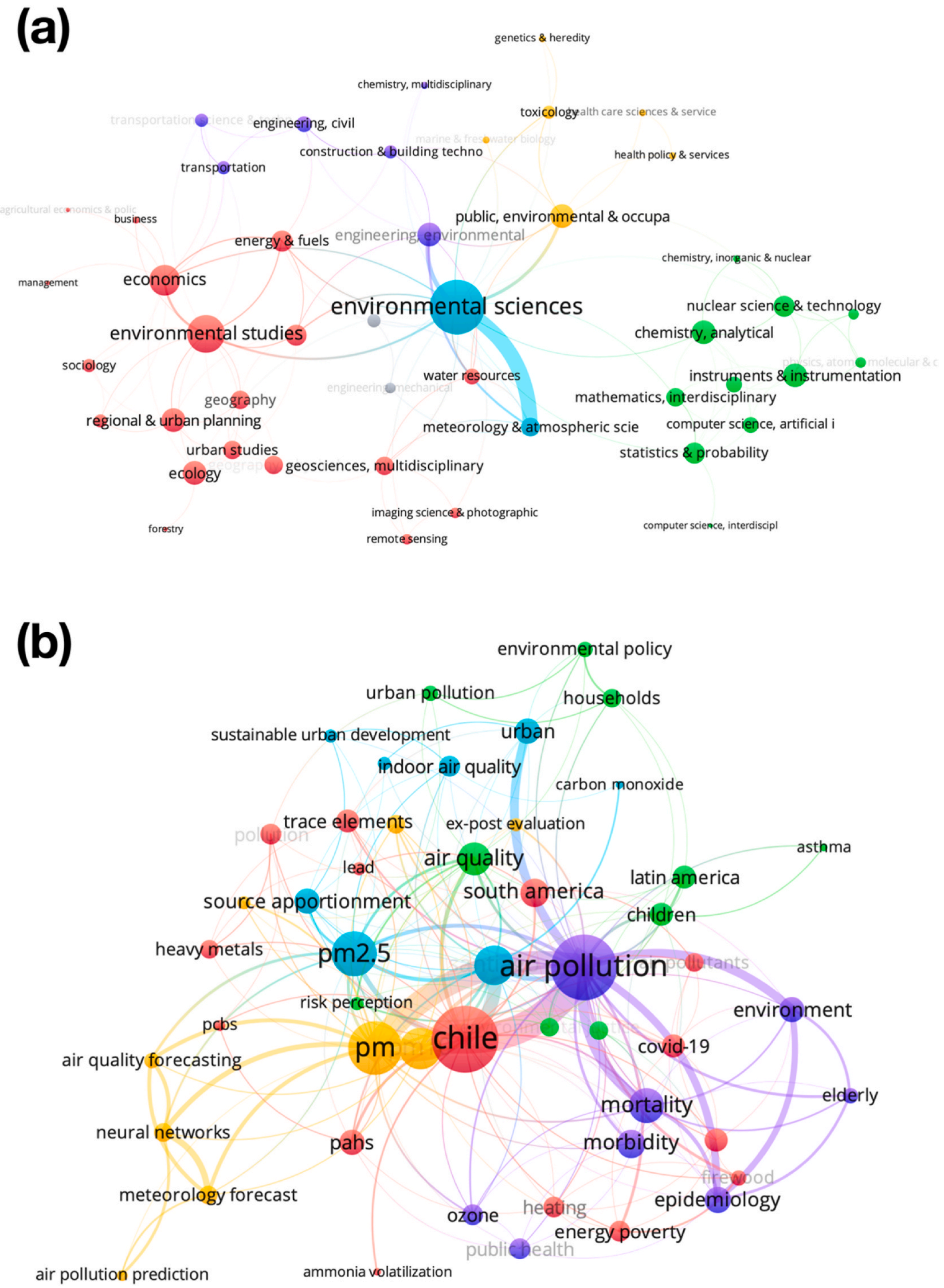

Fig. 6. Hotspots in air pollution research in Chile from 1980 to 2022: a) cooccurrence network of WoS subject categories; b) cooccurrence network of author keywords.

fields worldwide. In particular, the local articles most frequently cited perform a health impact analysis and source attribution analysis, particularly in urban and regional particulate matter, wood combustion, copper smelting, and soil emission sources. These topics have evidently resonated with the scientific community, contributing to the high citation rates observed among these articles.

Concerning the analysis of global citations (Table 2), these GCs display an average of 25 citations per article (95 % CI 0–148), ranging from 407 to 0 citations throughout the collection. Approximately 1.98 % (13 articles) have received more than 149 citations, surpassing the 98th percentile. Meanwhile, 10 %, 70 %, and 18 % of all articles fall within the citation ranges of 1–50, 51 to 149, and above 150, respectively. Furthermore, approximately 18 % of the articles have not received global citations.

The LC/GC ratio for articles exceeding the 98th percentile is, on average, 2.8 %, ranging from 0 % to 7.7 %. This suggests that articles with greater global interest may not necessarily align with local interest. In general, the articles most widely cited focus on health effects, primarily involving particulate matter, and/or compare national and international results. Furthermore, these articles explore the impact of climatic factors on pollutant concentrations and analyze trends while incorporating atmospheric transport models and assessing their links.

3.7. Research hotspot analysis

Two types of analyses were performed to determine the hotspots in the investigation of air pollution in Chile. The first analysis considered aspects related to the WoS subject categories (Fig. 6a) and author keywords (Fig. 6b) in the focal articles. This analysis utilized the co-occurrence method, that is, terms with at least three interactions were grouped using the leading eigenvectors algorithm [83]. Cooccurrence analysis is a research strategy that has been successfully employed in previous studies [84] to identify significant research topics and emerging trends.

The second analysis involved a comprehensive review of each article in the collection that extracted and categorized explicitly mentioned information on the scope, goals, methods, focal pollutants and/or variables, space-time variability, emission sources, and the potential impact of their findings. The results of this analysis, expressed as a percentage of weighted occurrences, provide information on the main characteristics of the research carried out in Chile and reveal some potential research gaps.

