WASTEWATER CHALLENGES, TREATMENTS AND BENEFITS : LITERATURE ANALYSIS

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Abstracts
This research focuses towards analysing the problems associated with wastewater and treatment process as well as its application in our daily living. The research implore both the generalized and bibliometric literature review method. The findings of the literature review reveals that wastewater has both health and environmental hazards such as water polution, health risks, eutrophication, environmental damage, climate change and infrastructure challenges. Meanwhile, the bibliometric literature review showed that optimization, removal and wastewater are the most frequently used terms based on the bibliometrics data extracted from web of sciennce between the period of 2012 and 2023, Zhang and Wang who had h-index citation of 15 and 14 respectively are the most global authors while China-USA had highest global international collaboration frequency. The researchers reconmmended that more wastewater treatment facilities should be deployed in Nigerian industries by the stakeholders.

Keywords: Wastewater, treatment, bibliometrix, collaboration and Disinfection

1 INTRODUCTION

Wastewater presents various environmental and public health problems. Some of the key issues associated with wastewater are water pollution, health risks, eutrophication, environmental damage, climate change, resource depletion, and infrastructure challenges.

Water Pollution: Wastewater contains a wide range of pollutants, including organic matter, nutrients (nitrogen and phosphorus), heavy metals, pathogens, and emerging contaminants (e.g., pharmaceuticals and personal care products). When released into water bodies without proper treatment, it can lead to water pollution, affecting aquatic life and ecosystem health UNEP (2016).

Health Risks: Untreated or poorly treated wastewater can contain disease-causing pathogens. The discharge of such wastewater can contaminate drinking water sources and lead to the spread of waterborne diseases (WHO 2006).

Eutrophication: Excess nutrients, mainly nitrogen, and phosphorus, from wastewater can lead to eutrophication in water bodies. This can result in harmful algal blooms, oxygen depletion, and the death of aquatic life (Smith *et al.*, 1999).

Environmental Damage: The discharge of wastewater into natural water bodies can harm aquatic ecosystems, including fish and other wildlife. It can disrupt the balance of aquatic ecosystems and lead to long-term environmental damage.

Climate Change: Wastewater treatment is energy-intensive, and the release of untreated methane gas from wastewater can contribute to greenhouse gas emissions, exacerbating climate change (WWAP, U. 2019).

Resource Depletion: Wastewater often contains valuable resources, such as water, energy, and nutrients. Failing to recover and reuse these resources represents a missed opportunity and can lead to resource depletion.

Infrastructure Challenges: Many wastewater treatment systems are outdated and inadequate, especially in developing countries. The lack of proper infrastructure for wastewater treatment poses a significant challenge in managing wastewater (Smith *et al.*, 1999).

Wastewater treatment plays a crucial role in safeguarding public health and protecting the environment. It is an interdisciplinary field that combines engineering, biology, chemistry, environmental science and Operations Research to address the challenges associated with water pollution and the disposal of wastewater. The effectiveness of wastewater treatment processes is continually improved through research and technological advancements to meet the evolving needs of society and the environment.

Water and wastewater process optimization refers to the systematic improvement of processes and technologies involved in the treatment and distribution of clean water and the collection and treatment of wastewater. The primary goals of optimization in this context are to ensure the delivery of safe, clean water to consumers and to manage and treat wastewater effectively while minimizing costs and environmental impact. Wastewater treatment is the process of removing contaminants and pollutants from domestic, industrial, and agricultural wastewater before it is released into the environment or returned to the water cycle. This essential process helps protect the environment and human health by ensuring that harmful substances are not discharged into rivers, lakes, or oceans.

Wastewater treatment typically involves several stages, including Preliminary Treatment: This stage involves the removal of large objects such as sticks, leaves, and plastics that could clog or damage equipment in the subsequent treatment stages. It may also include the removal of grit and sand (Metcalf *et al 2003*).

Primary Treatment: In this stage, solid particles and organic matter are settled and removed from the wastewater. This is often achieved through sedimentation in large tanks. Primary treatment reduces the biochemical oxygen demand (BOD) of the wastewater but does not completely eliminate dissolved and suspended contaminants (Vesilind *et al., 2003).*

Secondary Treatment: Secondary treatment is a biological process that uses microorganisms to break down the organic matter in the wastewater. Common methods include activated sludge processes, trickling filters, and rotating biological contactors. Secondary treatment further reduces BOD and suspended solids (Henze *et al.*, 2008).

