Urban Pollution: A Bibliometric Review

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Prominent anthropogenic sources of pollution within urban areas, such as automobiles, industrial operations, and increased electricity usage, are linked to human activities that risk human health. This study aimed to examine the publication patterns and annual growth rates related to urban pollution in the Scopus and Web of Science (WoS) databases. The comprehensive analysis encompasses productive countries, network connectivity, proactive institutions, and research keywords examined through ScientoPy and VOSviewer. This analysis revealed a fluctuating trend in urban pollution research in both databases from 1990 to 2021. Nonetheless, there was a notable surge in publications on the WoS database after 2008. Within the scope of this study, "Environmental Science and Ecology" has been identified as the most pivotal subject area. This study indicated that scholars from France, Brazil, the United Kingdom, Germany, Canada, the United States, and China collaborated extensively, establishing robust research partnerships. The keyword "Urban pollution" has become the most prevalent, followed by "Pollution" and "Air pollution". This study is subject to certain limitations, primarily from its reliance on the Scopus and WoS databases, which consequently influenced the data quality. Nevertheless, the study elucidates prevailing trends in urban pollution research, offering guidance to practitioners, prospective researchers, and policymakers in formulating novel concepts and a research agenda conducive to sustainable environmental dimensions.

Keywords: Urban pollution; anthropogenic pollutant; bibliometric; Scopus; Web of Science

I. INTRODUCTION

In a general sense, "urban" can be used interchangeably with terms like "city", "town", "metropolitan", and "suburb". An intriguing facet of urbanism pertains to the impact exerted by both physical and social environments on individuals' lives (Zhang & Lu, 2018). Additionally, urban areas are marked by elevated population density and a predominance of industrial occupations. These areas are surrounded by densely constructed artificial structures comprising residential buildings, commercial establishments, highways, and railroads (Abdullah, 2023). By 2050, the urban population, particularly in developing countries, is projected to have doubled (Goi, 2017). Thus, to maintain a sustainable environment amidst rapid urbanisation and global population growth, examining the measures that can be implemented to mitigate urban pollution is imperative. A significant factor is that human activities constitute one of the primary drivers of urban environmental challenges and are associated with substantial anthropogenic sources of pollution, such as vehicular emissions, industrial processes, and heightened electricity consumption (Zheng & Kahn, 2013). The escalation of human activities in urban areas has also led to increased ozone pollution, which exerts adverse effects on air quality and public health (Zhao *et al.*, 2019).

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The presence or entrance of harmful or hazardous substances in cities or metropolitan areas is called urban pollution (Martnez-Bravo & Martnez-del-Ro, 2020). Martínez-Bravo and Martínez-del-Río (2020) emphasised that air pollution, water pollution, chemical pollution, waste pollution, and noise pollution are the most predominant forms of urban pollution. Air pollution substantially threatens human health and mortality and is particularly concerning in urban areas, where large pollutant concentrations and potential victims are concentrated (Barwise & Kumar, 2020). The degradation of air quality adversely affects public health, primarily stemming from the rise in air pollutants emanating from various sources. For example, the swift urbanisation in China is giving rise to substantial air quality challenges, particularly concerning NO_2 and particulate matter (He et al., 2018). Besides, most mid-sized cities in southern Chile have the highest ambient particle matter concentrations recorded in Latin America due to widespread urban poverty, poor building standards (particularly subsidised housing for migrant residents), the availability of inexpensive wood for heating and cooking, and climatic conditions (Jorquera et al., 2019).

Another aspect of urban pollution that merits consideration pertains to water pollution. The study and characterisation of emerging water impurities are rising to comprehend their environmental and toxicological implications on metropolitan regions. Despite the highly restricted quantity, precipitation and groundwater resources satisfy most human water needs. Even in urban areas where water use is increasing due to industry, population growth, and other factors, the water quality is decreasing (Martínez-Bravo & Martínez-del-Río, 2020). Depending on the location, urban areas may have surface water and groundwater; it is essential to note that the level of pollution caused by various types of contaminant exposure will vary depending on the water impacted (Schweitzer & Noblet, 2018). Haseena et al. (2017) state that domestic and industrial effluent wastes, water tank leakage, marine dumping, radioactive waste, and atmospheric deposition are the most prominent causes of water pollution. Poisonous solid wastes, effluents, and emissions are also discharged, contaminating groundwater with toxic and hazardous metals. Groundwater quality has deteriorated due to untreated industrial effluents in sewage channels; thus, healthy, clean drinking water is a problem in urban areas (Farid et al., 2012).

There are also links between chemical pollution and water pollution. Modern society uses chemicals to produce several products, severely affecting ecosystems (Kosnik et al., 2022). Chemicals can be released into the environment at any point in their life cycle, from getting the raw materials, making the materials and products, using the products, and recycling them. Chemicals that remain dissolved or suspended in water generate environmental reactions that lead to water contamination and are possible sources of water pollution (Chaudhry & Malik, 2017). Another concern is that a chemical pollutant is a by-product of factories that produce dangerous chemicals; this by-product has also become a primary contributor to water pollution. The widespread presence of heavy metals and other pollutants in polluted areas directly results from the anthropogenic imbalance of chemical contaminants in the environment, which is a severe threat to all life forms (Rahman, 2020). Importantly, it is not only humans and the environment susceptible to chemical pollution through water but also contaminated food, employment settings, sprays, detergents, fabrics, cosmetics, construction materials, and furniture (Ke et al., 2015).

Likewise, waste is a significant source of pollution in most urban areas. Urban waste accumulation is a critical global issue because it threatens human health and the environment if not adequately addressed (Knickmeyer, 2020). Massive amounts of municipal solid waste have been produced due to the global population boom. The global population currently produces approximately 2.01 billion metric tonnes of municipal solid waste annually, with projections indicating that this figure is expected to triple by 2050. This anticipated increase poses significant concerns for future environmental issues (Gautam & Agrawal, 2021).

Consequently, there is an obvious and direct correlation between the amount of solid waste produced by individuals and the income levels of their various countries. In some countries (often those with developing or undeveloped economies), there is a shortage of equipment and personnel to manage multiple forms of waste (Martínez-Bravo & Martínez-del-Río, 2020). In Asian cities, municipal solid

waste generation is expanding dramatically, contributing to urbanisation and commercial activity (Abdullah *et al.*, 2021). In addition, cities in rising Asia have poor waste management and energy shortages (Sohoo *et al.*, 2021), and in East Africa, municipal solid waste management has worsened (Ntagisanimana *et al.*, 2021). Municipal solid waste management in the United States is a multifaceted system with many moving parts, including regulatory, administrative, commercial, technological, and social aspects (Louis, 2004). Thus, environmental ramifications and health risks are of concern. The most critical and fundamental means of managing municipal solid waste are regulating production, enhancing its collection system, and transferring it to treatment locations.