Analysis of the WoS subject categories (Fig. 6a) revealed that the top five categories of articles in the collection have been published in journals in environmental science, meteorology & atmospheric science, engineering-environmental, environmental studies, and public, environmental & occupational health. These categories can be grouped into six topic clusters as follows: 1) Environmental sciences (shown in cyan in Fig. 6a): This prominent group encompasses categories related to environmental sciences and meteorology and atmospheric sciences. 2) Environmental and social sciences (red color in Fig. 6a): This group includes environmental studies, economics, energy and fuels, green and sustainable science, and technology. 3) Environmental engineering and transport (purple color in Fig. 6a): This group consists of categories that include environmental engineering and construction and building. 4) Health and toxicology (orange group in Fig. 6a): This group encompasses categories such as public health, environmental and occupational health, and toxicology. 5) Analytical chemistry and instrumental analysis (green group in Fig. 6a): This group includes categories such as chemistry, analytical, nuclear science and technology, and statistics and probability. 6) Chemical and mechanical engineering (gray group in Fig. 6a): This group comprises categories such as chemical engineering and mechanical engineering.

Regarding the analysis of author keywords (Fig. 6b), the top five keywords in the collection are air pollution, Chile, PM, Santiago, and $PM_{2.5}$. These author keywords are grouped into five clusters: 1) air pollution and health (blue cluster in Fig. 6b): This cluster is associated with keywords related to air pollution and health, including mortality, morbidity, epidemiology, and the environment. 2) Pollutants (red cluster in Fig. 6b): This cluster mainly encompasses keywords associated with pollutants measured in Chile, such as PAHs, heavy metals from wood burning emissions, and climate impacts. 3) Airborne pollutant models (yellow cluster in Fig. 6b): This cluster is related to terms such as PM, neural networks, meteorological prediction, air quality prediction, airborne pollutant assessment, and airborne pollutant forecasting. 4) Sources and chemistry (cyan cluster in Fig. 6b): This cluster is associated with keywords such as chemical composition, indoor air quality, source distribution, and sustainable urbanism. 5) Air pollution and social sciences (green cluster in Fig. 6b): This cluster includes keywords such as environmental justice and environmental policy.

The quantitative results obtained by assigning normalized keywords to extract information from the article collection (which included author affiliation characteristics, study objectives, study characteristics, effects or implications of results, assessment methods, pollutants or variables, spatiotemporal resolution, spatial coverage at the national level, and pollutant emission citations) are presented and discussed below. In the Supplementary Materials (Tables S3–S14), detailed definitions of these normalized keywords are provided.

Given the primary characteristics of the focal studies, it is evident that most of the collection, 79.53 %, is concerned with understanding pollution issues. Furthermore, 17.98 % of the studies deal with managerial, economic, legal, and social issues. Other areas of research include indoor pollution (7.60 %), laboratory investigations (5.27 %), and technological advances (3.72 %). Table S5 and Fig. S5 in the Supplementary Material illustrate these areas. The topics of these studies are diverse and include the causal factors of air pollution (32.87 %), exposure levels (24.34 %), representativeness (13.95 %), atmospheric modeling (12.71 %), dissemination of information to the public (11. 63 %), management tools (8.84 %), compliance measures (5.12 %), laboratory analysis (3.26 %), receptor models (2.33 %), monitoring networks (2.17 %), and contaminant screening (0.47 %), as detailed in Table S6 and Fig. S6 in the Supplementary Appendix.

Several categories can be distinguished with respect to the potential impacts of research in this area. Human health and regulatory/legal factors were dominant at 42.02 % and 41.09 %, respectively. These are followed by ecological impacts (17.21 %), economic impacts (11.78 %), climatic impacts (8.53 %), sociocultural considerations (6.51 %), and impacts on the built environment and materials (2.33 %). These are detailed in Table S7 and Fig. S7 of the Supplementary Material. The variables examined cover a wide range, including pollutant concentrations (74.42 %), meteorological data (29.77 %), numerical modeling data (20.78 %), chemical compositions of pollutants (19.69 %), epidemiological data (13.80 %), physical properties of pollutants (10.85 %), satellite-derived measurements (5.74 %), toxicological data (3.57 %), and biological compositions (1.40 %), as detailed in Table S8 and Fig. S8 in the Supplementary Material.

The importance of temporal and spatial scales cannot be overestimated when analyzing the dynamics of environmental phenomena, especially in the field of air pollution. By selecting appropriate scales, researchers can unravel the complexity and variability of these phenomena, as demonstrated by Fan et al. (2021) and Jiang et al. (2020) [85,86]. Temporarily, most authors (45.89 %) adopt a time frame beyond one year, capturing seasonal/annual patterns, long-term trends, and cumulative effects; this helps to consider environmental phenomena in a more integrated way. Next, 17.83 % of the studies examine seasonal variations and their impacts on an annual to seasonal scale. Short-term variations and events are elucidated by scales ranging from three months to one month (12.71 %) and from three weeks to 1 h (12.87 %). These scales are detailed in Table S10 and Fig. S10 in the Supplementary Material.

Spatially, the local scale is predominant, representing 59.22 % of the studies; it allows for the identification of local variations and sources of pollution, providing a multifaceted analysis ranging from rural to urban landscapes. The regional scale accounts for 24.19 % of the studies and reveals overarching patterns and relationships within a specific geographic area, often encompassing larger regions or countries. The global scale, which is less prevalent at 8.99 %, explores large-scale areas; in contrast, the microscale, at 7.75 %, provides an understanding of specific places, including indoor environments, workplaces, residential areas, and street canyons. See Table S11 and Fig. S10 in the Supplementary Material.