Tertiary Treatment: This stage aims to further improve the water quality by removing additional contaminants, such as nutrients (nitrogen and phosphorus), pathogens, and trace organic compounds. Common methods include chemical precipitation, filtration, and advanced oxidation processes (Tchobanoglous *et al.*, 2008).

Disinfection: Disinfection is the final step to kill or inactivate any remaining disease-causing pathogens in the treated wastewater. Common disinfection methods include chlorination, ultraviolet (UV) irradiation, and ozonation.

The choice of treatment methods and the extent of treatment depend on the characteristics of the wastewater and the environmental regulations in place. The treated water can then be discharged into bodies of water, used for irrigation, or even treated further for potable water supply in some cases ((EPA 2020).

2 Wastewater Treatment and its Benefits

Clean water is a basic necessity for humans. While the human population grows, the demand for water grows as well. Since water is a finite resource, used water must be treated to continuously serve end-uses. It is on this basis that wastewater treatment comes in. These papers collectively provide information on the definition and characteristics of wastewater. Welch and Naczk (1992) defines wastewater as water negatively affected by humans and highlights its complex mixture of inorganic and organic materials. High amounts of inorganic and organic matter discharged via process effluent can seriously impair water sources or result in toxic levels in soil (Welch and Naczk, 1992). Sane, Nagarkar and Shinde (2020) emphasized the need for wastewater reuse in various sectors due to water scarcity issues, particularly in developing economies. They opined that Wastewater is a by-product of domestic, industrial, commercial, or agricultural activities. Muralikrishna and Manickam (2017)

discusses different wastewater treatment technologies, focusing on domestic wastewater and the various treatment methods available. Domestic wastewater generated from domestic sources are well documented and designed (Muralikrishna and Manickam, 2017).

Wastewater is a contaminated form of water resulting from human activities, including domestic, industrial, commercial, and agricultural uses. They also emphasize the importance of wastewater management and treatment to mitigate environmental impacts and ensure the availability of clean water resources.

Therefore, Wastewater treatment is highly beneficial in manufacturing companies and other industrial businesses. Besides preserving water and avoiding water pollution, wastewater treatment boost productivity avoids equipment damage and promotes efficient operations.

Yu-shan & Wanmeng (2010) submitted that, effluent of wastewater plant after appropriate treatment could be used to circulating, cooling, agricultural irrigation, scenery, greening, underground recharging water and so on, which had broad application prospects. Wastewater reclamation and reuse not only provided direct economic benefits for industry, but also decreased industry and agriculture loss, body healthiness loss, and had remarkable social and environmental benefits.

Culp (2016) observed that wastewater treatment prevents pollution of water sources and increases the available water supply, which is crucial for future water use expansion.

Wastewater provides an effective source of nutrients that vegetation roots can absorb and allow the plant to assimilate (Mexal, et al, 2005).

Land application of wastewater is recommended as a method of recycling nutrients and organic matter while conserving freshwater resources (Mexal, et al, 2005).

It helps create a supplemental irrigation source, reduces fertilizer costs, and allows for effective remediation of wastes (Mexal, et al, 2005). Additionally, wastewater use in agriculture has been implemented worldwide and can contribute to food production in water-scarce regions (Rebora, 2011).

The benefits of treating wastewater are summarized below, note that the lists are not exhaustive:

i. Averts waterborne pollution
ii. Safeguard public health and safety
iii. Profitable to the environment
iv. Clean and safe (usable) water
v. Energy production
vi. Benefits the economy and economic activities such as employment
vii. It serve as a way of recycling nutrients while conservating fresh water resources
viii. Waste reduction
ix. Food production in water-scarce areas
x. It increases the availability of water supply

3 Wastewater Treatment Process

Wastewater treatment is the process of removing contaminants and pollutants from wastewater before it is released into the environment or returned for reuse. The specific methods and technologies used can vary depending on the source of the wastewater, its intended use, and the local regulatory requirements. Here's a general overview of the wastewater treatment process (Metcalf *et al* 2018) :

3.1 Preliminary Treatment:

Screening: Large debris, such as sticks, leaves, and plastic, are removed using screens or grates.