Another critical factor contributing to urban pollution is noise pollution, partly attributed to the urban layout and design. Numerous urban planning factors influence traffic volume, vehicle distribution, and overall traffic conditions. It is worth noting that road traffic constitutes the primary noise source in cities in terms of timing and spatial distribution (Morillas *et al.*, 2018). The World Health Organization (WHO) identifies noise pollution as one of the three environmental pollutants most detrimental to human health in urban areas (Martínez-Bravo & Martínez-del-Río, 2020). This is because the increased volume of noise in a city with a growing population indicates a more severe issue. Drawing from research conducted by experts on a global scale, the WHO has authored several papers showcasing the detrimental health impacts of noise pollution (Morillas *et al.*, 2018). It is imperative to investigate this matter, as continuous noise pollution is one of the most pervasive contaminants in urban settings, posing risks to human health. From a psychological standpoint, high noise levels can provoke irritation, producing potent emotions like anger, anxiety, and depression (Williams & Short, 2022). In addition, the physiological effects of noise pollution will result in alterations to the body's systems, as exposure to high noise levels over an extended period is detrimental to hearing and harms the cardiovascular, nervous, and endocrine systems (Münzel *et al.*, 2018). Consequently, noise control is essential for the health and well-being of individuals. Prior research has proven that noise pollution harms persons' emotional and psychological characteristics,

particularly in urban regions where this problem must be addressed appropriately.

Urban pollution is one of the most significant obstacles in a country's efforts to solve environmental issues in urban areas, mainly because this problem negatively affects the health and well-being of urban residents. Moreover, if this issue is not addressed as effectively as feasible, the urban pollution situation will worsen due to the rise in urban population and rapid economic growth. Consequently, refining the study on urban pollution would be of importance. In this context, bibliometric analysis related to urban pollution is a study method that can provide valuable information to future readers and researchers, particularly about frequently explored research trends, themes, and concepts. Nevertheless, bibliometric analysis related to urban pollution is limited to the focus of previous publications revolving around the topic, such as (i) urban rainfall-runoff pollution (Wang *et al.*, 2021), (ii) urban sustainability (Xue *et al*, 2020), (iii) urban heat island research (Huang & Lu, 2018), (iv) urban health impact assessment research (Luo *et al.*, 2022), and (v) urban afforestation and its ecosystem balance (Wiesel *et al.*, 2021).

The primary objective of this study is to address the following questions:

1. What are the annual growth rates of urban pollution-related publications in Scopus and Web of Science (WoS)?

2. What are the most productive countries that published articles on urban pollution studies?

3. How do productive countries build a network of international cooperation?

4. What are the most proactive institutions that published articles on urban pollution studies?

5. What are the most important and often used authors' keywords in urban population studies?

II.   MATERIALS AND METHOD

This section holds paramount importance in elucidating the methodology for extracting metadata from the designated databases, adhering to established research protocols. Metadata furnishes organised information about particular data, streamlining the tracking and manipulation of said data (Abdullah & Sofyan, 2023). By employing

apprehensible research protocols, potential readers could comprehend the topic discussed and encourage future researchers to perform extensive research (Sofyan *et al.*, 2022). Accordingly, this study designs and presents results based on research protocols and tools described in the following subtopic to illustrate the article's overall analysis output that can guide future researchers.

A. Research Protocols

A bibliometric study evaluates research trends, measures the impact of publications, and visualises bibliometric networks within a specific research domain. Importantly, bibliometric analysis can be conducted across various disciplines, encompassing both pure and social sciences (Abdullah, 2023). Additionally, it's worth mentioning that while a bibliometric study doesn't adhere to specific research protocols, the procedures need to be in alignment with the study's objectives, ensuring a coherent and systematic flow from data retrieval to acquisition (Pulsiri & Vatananan-Thesenvitz, 2018).

In this study, the research protocol proposed by Zare *et al.* (2017), outlined in Figure 1, was adopted. Figure 1 illustrates the research protocol, commencing with selecting the topic and keywords and progressing to delineating the scope and coverage for gathering the final set of metadata.
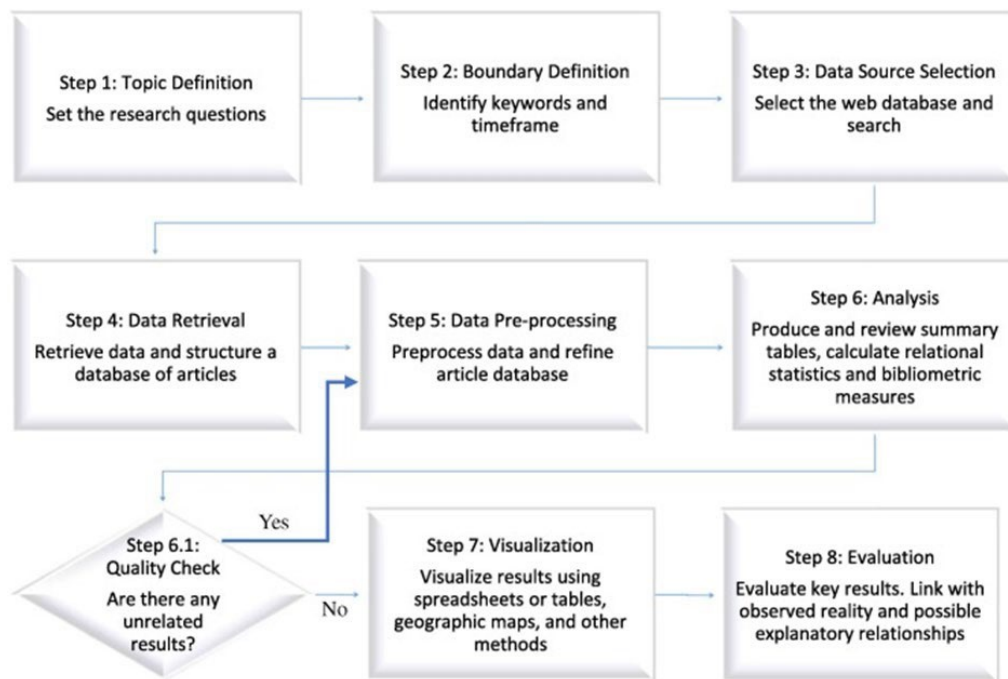

Figure 1. Research protocol for obtaining data (Zare *et al.*, 2017).