From an administrative perspective, a substantial 91.01 % of the studies focus on the national level, with national policies and regulations playing a central role in addressing environmental issues. In contrast, a modest 19.07 % of the studies emphasize the international level. This underscores the need for global cooperation and understanding to address environmental challenges, as shown in Table S12 and Fig. S12 in the Supplementary Material. Within Chile's administrative divisions, the Central Zone receives the most attention (59.84 %). This is due to its dense population and urban expansion. A close second is the southern zone (22.95 %), characterized by its diverse ecosystems and the prevalence of wood burning emissions. The Great North (6.51 %), Austral (6.36 %), Little North (3.26 %), and Antarctic (2.02 %) zones, each with unique environmental contexts and challenges, are less explored, as shown in Supplementary Material Table S13 and Fig. S13.

3.8. Strengths and weaknesses

The current bibliometric analysis, like similar studies, has certain limitations that need to be acknowledged. One limitation pertains to the focal database. To compile this database, Boolean strings were created with various keywords. However, importantly, these strings may introduce bias in a bibliographic review due to potential inconsistencies among the keywords chosen by the article authors, the actual content of the focal articles, and the adopted Boolean strings. Additionally, reviewing and harmonizing the database can potentially lead to omissions, e.g., in the harmonization of author names, keywords, and affiliations. Furthermore, throughout the study, a series of decisions must be made that can impact the visualization results, and different researchers can adapt these decisions based on their specific objectives, thus influencing the results. Another potential limitation is the restriction to English-language articles, which could introduce bias and omit some articles written in other languages. However, using a comprehensive database such as Web of Science helps mitigate this issue, ensuring a more extensive collection of relevant research.

Another potential limitation of our study is our focus on the top 10 authors and the bibliometric index used to create this ranking. These may overlook the contributions of early-career researchers or those in niche areas of the field. The senior research, despite potentially significant contributions by years carriers or for a decation unique to the field. In recognition of this, we spect in future updates of this work to broaden bibliometric indexes to encompass a wider range of contributors, thereby saving these limitations.

Given the inherent weaknesses of bibliometric analysis, the authors of this study believe that one of its strengths is the design of the database review, which used a panel approach. In this approach, two of the three database reviewers had to agree on the results. Conflicts that arose during the review process were discussed in subsequent work meetings to harmonize the adopted criteria, and redundant review steps were carried out amid successive discussions of the results. This rigorous approach was implemented to ensure consistency and reliability in the present study.

4. Future directions of research

Based on a bibliometric analysis and the insights gained from the quantitative characterization of the articles in the collection, several critical research areas have been identified that address the existing knowledge gaps in the field of air pollution in Chile. By identifying these research areas as comprehensively as possible, scientists and other stakeholders will be able to better understand how air pollution research in Chile has developed and evolved and which areas need to be further strengthened. The identified areas are outlined below:

Predictive Modeling: Emphasis should be placed on analyzing long-term air pollution patterns in Chile. The development of predictive models to forecast pollutant concentrations and their subsequent impacts will be instrumental in anticipating future scenarios, pinpointing areas of concern, and formulating targeted interventions.

Health Impacts: The correlation between air pollution and health implications remains a central research domain. In-depth studies are essential to unravel the mechanisms driving the health consequences of pollutants, particularly for susceptible populations. Addressing this issue will not only enrich scientific comprehension but also shape public health directives.

Emission Sources and Control Strategies: Detailed investigations into emission sources, encompassing sectors such as power generation, mining, wildfires and agriculture, are critical. The aim should be to outline effective control strategies, focusing on sustainable and region-specific solutions for Chile.

Ecological Impacts The repercussions of air pollution on ecosystems and biodiversity in Chile's diverse regions warrant thorough exploration; this includes evaluating impacts on plant and animal life, discerning alterations in biodiversity, and elucidating the long-lasting ecological outcomes of pollutant interactions.

Interplay with Climate Change: The complex interrelation between air pollution and Chile's shifting climate patterns is essential and involves discerning how climatic factors influence pollutant levels and their cascading implications on health, ecology, and air quality.

Policy Evaluation and Governance: An assessment of Chile's existing air pollution policies and regulations, grounded in empirical data, is crucial. Research endeavors should offer evidence-based suggestions to refine the regulatory structure and evaluate emission reduction strategies and stakeholder engagement.

Technological Advancements: Advancing technologies for air pollution surveillance and mitigation in Chile is essential and involves the adoption of cutting-edge sensor technologies, the deployment of advanced remote sensing methodologies, and the use of data analytics to optimize real-time surveillance, thus facilitating data-driven decision-making processes.

Public Engagement: Efforts to increase public awareness and encourage active participation in addressing air pollution problems in Chile are essential; this requires a thorough evaluation of communication methodologies, understanding of public sentiment/perceptions, and the development of structured engagement platforms to foster collective action.

International Collaborations: Given the global ramifications of air pollution and Chile's unique environmental diversity, the establishment of research partnerships with international entities is of the utmost importance. These collaborations not only enable the exchange of knowledge and dissemination of tried-and-true practices but also pave the way for joint research projects. Furthermore, such alliances allow Chile to share its unique lessons learned from its diverse ecosystems and, in return, benefit from global expertise.

Interdisciplinary Collaboration: Given the nuanced intricacies of air pollution and Chile's unique environmental landscape, the need for an interdisciplinary approach is heightened. When atmospheric scientists, health specialists, social scientists, and policy makers are united in joint research endeavors, a harmonization of varied insights is achieved. This collaborative synergy among research groups is instrumental in formulating comprehensive strategies, ensuring that the multifaceted challenges of air pollution in Chile are addressed with depth and precision.

By following these future research directions, the scientific community can advance knowledge on air pollution in Chile, better support evidence-based decision making, and promote sustainable air quality management practices for the benefit of both human health and the environment.

5. Conclusions

In the current study, a comprehensive bibliometric analysis and scoping review of air pollution research in Chile, the field has advanced and expanded significantly in recent decades. An increasing number of publications, a higher citation-per-article ratio and a commendable H-index are evidence of this progress. Taken together, these metrics underscore the field's significant influence and recognition within the scientific community. International collaboration has increasingly become part of the research landscape in Chile.