Grit Removal: Sand, gravel, and other heavy materials are settled out.

Primary Treatment: In primary treatment, sedimentation tanks, gravity separates the remaining suspended solids and organic matter from the water. Primary treatment reduces the biological oxygen demand (BOD) and suspended solids in the wastewater.

3.2 Secondary Treatment:
Biological treatment is used to further remove dissolved and suspended organic matter. Common methods include activated sludge, trickling filters, or rotating biological contactors. Microorganisms (e.g., bacteria) break down organic matter in the wastewater, reducing BOD and producing sludge. Secondary treatment typically follows primary treatment and is designed to remove up to 90% of the pollutants.

3.3 Tertiary Treatment (if needed):
Tertiary treatment is used to remove specific contaminants like nutrients (nitrogen and phosphorus) and fine suspended solids. Methods can include chemical precipitation, filtration, and advanced biological processes.

3.4 Disinfection:
To eliminate harmful pathogens and bacteria, wastewater is disinfected with chlorine, ultraviolet (UV) light, or ozone. This step ensures that the treated water is safe for discharge or reuse. Sludge Treatment and Disposal:the solids removed during primary and secondary treatment, known as sludge, are further processed. Options for sludge treatment include digestion, dewatering, and disposal in landfills or beneficial reuse (e.g., fertilizer) (Vesilind, *et al* 2016 & WEF 2014).

4 Bibliometrics

A bibliometrics literature review is a research methodology that involves systematically analyzing and evaluating the existing literature related to a specific field or topic using bibliometric techniques and tools. Bibliometrics is a quantitative method for studying patterns and trends in scholarly publications, such as academic papers, journal articles, books, and conference proceedings. It provides insights into how research is conducted, disseminated, and cited within a particular domain. A bibliometrics literature review aims to provide a comprehensive overview of the existing research in a specific field while also examining the various aspects of scholarly communication, collaboration, and impact (Waltman & van Eck, 2012).
The bibliometric data for this study were obtained from reputable articles database known as Web of science (WOS). Bibliometric data were analyzed using an R interface software known as bibliometrix. The wsummaryb of the main information regarding the articles extracted are as shown in table 1. The time span of the articles considered was between 2012 and october 2023, there were 256 journal sources within the time frame considetred, 2,298 related articles to the area of study published by 6,189 authors with 20.05% annual rate of growth while the total authors' keyword was 5,292.
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Table 1: Main Information

Description	**Results**
MAIN INFORMATION ABOUT DATA	
Timespan	2012:2023
Sources (Journals, Books, etc)	256
Documents	2298
Annual Growth Rate %	20.05
Document Average Age	3.59
Average citations per doc	17.94
References	78790
DOCUMENT CONTENTS	
Keywords Plus (ID)	3982

Author's Keywords (DE)	5292
AUTHORS	
Authors	6189
Authors of single-authored docs	21
AUTHORS COLLABORATION	
Single-authored docs	30
Co-Authors per Doc	4.61
International co-authorships %	28.89
DOCUMENT TYPES	
article	2026
article; early access	72
article; proceedings paper	39
review	153
review; early access	8

5 Word Cloud Related to Wastewater Treatment

A bibliometrics word cloud is a graphical representation of the most frequently occurring words or phrases in a collection of bibliometric data, such as academic publications, research articles, or scientific journals. Bibliometrics is the quantitative analysis of scholarly publications to measure and analyze the impact, productivity, and characteristics of scientific research. Word clouds are a visual tool used to highlight and visualize the most significant terms or keywords within a dataset, providing a quick and intuitive way to understand the key themes, topics, and trends present in a body of academic literature (Boyack *et al.,* 2005; Van & Waltman, 2010 and Leydesdorff, & Rafols 2009)

The word cloud for the wastewater treatment is as presented in figure 1, which shows that optimization having the largest font as the most frequently used words followed by removal and other words follows subsequently.