This study utilised datasets sourced from the Scopus and WoS databases. The selection of Scopus and WoS was motivated by their multidisciplinary nature, allowing for the evaluation of research across nearly any discipline. The databases are also envisioned for researchers who seek to examine publication patterns across a broad spectrum of research contexts (AlRyalat *et al.*, 2019). It is crucial since the initial goal of scientific publishing was to facilitate the global sharing of scientific discoveries, ideas, and discussions among scholars for more effective scientific achievements (Abramo, 2018).

The data collected in this study aligns with the discussion topic focused on urban pollution. The search strings for the Scopus and WoS databases were obtained in May 2022, incorporating pertinent keywords (refer to Table 1). The retrieval process entailed a title search approach, allowing for exploring and identifying relevant journal articles, conference proceedings papers, books, and book chapters without linguistic limitations. In this study, employing title-based retrieval of datasets is imperative in delineating specific research areas' structural and content evolution (Tullu, 2019). Subsequently, this study effectively garnered 690 publications from both databases. The compiled list of

retrieved datasets underwent the subsequent step in the methodology, which utilises ScientoPy to remove duplicate publications.

Table 1. The search string of urban pollution.

Database	Search field	Search string
Scopus	Article title	"urban pollution" OR "city pollution" OR "town pollution" OR "metropolitan pollution" OR "suburban pollution" OR "municipal pollution" OR "non-rural pollution" OR "urban contamination" OR "city contamination" OR "town contamination" OR "metropolitan contamination" OR "suburban contamination" OR "municipal contamination" OR "non-rural contamination"
WoS	Title	"urban pollution" OR "city pollution" OR "town pollution" OR "metropolitan pollution" OR "suburban pollution" OR "municipal pollution" OR "non-rural pollution" OR "urban contamination" OR "city contamination" OR "town contamination" OR "metropolitan contamination" OR "suburban contamination" OR "municipal contamination" OR "non-rural contamination"

B. Tools and Techniques

In this study, ScientoPy is a vital tool for pre-processing and analysing the ultimate datasets. Furthermore, the application of VOSviewer facilitates the generation of a co-occurrence map based on authors' keywords. VOSviewer employs mapping techniques to transform CSV data into diagrams or clusters. These mapping methods empower researchers to scrutinise datasets related to authors, affiliations, institutions, citations, and co-citations (Abdullah, 2021). Furnishing reliable information regarding the extensive array of central themes or topics that have

been investigated and influenced past research endeavours is of utmost significance.

Likewise, ScientoPy is an open-source Python-based bibliometric analysis tool that is capable of (i) importing Scopus and WoS data sets, (ii) filtering publications by document type, (iii) merging Scopus and WoS data sets based on a field tags correlation table, locating and removing duplicate documents, and (iv) extracting the H-index for the analysed topics (Ruiz-Rosero *et al.*, 2019). In addition, the ScientoPy pre-processing step enhanced the readability and precision of the metadata analysis for classifying the most popular, specific, and trending subjects. ScientoPy automatically filters publications classified as articles, conference papers, proceeding papers, book chapters, or reviews by default (Ruiz-Rosero *et al.*, 2019). Following removing duplicate records, 376 publications remained, comprising 112 from Scopus and 264 from WoS. Donthu *et al.* (2021) outlined that the total count of papers meeting the minimum criteria for bibliometric analysis must exceed 300 after duplicates have been eliminated. Hence, this study successfully fulfilled the minimum requirement for a bibliometric study.

III.   RESULT

A. The Annual Growth Rates of Urban Pollution-related Publications

This topic scrutinises the publication patterns of urban pollution, encompassing the annual count of publications and subject areas' evolutionary trajectory. The quantity of publications is paramount in propelling any research domain forward (Abdullah, 2021). This is aligned with the idea that the volume of published papers can indicate the evolution and future trajectory of research topics (Abdullah & Othman, 2022). Figure 2 depicts the timeline graph of publication growth in Scopus and WoS databases.

As illustrated in Figure 2, the rate of scientific publication on urban pollution in both databases experienced fluctuating cycles. However, the number of publications on WoS increased significantly after 2008 compared to Scopus. In addition, the number of articles on WoS has been greater than ten since 2012, whereas the number of publications in Scopus has been less than ten for the entire year. Upon close inspection, the frequency of urban pollution-related

publications in both databases is below 20. This can be seen in the WoS database graph, which shows that 2019 is the most significant number of publications but is under the threshold of 20 documents. This scenario could be a reason that a new journal may choose to publish more frequently to establish a presence in the field and attract submissions. In contrast, a well-established journal with a strong reputation may publish less frequently but receive numerous submissions and maintain a high impact factor (Bajwa *et al.*, 2019).
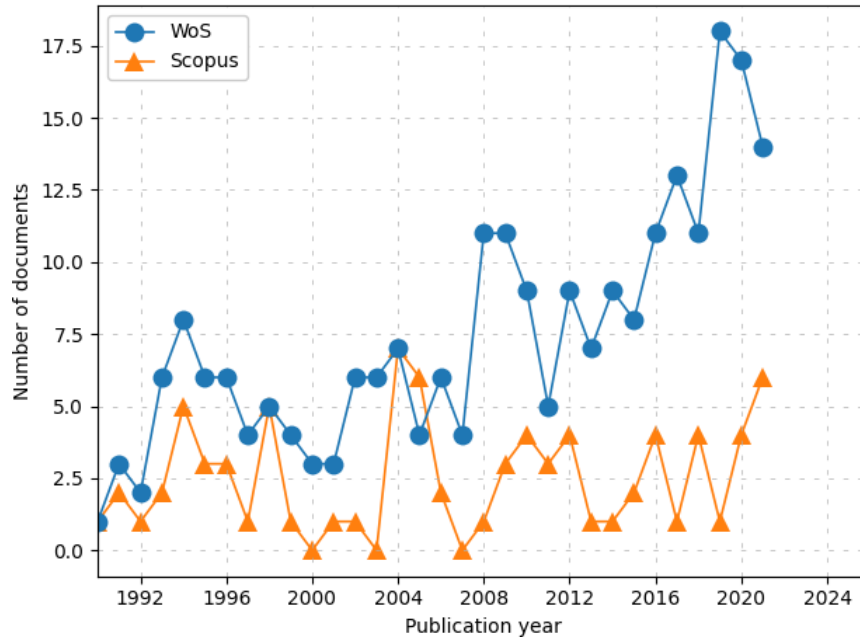

Figure 2. Scopus and WoS publication timeline graph.