The distribution of publications is concentrated in a select group of journals, with eight journals clearly emerging as focal points. This concentration highlights the preference of the academic community for journals that have a high impact index. The crucial role of academic institutions, especially the University of Chile and the Pontifical Catholic University of Chile, in the advancement of air pollution research in the country is undeniable.

Subject analysis shows that a significant proportion of articles are rooted in environmental sciences, meteorology and atmospheric sciences, and related disciplines. Thematic clusters, including air pollution and health, pollutants, modeling, sources and chemistry, and social sciences, were identified in the keyword analysis. These clusters cover a wide range of topics. They include pollution-related challenges, management strategies, economic and legal aspects, indoor pollution, laboratory investigations, and technological advances. The implications of these articles span human health, regulatory structures, ecological consequences, economic impacts, climatic changes, sociocultural considerations, and infrastructure and material impacts.

In addition, the study highlights critical areas for future research. The need to analyze long-term air pollution patterns and develop predictive models to anticipate potential outcomes is emphasized. A thorough study of the sources of emissions, the regulatory measures to control them, the impacts on ecosystems and biodiversity, and the interrelationships between air pollution, climate change, and health impacts are of paramount importance. Assessing the effectiveness of current policies and exploring technological advances to monitor and mitigate them are critical. Increasing public awareness and fostering international partnerships are essential components of a comprehensive strategy. Adopting a multidisciplinary approach, integrating expertise from different disciplines, is essential to understanding and managing air pollution in Chile. The overarching goal is the protection of the health of people and the environment.

A bibliometric analysis and scoping review prove to be tools to systematically map the literature and identify patterns, gaps, and trends. These methodologies facilitate a comprehensive understanding of the research landscape. The rigorous methodology employed in this study strengthens the reliability and consistency of the findings, although it is important to acknowledge the inherent limitations associated with database selection and potential biases.

Finally, this study offers an in-depth look at the evolution of Chilean air pollution research, highlighting its global relevance and the urgent need for continued research and cooperation. The lessons learned from this analysis will undoubtedly serve as a foundation for future research efforts, for the formulation of policy, and for the continued pursuit of knowledge in the field of air pollution.

Data availability statement

Data pertinent to this study are available in the OSF (Open Science Framework) registry at https://osf.io/ywhrz/. This repository includes the detailed methodological information and encompasses essential documents such as the PRISMA-ScR Checklist, which indicates compliance with reporting standards; the Scoping Review Protocol, which details the methodology in line with PRISMA-ScR guidelines; the Results from the Scoping Review, providing an overview of the findings; and the Database of Selected Articles, containing the collection of sources analyzed. Further data supporting the findings of this study can be requested from the corresponding author, MALG.

Disclaimer of generative AI and AI-assisted technologies in the writing process

During the preparation of this article, the author(s) used ChatGPT Plus to edit and proofread English writing. After using this tool/service, the author(s) reviewed and edited the content as needed. The author(s) assumes full responsibility for the content of the publication.

CRediT authorship contribution statement

Loreto Villacura: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Luis Felipe Sánchez:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Francisco Catalán:** Visualization, Formal analysis, Data curation. **Richard Toro A:** Conceptualization, Writing - review & editing. **Manuel A. Leiva G:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Manuel A. Leiva reports financial support was provided by University of Chile. Manuel Leiva reports a relationship with University of Chile that includes: employment. Manuel Leiva has patent No proceed pending to No proceed. No proceed.

Acknowledgments

The authors acknowledge and are grateful for the contribution of Sciome (https://www.sciome.com) for providing free-of-charge SWIFT-Active Screener software, which allowed a fast and efficient systematic review of the articles included in this study. This research was partially funded by Vicerrectoría de Investigación y Desarrollo (VID), Universidad de Chile, Programa de Apoyo a Proyectos de Enlace con Concurso Fondecyt Regular VID 2020 and 2023, grants No. ENL17/20 and ENL21/23, and the Chilean National Fund for Scientific and Technological Development (FONDECYT) ANID FONDECYT Regular Grant No. 1220948 LV acknowledges support from ANID: 2021 National Doctoral degree Scholarship Program, No. 21212276. LFS acknowledges support from ANID, CONICYT: 2019 National Doctoral degree Scholarship Program, No. 21191906.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e25431.

References

[1] H. Ritchie, M. Roser, Air Pollution, Publ. Online OurWorldInData.Org., 2017. Available online, https://ourworldindata.org/air-pollution.

[2] WHO, Ambient (outdoor) air pollution, [Fact Sheet], World Heal. Organ. Ginebra, Suiza, 2022. Suiza. Available online: https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health. (Accessed 1 March 2023).

[3] F.H. Dominski, J.H. Lorenzetti Branco, G. Buonanno, L. Stabile, M. Gameiro da Silva, A. Andrade, Effects of air pollution on health: a mapping review of systematic reviews and meta-analyses, Environ. Res. 201 (2021), https://doi.org/10.1016/j.envres.2021.111487.

[4] X. Liu, S. Mubarik, F. Wang, Y. Yu, Y. Wang, F. Shi, Lung Cancer Death Attributable to Long-Term Ambient Particulate Matter (PM 2 . 5) Exposure in East Asian Countries during 1990 – 2019, 2021, pp. 1–12, https://doi.org/10.3389/fmed.2021.742076, 8.

[5] K. Wolf, B. Hoffmann, Z.J. Andersen, R.W. Atkinson, M. Bauwelinck, T. Bellander, J. Brandt, B. Brunekreef, G. Hoek, A. Peters, P.L.S. Ljungman, Articles Long-Term Exposure to Low-Level Ambient Air Pollution and Incidence of Stroke and Coronary Heart Disease : a Pooled Analysis of Six European Cohorts within the ELAPSE Project, 2021, pp. 620–632, https://doi.org/10.1016/S2542-5196(21)00195-9.