5.1 A Treemap

A treemap is a data visualization technique used to display hierarchical data in a nested, rectangular layout. It provides a way to represent data with a hierarchical structure while also showing the distribution of values within each level of the hierarchy. Treemaps are especially useful when dealing

with large datasets and want to visualize the relationships between various categories and subcategories (Johnson & Shneiderman 1991)
Figure 3 presents the tree map for wastewater treatment process optimization. The top five components that have higher percentages are: optimization 11%, removal 10%, waste-water 9%, waste-water treatment 5%, and degradation 3%

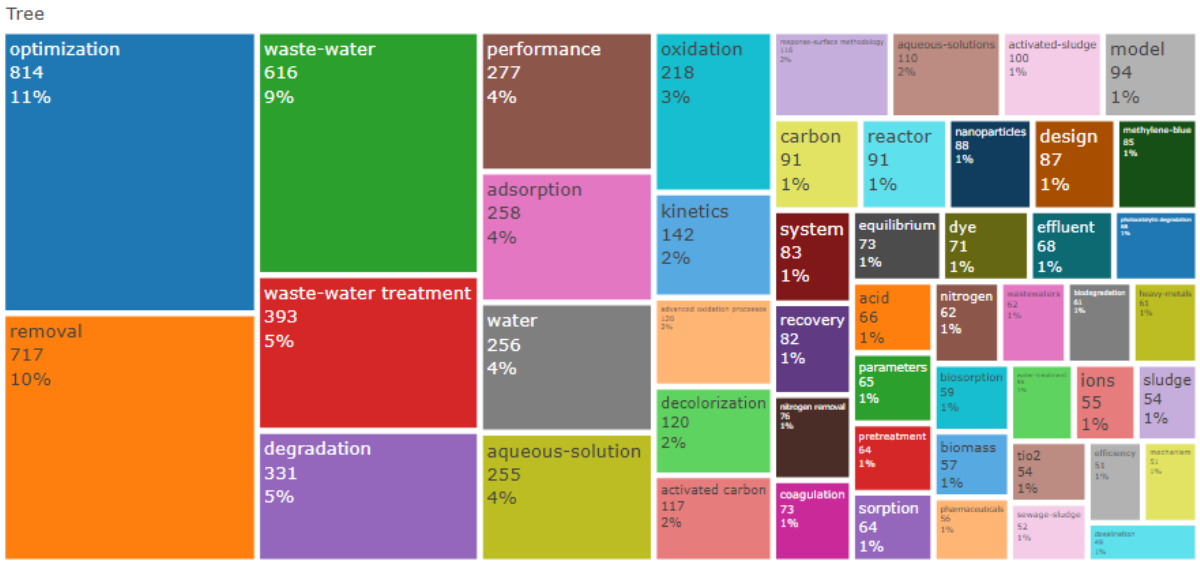

Fig 2: Treenmap

5.2 Thematic Map

A bibliometrics thematic map is a visualization tool used to explore and analyze the landscape of scientific research in a specific field or discipline. It is a graphical representation that helps researchers and decision-makers to understand the structure, trends, and connections within a particular area of scholarly literature. This map typically uses bibliometric data, such as citation networks, co-authorship relationships, and keyword co-occurrence, to create a visual representation of the knowledge domain (Klavans & Boyack 2017). Figure 3 presents the thematic map for waste-water treatment optimization as follows: Niche theme oxidizing bacteria, partial nitrification, and dissolved-oxygen, while basic theme were optimization, Wastewater, and waste-water treatment.