The breadth of a particular field of study surpasses the confines of an individual research subject. Conducting a thorough examination of pertinent subject domains is crucial. This approach discerns the essential disciplines in which studies on urban pollution have been undertaken. Figure 3 illustrates the top ten subject areas that can be employed for categorising research on urban pollution, as obtained from the Scopus and WoS databases.

With over 120 publications, "Environmental Science and Ecology" has been designated the premier subject area in this study. This outcome was anticipated, considering that the topic under investigation is crucial from an environmental science and ecology perspective, focusing on the occurrence of toxic or dangerous compounds in cities and urban regions (Manisalidis *et al.*, 2020; Naidu *et al.*, 2021). The state of the environment is one of the essential concerns of cities worldwide, mainly when excessive pollution and environmental degradation significantly influence the quality of life of people (Arsovski *et al.*, 2018). The second-ranked discipline is "Engineering". In line with urban pollution research, engineers use their scientific knowledge to design systems that regulate pollutants and protect public health, especially in urban settings, such as incorporating weigh-in-motion sensors with intelligent transportation systems to reduce urban pollution (Dontu *et al.*, 2019). Another fascinating subject is "Meteorology and Atmospheric Sciences"; this topic is relevant to urban decay since it relates to weather forecasting, and the study of weather is related to pollution. Urban decay refers to the deterioration and decline of urban areas, often caused by neglect, abandonment, and lack of maintenance (Swanepoel & Smallwood, 2019). Accurate co-predictions of urban heat and air quality under normal and extreme situations are essential for prompt countermeasures and emergency operations, especially in light of the increasing heat and pollution-related dangers in cities worldwide (Ulpiani *et al.*, 2022).

Information on source titles is depicted in Table 2. It is ranked based on the number of publications. A list of ten sources and the last two years' trending percentages (2020 to 2021) are included. The results were obtained using a default ScientoPy setting, as Ruiz-Rosero *et al.* (2019)

recommended. The source titles with the most published articles, with more than 10, are the Science of the Total Environment (21 publications) and the Atmospheric Environment (12 publications). In addition, both source titles contributed to the highest h-Index rating, correspondingly 13 and 10. There is evidence that Science of the Total Environment and Atmospheric Environment contributed to the significant influence of publications regarded as indispensable by their peers. The information in Table 2 will aid future researchers in discovering resources to publish their works based on the required scope and determine the optimal publication outlet.
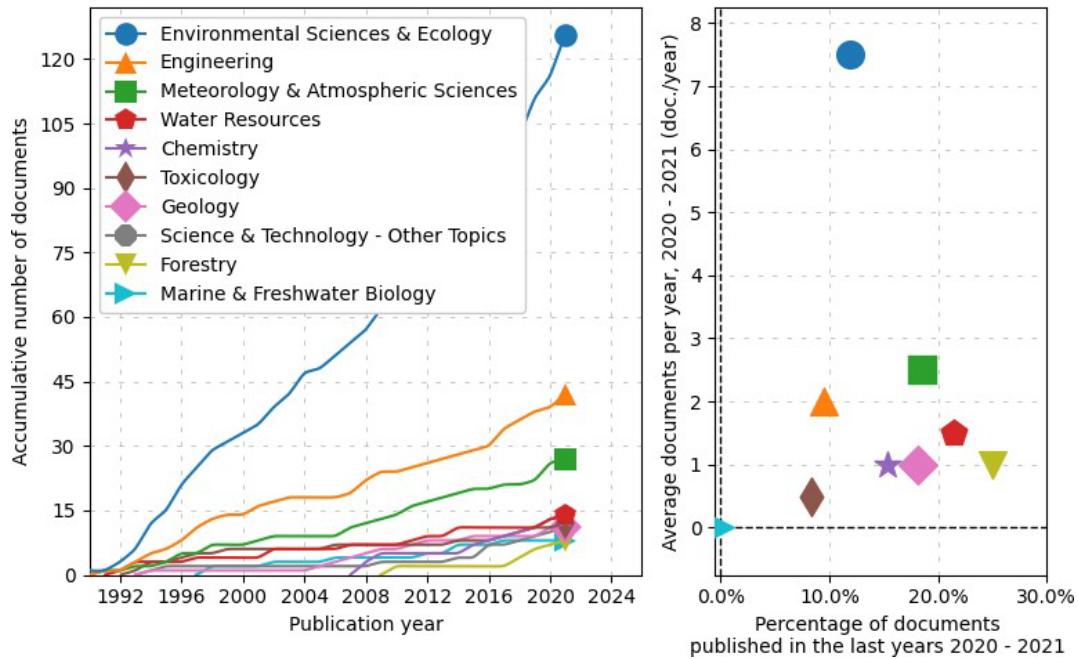

Figure 3. Subject evolution graph of urban pollution research.

Table 2. The top ten source titles

Position	Source Title	Total	AGR	ADY	PDLY	h-Index
1	Science of the Total Environment	21	0	1	9.5	13
2	Atmospheric Environment	12	0.5	1	16.7	10
3	Giornale Italiano di Medicina del Lavoro ed Ergonomia	6	0	0	0	4
4	Pollution Atmospherique	6	0	0	0	1
5	Environmental Health Perspectives	5	0	0	0	5
6	Environmental Monitoring and Assessment	5	1	1	40	2
7	International Journal of Cosmetic Science	5	-0.5	0.5	20	5
8	Environmental Pollution	4	0	0.5	25	4
9	Environmental Science and Technology	4	0.5	1	50	3
10	Environmental Science and Pollution Research	3	-0.5	0	0	2

Note. AGR = Average growth rate; ADY = Average documents per year; PDLY = Percentage of documents in last years.