[6] D. Doiron, K. de Hoogh, N. Probst-Hensch, I. Fortier, Y. Cai, S. De Matteis, A.L. Hansell, Air pollution, lung function and COPD: results from the population-based UK Biobank study, Eur. Respir. J. 54 (2019) 1802140, https://doi.org/10.1183/13993003.02140-2018.

[7] B. Alahmad, H. Khraishah, K. Althalji, W. Borchert, F. Al-Mulla, P. Koutrakis, Connections between air pollution, climate change, and cardiovascular health, Can. J. Cardiol. 39 (2023) 1182–1190, https://doi.org/10.1016/j.cjca.2023.03.025.

[8] M. Zhang, L. Shi, X. Ma, Y. Zhao, L. Gao, Study on Comprehensive Assessment of Environmental Impact of Air Pollution, 2021.

[9] EEA, Impact of air pollution on ecosystems, Eur. Environ. Agency. 2 (2022), https://doi.org/10.15406/oajs.2018.02.00112.
[10] The World Bank, Pollution, World Bank Gr., Washington, USA, 2019. Available online: https://www.worldbank.org/en/topic/pollution. (Accessed 1 March 2023).
[11] C. Jooste, T. Loch-temzelides, J. Sampi, D. Hasan, Pollution and labor productivity evidence from Chilean cities, Policy Res. Work. Pap. World Bank Gr, 2022. Available online: http://hdl.handle.net/10986/38350. (Accessed 1 March 2023).
[12] United-Nations, World urbanization prospects, Dep. Econ. Soc. Aff. 12, 2018, pp. 197–236. Available online. https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf. (Accessed 1 April 2023).
[13] N. Huneeus, A. Urquiza, E. Gayó, M. Osses, R. Arriagada, M. Valdés, N. Álamos, C. Amigo, D. Arrieta, K. Basoa, M. Billi, G. Blanco, J. Boisier, R. Calvo, I. Casielles, M. Castro, J. Chahuán, D. Chistie, L. Cordero, V. Correa, J. Cortés, Z. Fleming, N. Gajardo, L. Gallardo, L. Gómez, X. Insunza, P. Iriarte, J. Labraña, F. Lambert, A. Muñoz, M. Opazo, R. O'Ryan, A. Osses, M. Plass, M. Rivas, S. Salinas, S. Santander, R. Seguel, P. Smith, S. Tolvett, Resumen para tomadores de decisiones. El aire que respiramos: pasado, presente y futuro - contaminación atmosférica por MP2,5 en el centro y sur de Chile, Cent. Cienc. Del Clima y La Resilencia (CR) 2 (2020) 16. Available online: https://www.cr2.cl/contaminacion. (Accessed 1 March 2023).
[14] A.I.R. Iq, Informe de la Calidad del Aire en el Mundo 2022, 2023, p. 53.
[15] CCAC, Chile takes action on air pollution, clim. Clean air coalition, united nations environ, Program. París (2017). France. Available online: https://www.ccacoalition.org/en/blog/chile-takes-action-air-pollution. (Accessed 1 June 2023).
[16] Z. Safari, R. Fouladi-Fard, M. Vahedian, M.H. Mahmoudian, A. Rahbar, M. Fiore, Health impact assessment and evaluation of economic costs attributed to PM2.5 air pollution using BenMAP-CE, Int. J. Biometeorol. 66 (2022) 1891–1902, https://doi.org/10.1007/s00484-022-02330-1.
[17] M. Masiol, C. Agostinelli, G. Formenton, E. Tarabotti, B. Pavoni, Thirteen years of air pollution hourly monitoring in a large city: potential sources, trends, cycles and effects of car-free days, Sci. Total Environ. (2014) 494–495, https://doi.org/10.1016/j.scitotenv.2014.06.122, 84–96.
[18] H. Wang, Z. Fu, W. Lu, Y. Zhao, R. Hao, Research on sulfur oxides and nitric oxides released from coal-fired flue gas and vehicle exhaust: a bibliometric analysis, Environ. Sci. Pollut. Res. 26 (2019) 17821–17833, https://doi.org/10.1007/s11356-019-05066-5.
[19] N. Donthu, S. Kumar, D. Mukherjee, N. Pandey, W.M. Lim, How to conduct a bibliometric analysis: an overview and guidelines, J. Bus. Res. 133 (2021) 285–296, https://doi.org/10.1016/j.jbusres.2021.04.070.
[20] N.R. Matandirotya, Research trends in the field of ambient air quality monitoring and management in South Africa : a bibliometric review, Environ. Challenges. 5 (2021) 100263, https://doi.org/10.1016/j.envc.2021.100263.
[21] Y. Jia, Y. Chen, P. Yan, Q. Huang, Bibliometric analysis on global research trends of airborne microorganisms in recent ten years (2011-2020), Aerosol Air Qual. Res. 21 (2021) 200497, https://doi.org/10.4209/aaqr.2020.07.0497.
[22] S. Dhital, D. Rupakheti, Correction to: bibliometric analysis of global research on air pollution and human health: 1998–2017, Environ. Sci. Pollut. Res. 26 (2019), https://doi.org/10.1007/s11356-019-05792-w, 25386–25386.
[23] F. Wang, X. Jia, X. Wang, Y. Zhao, W. Hao, Particulate matter and atherosclerosis: a bibliometric analysis of original research articles published in 1973-2014, BMC Publ. Health 16 (2016) 4–11, https://doi.org/10.1186/s12889-016-3015-z.
[24] Y. Xie, K. Shi, Y. Yuan, M. Gu, S. Zhang, K. Wang, L. Fu, C. Shen, Z. Yuan, Bibliometric analysis reveals the progress of PM2.5 in health research, especially in cancer research, Int. J. Environ. Res. Public Health 20 (2023) 1271, https://doi.org/10.3390/ijerph20021271.
[25] M.J. Page, J.E. McKenzie, P.M. Bossuyt, I. Boutron, T.C. Hoffmann, C.D. Mulrow, L. Shamseer, J.M. Tetzlaff, E.A. Akl, S.E. Brennan, R. Chou, J. Glanville, J. M. Grimshaw, A. Hróbjartsson, M.M. Lalu, T. Li, E.W. Loder, E. Mayo-Wilson, S. McDonald, L.A. McGuinness, L.A. Stewart, J. Thomas, A.C. Tricco, V.A. Welch, P. Whiting, D. Moher, The PRISMA 2020 statement: an updated guideline for reporting systematic reviews, Int. J. Surg. 88 (2021) 105906, https://doi.org/10.1016/j.ijsu.2021.105906.
[26] WoS Core Colletion, Clarivate Analytics, Web Sci., 2022. Available online at: https://www-webofscience-com.uchile.idm.oclc.org/wos/woscc/basic-search (Accessed 1 May 2023).
[27] B.E. Howard, J. Phillips, A. Tandon, A. Maharana, R. Elmore, D. Mav, A. Sedykh, K. Thayer, B.A. Merrick, V. Walker, A. Rooney, R.R. Shah, SWIFT-Active Screener, Accelerated document screening through active learning and integrated recall estimation, Environ. Int. 138 (2020) 105623, https://doi.org/10.1016/j.envint.2020.105623.
[28] N.J. van Eck, L. Waltman, Software survey: VOSviewer, a computer program for bibliometric mapping, Scientometrics 84 (2010) 523–538, https://doi.org/10.1007/s11192-009-0146-3.
[29] A. Perianes-Rodriguez, L. Waltman, N.J. van Eck, Constructing bibliometric networks: a comparison between full and fractional counting, J. Informetr. 10 (2016) 1178–1195, https://doi.org/10.1016/j.joi.2016.10.006.
[30] Microsoft Corporation, Annual Report, Microsoft Corp., New York, 2018. USA. Available online: https://www.microsoft.com/investor/reports/ar18/index.html. (Accessed 1 June 2022).
[31] R Core Team, R.A. Language, And Environment for Statistical Computing, R Foundation for Statistical Computing, Vienna, 2021. Austria. Available online: https://www.r-project.org. (Accessed 1 June 2023).
[32] M. Aria, C. Cuccurullo, Bibliometrix : an R-tool for comprehensive science mapping analysis, J. Informetr. 11 (2017) 959–975, https://doi.org/10.1016/j.joi.2017.08.007.
[33] W. Chang, J. Cheng, J. Allaire, C. Sievert, B. Schloerke, Y. Xie, J. Allen, J. McPherson, A. Dipert, B. Borges, Shiny: Web Application Framework for R. R Package Version 1.7.4.9002, 2023. Available online: https://shiny.posit.co. (Accessed 1 May 2023).
[34] S. Jeworutzki, Cartogram: Create Cartograms with R R Package, 2023, version 0.3.0. https://cran.r-project.org/package=cartogram.
[35] H. Wickham, ggplot2, Springer International Publishing, Cham, 2016, https://doi.org/10.1007/978-3-319-24277-4.
[36] G. Csardi, T. Nepusz, The Igraph Software Package for Complex Network Research, InterJournal. Complex Sy, 2006, p. 1695. https://igraph.org. (Accessed 1 May 2023).
[37] Marc J. Lajeunesse, Facilitating systematic reviews, data extraction, and meta-analysis with the metagear package for R, Methods Ecol. Evol. 7 (2016) 323–330.
[38] R.S. Bivand, Applied Spatial Data Analysis with R, Springer, 2013.
[39] Jeroen Ooms, magick, Advanced Graphics and Image-Processing in R R Package, 2023, version 2.8.1. https://cran.r-project.org/package=magick. (Accessed 1 May 2023).
[40] P. Massicotte, A. South, Rnaturalearth: World Map Data from Natural Earth R Package, 2023, version 0.3.4. https://cran.r-project.org/package=rnaturalearth.
[41] O. Ellegaard, J.A. Wallin, The bibliometric analysis of scholarly production: how great is the impact? Scientometrics 105 (2015) 1809–1831, https://doi.org/10.1007/s11192-015-1645-z.
[42] J.E. Hirsch, An index to quantify an individual's scientific research output, Proc. Natl. Acad. Sci. USA 102 (2005) 16569–16572, https://doi.org/10.1073/pnas.0507655102.
[43] S. Nusrat, S. Kobourov, The state of the art in cartograms, Comput. Graph. Forum 35 (2016) 619–642, https://doi.org/10.1111/cgf.12932.
[44] T. Liu, Y. Li, J. Li, H. Fan, C. Cao, Temporal trend and research focus of injury burden from 1998 to 2022: a bibliometric analysis, J. Multidiscip. Healthc. 16 (2023) 1869–1882, https://doi.org/10.2147/JMDH.S414859.
[45] Y. Yang, T. Dwyer, B. Jenny, K. Marriott, M. Cordeil, H. Chen, Origin-destination flow maps in immersive environments, IEEE Trans. Vis. Comput. Graph. 25 (2019) 693–703, https://doi.org/10.1109/TVCG.2018.2865192.
[46] S. Saha, S. Saint, D.A. Christakis, Impact factor: a valid measure of journal quality? J. Med. Libr. Assoc. 91 (2003) 42–46.
[47] M.C. Sab, P.D. Kumar, B.S. Biradar, Bradford's law: identification of the core journals in the field of Indian chemical science literature, Int. J. Inf. Dissem. Technol. 8 (2018) 104, https://doi.org/10.5958/2249-5576.2018.00022.5.
[48] M. Murugan, R. Saravanakumar, A. Thirumagal, Lotka ' s law and pattern of author productivity of information literacy research output, Libr. Philos. Pract. (2019) 2509. Available online: https://digitalcommons.unl.edu/libphilprac/2509 (Accessed 1 March 2023)..
[49] L. Egghe, Theory and practise of the g-index, Scientometrics 69 (2006) 131–152, https://doi.org/10.1007/s11192-006-0144-7.