B. The Most Productive Countries, the Most Proactive Institutions, and International Cooperation

Our analysis revealed that the research on urban pollution, which we thoroughly examined, was published in 79 different countries. The study conducted in this research primarily targeted the top 10 countries with the highest number of publications, as illustrated in Figure 4. The ranking is determined by the number of published documents, with a prerequisite of at least 11 publications. Based on the data presented in Figure 4, it can be observed that both the United States and Italy have contributed significantly to the body of literature, with each country having published more than 40 papers. Specifically, the United States has published 44 documents, while Italy has published a slightly lower number of 40 documents. China has ascended to the third position, boasting 32 publications, surpassing France, which currently holds the fourth position. However, an analysis of the percentages of documents released during the past two years reveals a notable trend wherein China has emerged as a prominent hub for scientific publications, demonstrating a consistent upward trajectory.

Due to the importance of research collaborations in most scientific domains, this study also analysed co-authorship by countries using VOSviewer. Co-authorship denotes scientific collaboration between multiple authors to accomplish research goals. Researchers are also motivated to work together because it allows them to discover new knowledge and develop solutions to research problems (Abdullah & Othman, 2022). No specific number serves as a criterion for conducting co-authorship analyses by countries. However, this study utilised the minimum number of publications per country, which is ten, and the minimum number of citations per publication is five, using the VOSviewer software. As a result, 11 items in the dataset met the criterion of 79 countries. Figure 5 depicts the co-authorship by countries involved in urban pollution research worldwide. According to Figure 5, four clusters are represented by nodes of various hues (red, blue, green, and yellow). The rectangle size represents the number of documents per country, while the thickness of the lines indicates the degree of cooperation between regions. This study revealed that researchers from France (yellow), Brazil (yellow), the United Kingdom (green), Germany (green), Canada (green), the United States (blue), and China (blue) collaborated greater than those from other regions.
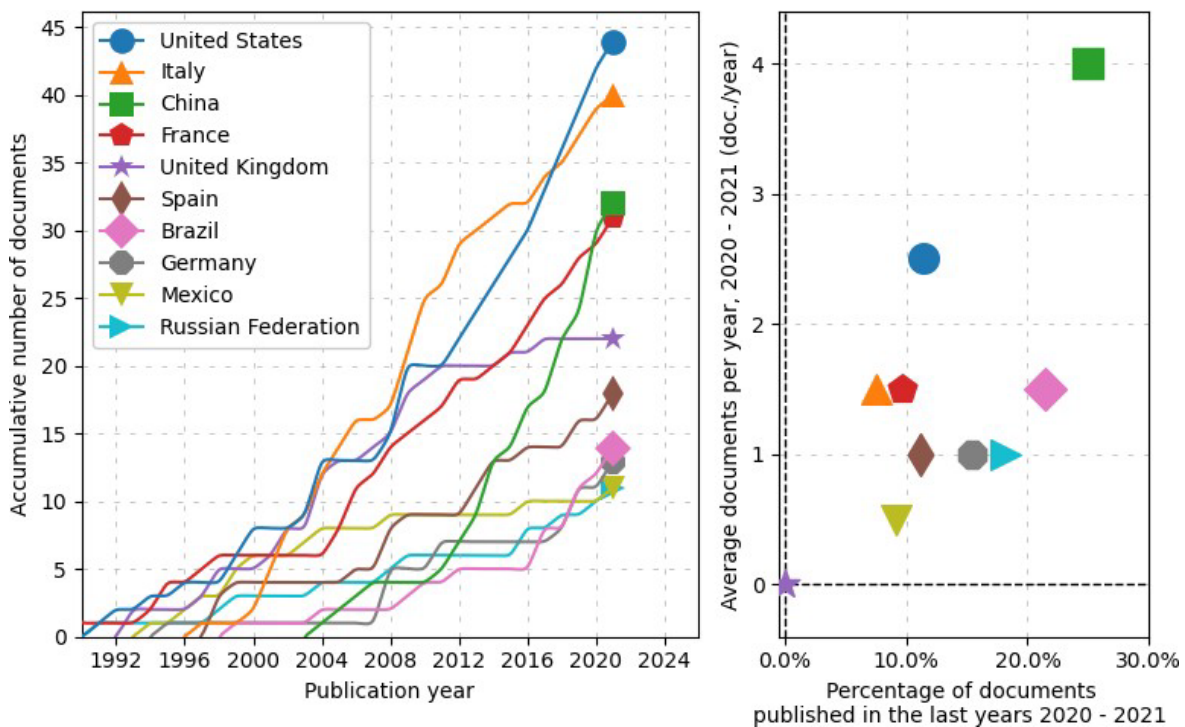

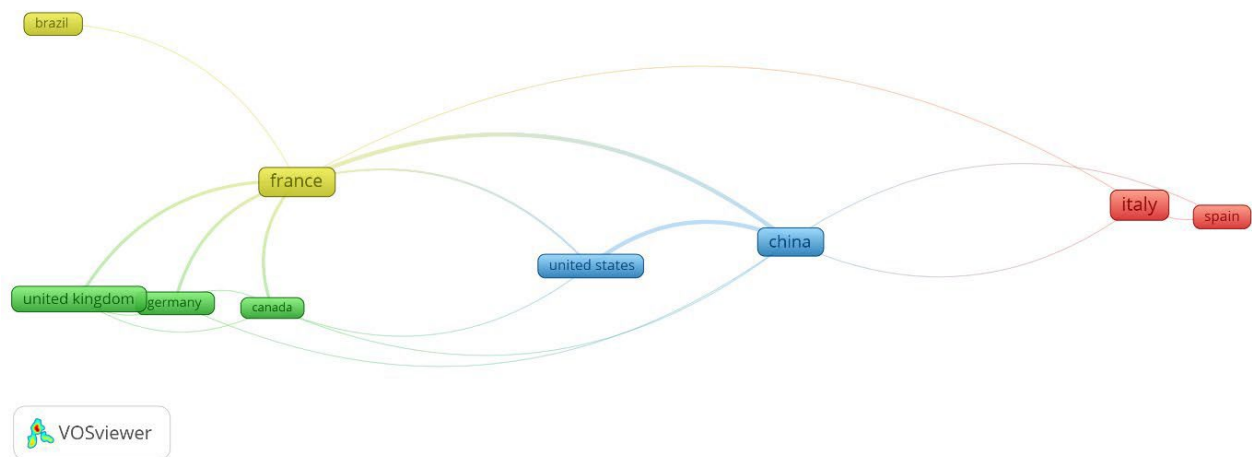Figure 4. Country evolution graph of urban pollution research.

Figure 5. Network visualisation of co-authorship by country.