[50] K. Börner, L. Dall'Asta, W. Ke, A. Vespignani, Studying the emerging global brain: analyzing and visualizing the impact of co-authorship teams, Complexity 10 (2005) 57–67, https://doi.org/10.1002/cplx.20078.
[51] M.S. Vidal, R. Menon, G.F.B. Yu, M.D. Amosco, Environmental toxicants and preterm birth: a bibliometric analysis of research trends and output, Int. J. Environ. Res. Publ. Health 19 (2022) 2493, https://doi.org/10.3390/ijerph19052493.
[52] I.G. Kavouras, P. Koutrakis, F. Cereceda-Balic, P. Oyola, Source apportionment of PM 10 and PM 25 in five Chilean cities using factor analysis, J. Air Waste Manage. Assoc. 51 (2001) 451–464.
[53] E. Gramsch, F. Cereceda-Balic, P. Oyola, D. Vonbaer, Examination of pollution trends in Santiago de Chile with cluster analysis of PM10 and Ozone data, Atmos. Environ. 40 (2006) 5464–5475, https://doi.org/10.1016/j.atmosenv.2006.03.062.
[54] P. Koutrakis, S.N. Sax, J.A. Sarnat, B. Coull, P. Demokritou, P. Demokritou, P. Oyola, J. Garcia, E. Gramsch, Analysis of PM 10 , PM 2.5 , and PM 2.5–10 concentrations in Santiago, Chile, from 1989 to 2001, J. Air Waste Manage. Assoc. 55 (2005) 342–351, https://doi.org/10.1080/10473289.2005.10464627.
[55] P. Artaxo, P. Oyola, R. Martinez, Aerosol composition and source apportionment in Santiago de Chile, Nucl. Instruments Methods Phys. Res. Sect. B Beam Interact. with Mater. Atoms. 150 (1999) 409–416, https://doi.org/10.1016/S0168-583X(98)01078-7.
[56] M. Ilabaca, I. Olaeta, E. Campos, J. Villaire, M.M. Tellez-Rojo, I. Romieu, Association between levels of fine particulate and emergency visits for pneumonia and other respiratory illnesses among children in Santiago, Chile, J. Air Waste Manage. Assoc. 49 (1999) 154–163, https://doi.org/10.1080/10473289.1999.10463879.
[57] P.A. Sanhueza, M.A. Torreblanca, L.A. Diaz-Robles, L.N. Schiappacasse, M.P. Silva, T.D. Astete, Particulate air pollution and health effects for cardiovascular and respiratory causes in temuco, Chile: a wood-smoke-polluted urban area, J. Air Waste Manage. Assoc. 59 (2009) 1481–1488, https://doi.org/10.3155/1047-3289.59.12.1481.
[58] S. Cakmak, R.E. Dales, C.B. Vidal, Air pollution and mortality in Chile: susceptibility among the elderly, Environ. Health Perspect. 115 (2007) 524–527, https://doi.org/10.1289/ehp.9567.
[59] H. Jorquera, F. Barraza, Source apportionment of ambient PM2.5 in Santiago, Chile: 1999 and 2004 results, Sci. Total Environ. 435–436 (2012) 418–429, https://doi.org/10.1016/j.scitotenv.2012.07.049.
[60] A.M. Villalobos, F. Barraza, H. Jorquera, J.J. Schauer, Chemical speciation and source apportionment of fine particulate matter in Santiago, Chile, Sci. Total Environ. 512–513 (2015) (2013) 133–142, https://doi.org/10.1016/j.scitotenv.2015.01.006.
[61] B.D. Ostro, G.S. Eskeland, J.M. Sanchez, T. Feyzioglu, Air pollution and health effects: a study of medical visits among children in Santiago, Chile, Environ. Health Perspect. 107 (1999) 69–73, https://doi.org/10.1289/ehp.9910769.
[62] H. Romero, M. Ihl, A. Rivera, P. Zalazar, P. Azocar, Rapid urban growth, land-use changes and air pollution in Santiago, Chile, Atmos. Environ. 33 (1999) 4039–4047, https://doi.org/10.1016/S1352-2310(99)00145-4.
[63] C. Molina, R. Toro A, R.G. Morales S, C. Manzano, M.A. Leiva-Guzmán, Particulate matter in urban areas of south-central Chile exceeds air quality standards, Air Qual. Atmos. Heal. 10 (2017) 653–667, https://doi.org/10.1007/s11869-017-0459-y.
[64] L. Gallardo, G. Olivares, J. Langner, B. Aarhus, Coastal lows and sulfur air pollution in Central Chile, Atmos. Environ. 36 (2002) 3829–3841, https://doi.org/10.1016/S1352-2310(02)00285-6.
[65] F. Moreno, E. Gramsch, P. Oyola, M.A. Rubio, Modification in the Soil and Traffic-Related Sources of Particle Matter between 1998 and 2007 in Santiago de Chile, J. Air Waste Manage. Assoc. 60 (2010) 1410–1421, https://doi.org/10.3155/1047-3289.60.12.1410.
[66] R. Schmitz, Modelling of air pollution dispersion in Santiago de Chile, Atmos. Environ. 39 (2005) 2035–2047, https://doi.org/10.1016/j.atmosenv.2004.12.033.
[67] P. Sanhueza H, C. Vargas R, P. Mellado G, Impacto de la contaminación del aire por PM10 sobre la mortalidad diaria en Temuco, Rev. Med. Chile 134 (2006) 754–761, https://doi.org/10.4067/S0034-98872006000600012.
[68] A. Schueftan, A.D. González, Reduction of firewood consumption by households in south-central Chile associated with energy efficiency programs, Energy Pol. 63 (2013) 823–832, https://doi.org/10.1016/j.enpol.2013.08.097.