Meanwhile, 431 institutions have published numerous articles on urban pollution. Figure 6 depicts the ten institutions with the most published articles.

The Pacific Northwest National Laboratory in the United States and Rhodes University in South Africa contributed the most to this research perspective, with five articles each. However, Rhodes University published 100% of all publications between 2020 and 2021, whereas the Pacific Northwest National Laboratory published only 40%. An institution's total number of publications between 2020 and 2021 indicated that it is conducting active research on urban pollution and has shifted its emphasis to its research interests.

C. The Most Important and Often Used Authors' Keywords

Authors employ keywords to communicate specific publications' fundamental concepts or themes (Abdullah & Sofyan, 2023). Innumerable search engines, databases, and journal websites frequently use author keywords to locate relevant publications. In this study, ScientoPy could examine the evolution of a research topic or search argument based on the authors' keywords. This section discusses the primary keywords identified by the previous authors pertinent to urban pollution research. American and British English spellings, singular and plural forms, and abbreviations were blended to obtain a more precise analysis of the author's keywords and eliminate repetition.

Figure 7 provides a comprehensive visual representation of ten previously employed keywords related to urban pollution sourced from Scopus and WoS databases. This figure illuminates that "Urban pollution" stands as the most frequently used keyword, closely followed by "Pollution" and "Air pollution". Additionally, Figure 7 offers insight into the proportion of documents published in the preceding years (2020-2021), serving as a metric for relative growth. Notably, "Biomonitoring" emerges as the ninth topic on this list, yet commands the highest percentage of documents in the last years (PDLY) at an impressive 80%. This indicates a conspicuous surge in interest and research activity in this area over the past two years (2020-2021) compared to other keywords. Another notable topic boasting a PDLY exceeding 50% is "Water quality". This suggests a recent surge in academic interest towards research on biomonitoring and water quality within urban pollution research.

Furthermore, cluster mapping was employed to ascertain the co-occurrence of authors' keywords, enabling the identification of themes and topics related to urban pollution. Prior to generating a network map with VOSviewer, the utilised dataset underwent pre-processing with ScientoPy, which combines metadata from both Scopus and WoS. Additionally, before mapping the co-occurrence of authors' keywords, this study established a thesaurus file as an additional method. The thesaurus file is crucial in consolidating synonyms, rectifying misspellings, and standardising singular or plural terms. Using the VOSviewer

software, this study applied a minimum threshold of five occurrences for author keywords to conduct the analysis. As a result, 12 items in the dataset satisfied the criterion of 841 keywords, as illustrated in Figure 8.
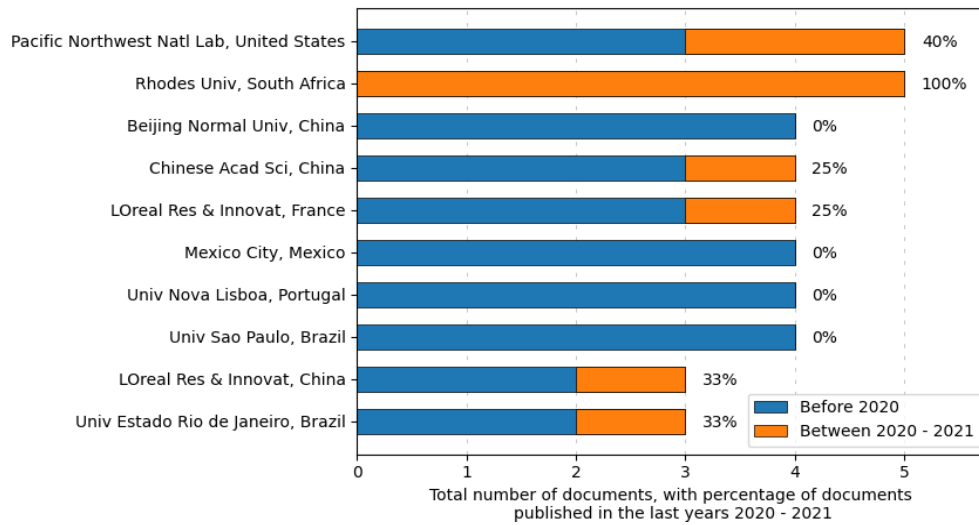

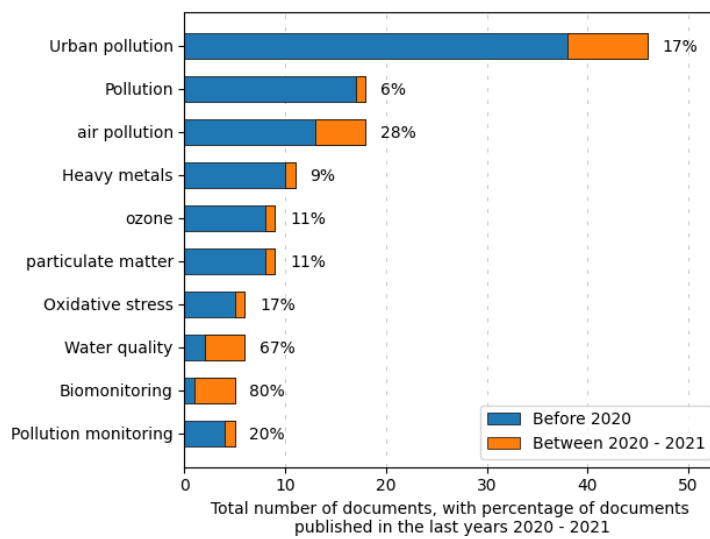Figure 6. Bar trend graph of top ten institutions.

Figure 7. Bar trend graph of top ten authors' keywords.

In Figure 8, each node signifies a specific keyword, with the thickness of the lines connecting nodes indicating the strength of their correlation. This correlation was determined by the frequency of appearance of the keywords in the published documents. Keywords exhibiting close relations were colour-coded and grouped into the same clusters. Based on Figure 8, four clusters are represented with green, red, blue, and yellow colours. The green cluster consists of three keywords, "Urban pollution", "Air Quality", and "Pollution monitoring". The red cluster contains keywords linked to urban pollution research, including the core keywords "Air pollution", "Particulate matter", and "Ozone". The blue keyword cluster contains the terms "Pollution", "Biomonitoring", and "Water Quality". And finally, the yellow cluster comprises "Heavy metal" and "Oxidative stress" keywords.
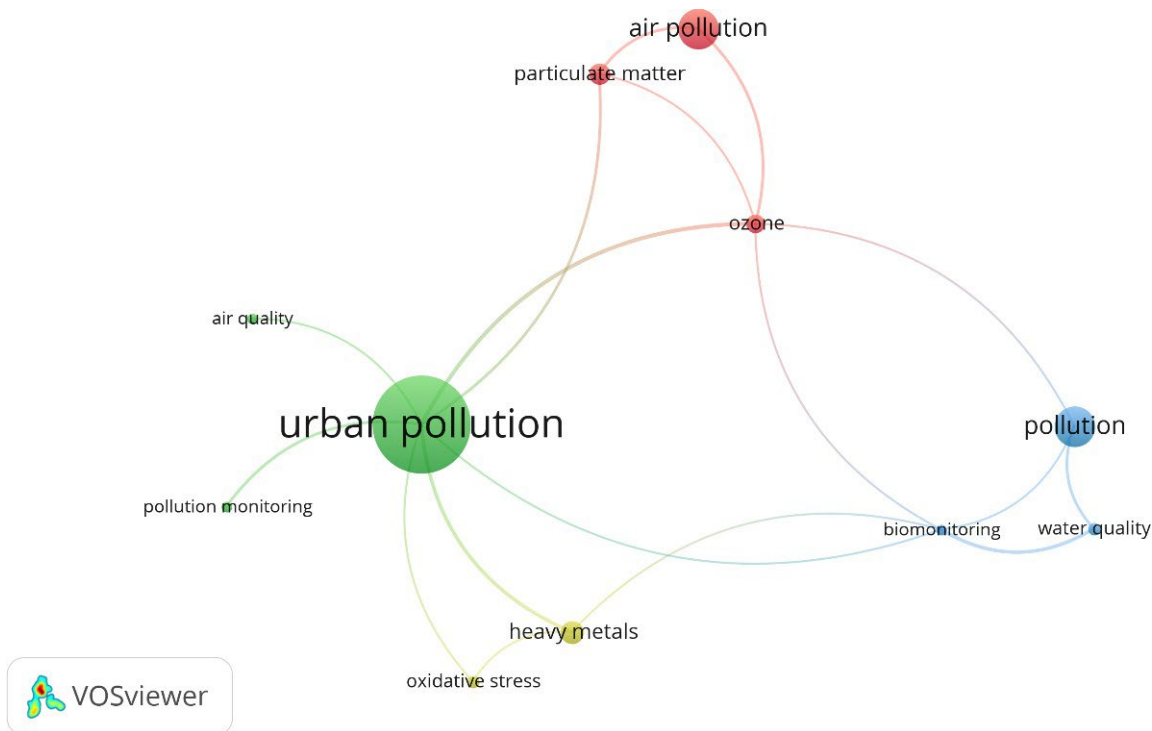
Figure 8. Network visualisation of the co-occurrence of authors' keywords.

IV. DISCUSSION

The urban population in emerging countries is projected to double by 2050 (Goi, 2017). It is imperative to explore strategies for mitigating urban pollution to safeguard a sustainable ecosystem, especially considering the increasing urbanisation of the global population. Moreover, understanding how to address urban pollution within the worldwide cycle is crucial for making informed management decisions that ensure ecosystems' future health and productivity.

This bibliometric review has highlighted that the volume of publications on urban pollution is relatively modest, with annual outputs in both Scopus and WoS databases falling below 20. Furthermore, the publication frequencies have displayed variability. This circumstance may be attributed to the strategy of a newly established journal, which may opt for more frequent publications to solidify its presence in the field and solicit submissions. Conversely, a well-established journal with a robust reputation might publish less frequently yet receive a substantial number of submissions, while upholding a commendable impact factor (Bajwa *et al.*, 2019). Thus far, compared to Scopus, the number of publications on WoS increased dramatically after 2008, but

it is still minimal. Therefore, various alliances, whether government or non-government organisations, must provide some allocations to researchers to advance their studies on this topic to expand the number of urban pollution research. One probable explanation is that the research project demands substantial funding to ensure that the focal parameters involve laboratory work, such as analysing pollution samples that require specialised chemicals and equipment. Without adequate allocation, conducting the research becomes a formidable undertaking.

This study also addressed that "Environmental Science and Ecology" has been deemed the most crucial subject. This finding has augmented our understanding of how this domain enhances theoretical advancements and elucidates the conceptual landscape of urban pollution research. Concerning this, "Environmental Science and Ecology" has aided in improving scientific communication and will facilitate future information retrieval processes crucial to scientific advancement. The increase in publications on a subject also depends on the central idea of a study. In this context, "Environmental Science and Ecology" is the appropriate subject for specifying the environmental situation in cities around the world, especially when excessive pollution and ecological degradation significantly

impact people's quality of life (Arsovski *et al.*, 2018). Besides, urban pollution research has been a favourite in other subjects such as "Engineering", "Meteorology and Atmospheric Sciences", and "Water Resources". This input revealed that the development of various disciplines had made outstanding contributions to incorporating urban pollution into a multidisciplinary theme. Sustainable cities must be economically prosperous, socially just, politically well-managed, and ecologically sustainable to enhance human comfort (Panagopoulos *et al.*, 2016). Therefore, a multidisciplinary approach is required to understand the quality of the urban environment, particularly concerning pollution, while simultaneously enhancing human well-being connected to sustainable urban development.

In this study, Science of the Total Environment and Atmospheric Environment are the source titles with the highest number of published articles exceeding 10. These source titles are significant for potential readers and future researchers to obtain or publish their research on urban pollution. An international, multidisciplinary natural science journal, Science of the Total Environment, is devoted to publishing new, hypothesis-driven, high-impact research on all aspects of the total environment. Thus, this journal focuses a great deal on the accumulation of knowledge, the development of theory, and a focus on the scientific aspects of urban pollution. In comparison, the Atmospheric Environment covers emissions science and reduction strategies related to urban pollution. This input may contribute to theory growth by enabling scholars to gain nuanced insights from objective research findings on urban decay concerning emissions science and mitigation techniques.