[69] I.G. Kavouras, P. Koutrakis, M. Tsapakis, E. Lagoudaki, E.G. Stephanou, D. Von Baer, P. Oyola, Source apportionment of urban particulate aliphatic and polynuclear aromatic hydrocarbons (PAHs) using multivariate methods, Environ. Sci. Technol. 35 (2001) 2288–2294, https://doi.org/10.1021/es001540z.
[70] A.J. McMichael, P. Wilkinson, R.S. Kovats, S. Pattenden, S. Hajat, B. Armstrong, N. Vajanapoom, E.M. Niciu, H. Mahomed, C. Kingkeow, M. Kosnik, M.S. O'Neill, I. Romieu, M. Ramirez-Aguilar, M.L. Barreto, N. Gouveia, B. Nikiforov, International study of temperature, heat and urban mortality: the 'ISOTHURM' project, Int. J. Epidemiol. 37 (2008) 1121–1131, https://doi.org/10.1093/ije/dyn086.
[71] F.J. Escobedo, D.J. Nowak, Spatial heterogeneity and air pollution removal by an urban forest, Landsc. Urban Plan. 90 (2009) 102–110, https://doi.org/10.1016/j.landurbplan.2008.10.021.
[72] A. Bollhöfer, K.J. Rosman, Isotopic source signatures for atmospheric lead: the Southern Hemisphere, Geochim. Cosmochim. Acta 64 (2000) 3251–3262, https://doi.org/10.1016/S0016-7037(00)00436-1.
[73] L.A. Díaz-Robles, J.C. Ortega, J.S. Fu, G.D. Reed, J.C. Chow, J.G. Watson, J.A. Moncada-Herrera, A hybrid ARIMA and artificial neural networks model to forecast particulate matter in urban areas: the case of Temuco, Chile, Atmos, Environ. Times 42 (2008) 8331–8340, https://doi.org/10.1016/j.atmosenv.2008.07.020.
[74] B.R.T. Simoneit, P.M. Medeiros, B.M. Didyk, Combustion products of plastics as indicators for refuse burning in the atmosphere, Environ. Sci. Technol. 39 (2005) 6961–6970, https://doi.org/10.1021/es050767x.
[75] R. Schlitzer, Carbon export fluxes in the Southern Ocean: results from inverse modeling and comparison with satellite-based estimates, Deep Sea Res. Part II Top. Stud. Oceanogr. 49 (2002) 1623–1644, https://doi.org/10.1016/S0967-0645(02)00004-8.
[76] P. Pérez, A. Trier, J. Reyes, Prediction of PM2.5 concentrations several hours in advance using neural networks in Santiago, Chile, Atmos. Environ. 34 (2000) 1189–1196, https://doi.org/10.1016/S1352-2310(99)00316-7.
[77] K. Pozo, T. Harner, M. Shoeib, R. Urrutia, R. Barra, O. Parra, S. Focardi, Passive-sampler derived air concentrations of persistent organic pollutants on a North−South transect in Chile, Environ. Sci. Technol. 38 (2004) 6529–6537, https://doi.org/10.1021/es049065i.
[78] I.G. Kavouras, P. Koutrakis, M. Tsapakis, E. Lagoudaki, E.G. Stephanou, D. Von Baer, P. Oyola, Source apportionment of urban particulate aliphatic and polynuclear aromatic hydrocarbons (PAHs) using multivariate methods, Environ. Sci. Technol. 35 (2001) 2288–2294, https://doi.org/10.1021/es001540z.
[79] M.L. Bell, M.S. O'Neill, N. Ranjit, V.H. Borja-Aburto, L.A. Cifuentes, N.C. Gouveia, Vulnerability to heat-related mortality in Latin America: a case-crossover study in São Paulo, Brazil, Santiago, Chile and Mexico City, Mexico, Int. J. Epidemiol. 37 (2008) 796–804, https://doi.org/10.1093/ije/dyn094.
[80] F.J. Escobedo, J.E. Wagner, D.J. Nowak, C.L. De la Maza, M. Rodriguez, D.E. Crane, Analyzing the cost effectiveness of Santiago, Chile's policy of using urban forests to improve air quality, J. Environ. Manag. 86 (2008) 148–157, https://doi.org/10.1016/j.jenvman.2006.11.029.
[81] L.A. Cifuentes, J. Vega, K. Köpfer, L.B. Lave, Effect of the fine fraction of particulate matter versus the coarse mass and other pollutants on daily mortality in Santiago, Chile, J. Air Waste Manage. Assoc. 50 (2000) 1287–1298, https://doi.org/10.1080/10473289.2000.10464167.
[82] M.A. Leiva G, D.A. Santibañez, S. Ibarra E, P. Matus C, R. Seguel, A five-year study of particulate matter (PM2.5) and cerebrovascular diseases, Environ. Pollut. 181 (2013) 1–6, https://doi.org/10.1016/j.envpol.2013.05.057.
[83] H. Müller, F. Mancuso, Identification and analysis of Co-occurrence networks with NetCutter, PLoS One 3 (2008) e3178, https://doi.org/10.1371/journal.pone.0003178.
[84] S. Rajeswari, P. Saravanan, K. Kumaraguru, N. Jaya, R. Rajeshkannan, M. Rajasimman, The scientometric evaluation on the research of biodiesel based on HistCite and VOSviewer (1993–2019), Biomass Convers. Biorefinery. 13 (2023) 4093–4103, https://doi.org/10.1007/s13399-021-01461-6.
[85] H. Fan, C. Zhao, Y. Yang, A comprehensive analysis of the spatio-temporal variation of urban air pollution in China during 2014 – 2018, Atmos, Environ. Times 220 (2020) 117066, https://doi.org/10.1016/j.atmosenv.2019.117066.
[86] L. Jiang, S. He, H. Zhou, Spatio-temporal characteristics and convergence trends of PM 2 . 5 pollution : a case study of cities of air pollution transmission channel in Beijing-Tianjin-Hebei region , China, J. Clean. Prod. 256 (2020) 120631, https://doi.org/10.1016/j.jclepro.2020.120631.