According to the research findings, the United States, Italy, China, and France have become the most proactive countries regarding publishing academic works on urban pollution. It is depicted that the number of publications is highest in developed countries. The Pacific Northwest National Laboratory in the United States researched urban pollution in this study. Concerning the percentages of documents published over the past two years, it is indicated that China's scientific production core has expanded steadily. These findings could explain that China's rapid economic and technological development is related to

increased environmental risks. For instance, the increased risk of heavy metals contamination of urban soil will lead to ecological problems; if this issue is not seriously considered, soil toxicity and biological accumulation will threaten the sustainability of China's development (Shifaw, 2018). In addition, urbanisation and land expansion are massive in developing countries like China, and their publication output has been among the highest in the past few years (Liu *et al.*, 2022). The analysis of cooperation networks has also emphasised countries' importance and relevance of network collaborations. Researchers from France, Brazil, the United Kingdom, Germany, Canada, the United States, and China collaborated more than those from other regions, as revealed by research power and cooperation intensity distribution across different global network nodes. By analysing the international cooperation network, it is possible to identify the countries that have published the most articles on urban pollution and determine the nature of their cooperation. The proliferation of philosophical ideas from researchers in different countries can ensure that close research cooperation between countries can be the foundation for resolving issues related to urban pollution and sustaining environmental development across regions.

This study revealed that "Urban pollution", "Pollution", and "Air pollution" were the most commonly used keywords by previous researchers. In this study, the predominant environmental concern is urban pollution, which is mainly related to air pollution. Most research on this topic has focused on the effects of pollutants on the urban landscapes of megacities, but less is known about their connections in small- to medium-sized cities (Liang & Gong, 2020). It has been established that research on urban pollution is an immediate necessity. In addition, to protect a sustainable environment in light of the urbanisation of most of the world's population, it is essential to examine the methods that could be used to combat urban pollution.

Regarding air pollution, it is noted that identifying the primary sources that significantly contribute to air pollution is a delicate and crucial task for managing air pollution that necessitates the use of advanced scientific methods and instruments (Jeričević *et al.*, 2019). According to Jeričević *et al.* (2019), pinpointing the contribution of sources in complex urban areas affected by significant point sources

such as oil refineries is crucial for developing emission control strategies. Consequently, "Air pollution" has become a popular keyword for urban pollution research amongst previous scholars. Also, urban air pollution is becoming the most significant issue in the physical environment in high-density urban areas, affecting the environment and human health (Yang *et al.*, 2020).

This study also indicated that the keyword "Biomonitoring" had the highest PDLY in the last two years (2020-2021), accounting for 80% of all search queries. "Water quality" is another topic with a PDLY greater than 50%. In addition, "Biomonitoring" and "Water Quality" were grouped in the blue cluster of VOSviewer results. It has been observed that biomonitoring and water quality research have recently piqued academics' interest in urban pollution. Reservoirs are heavily influenced by human activities, which contribute to their imbalance. In water quality assessments, bioassays and biomarkers are valuable tools for linking chemical, ecological, and toxicological evaluations (Rodrigues *et al.*, 2021). In addition, developing effective biomonitoring and bioassessment programmes serves as a crucial foundation for restoring aquatic ecosystems. In this regard, developed countries have made significant progress, whereas developing countries have much work to do to improve the ecological status of their aquatic systems (Abdelkarim, 2020).

Bibliometric mapping with VOSviewer generated four clusters of authors' keywords in green, red, blue, and yellow, respectively. The green keyword cluster includes the keywords "Urban pollution", "Air Quality", and "Pollution monitoring". This result explained that research on urban pollution is closely related to air quality and pollution monitoring. Pollution monitoring in urban areas has become one of the most pressing concerns for local public authorities, who want to ensure that pollution levels do not exceed those deemed unsafe or mandated by local laws (Ferrigno *et al.*, 2012).

The red cluster contains keywords associated with research on urban pollution, including the core keywords "Air pollution", "Particulate matter", and "Ozone". The spatial composition, configuration, and density of urban land will continue to change due to the global trend of urbanisation, which is emphasised. Empirical and theoretical investigation of the effects of urban form on air quality has recently emerged (Liang & Gong, 2020). In 2015, exposure to particulate matter (PM2.5) was estimated to have caused 4.2 million deaths, placing ambient air pollution as the fifth leading cause of death (Cohen *et al.*, 2017). In urban areas, particulate matter with an aerodynamic diameter of fewer than 2.5 μm and 10 μm ($PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO_2), and tropospheric ozone (O_3) are among the most dangerous air pollutants in terms of their adverse effects on respiratory and cardiovascular disease (Sicard *et al.*, 2019). As a result, communities and individuals exposed to high pollution levels incur higher healthcare costs and lower labour productivity. The connection between these terms is crucial for examining urban pollution.

And finally, the yellow cluster comprises "Heavy metal" and "Oxidative stress" keywords. In biomedical science, cellular and organismal toxicity induced by heavy metals has become a significant health concern. According to Paithankar *et al.* (2021), the indiscriminate use of heavy metals in numerous industries, such as industrial, agricultural, healthcare, cosmetics, and household, has contaminated environmental matrices and constitutes a significant threat to human health and the environment. This effect is a widespread cellular reaction mediated by xenobiotics; one of these fundamental cellular responses is oxidative stress, which is triggered by a redox system imbalance (Paithankar *et al.*, 2021).

V.   CONCLUSION

This study embarks on a bibliometric analysis of publications from the Scopus and WoS databases concerning urban pollution. Employing ScientoPy and VOSviewer, the current study scrutinised the retrieved documents' annual publications, publication categories, and sources. Additionally, the study establishes networks of country cooperation and analyses the authors' keywords.

We can conclude that less attention has been paid to urban pollution research, as depicted in our results in Figure 2. The highest publication was in 2020 for the Scopus database, which was not more than 20 publications. However, international cooperation revealed that scholars from

France, Brazil, the United Kingdom, Germany, Canada, the United States, and China collaborated more efficiently.

Based on the analysis of keyword co-occurrence, it is evident that "Urban pollution", "Pollution", and "Air pollution" have been the most commonly utilised terms by previous researchers. This suggests a pressing need to intensify research efforts on urban pollution, focusing on resolving its environmental and sustainable impacts.

Acknowledging that this bibliometric analysis relies solely on documents obtained from Scopus and WoS is crucial. This could potentially limit the comprehensiveness of the collected literature. To mitigate this, leveraging additional databases like PubMed could offer valuable insights for researching urban pollution. Another limitation of this study is the absence of an evaluation of the content and scope of research within the specific area of interest. Future research endeavours may address these limitations by considering a broader range of sources and conducting a more thorough assessment of the research landscape in urban pollution.

VI. ACKNOWLEDGEMENT

VII. REFERENCES

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