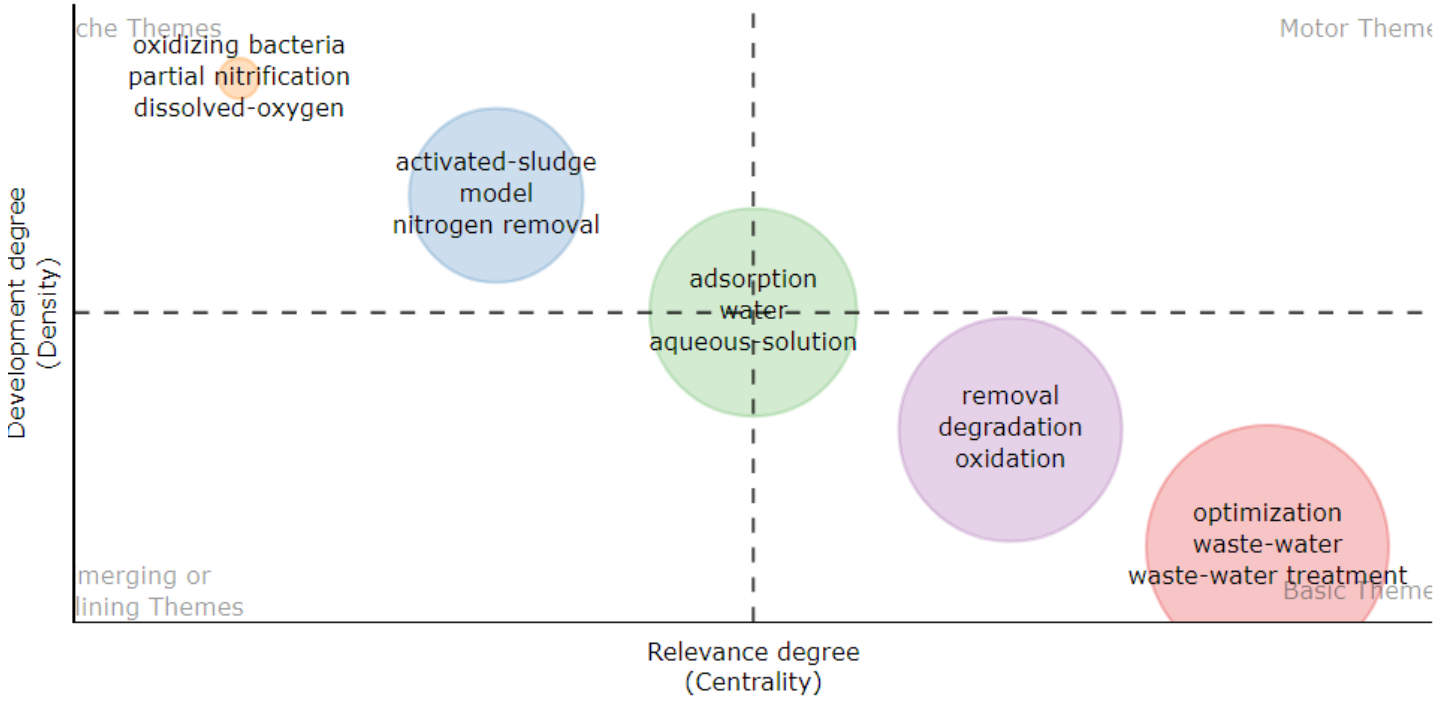

Figure 3: Thematic Map

5.4 Country Collaboration

International collaboration in academic journals refers to the practice of researchers from different countries working together to produce scholarly articles or papers. This collaboration is crucial for advancing scientific knowledge and promoting diversity of thought and perspectives in academia. Here's an explanation of international collaboration in academic journals, and its benefits (Wagner & Leydesdorff, 2015 and Abramo, *et al.*, 2013):

Diversity of Perspectives: International collaboration brings together researchers with diverse backgrounds, experiences, and perspectives. This diversity can lead to more comprehensive and well-rounded research, as different cultural, social, and academic viewpoints are integrated.

Access to Varied Resources: Collaboration often allows researchers to access resources that may not be available in their home countries. This can include specialized equipment, unique data sets, or expertise in a particular field.

Increased Credibility: Articles resulting from international collaboration tend to be viewed as more credible and authoritative. This is because they are often subject to a rigorous peer-review process, and the diversity of perspectives can enhance the quality of the research.

Enhanced Impact and Visibility: International collaboration can lead to research findings that have a broader impact, as they reach a wider audience. This can contribute to the visibility and recognition of the researchers involved.

Networking Opportunities: Collaborating internationally provides researchers with the opportunity to build a global network of colleagues, which can be valuable for future projects, career advancement, and knowledge exchange.

Access to Funding: Some research projects may require significant funding. International collaborations can access funding sources from multiple countries or organizations, increasing the likelihood of securing necessary financial support.

Addressing Global Challenges: Many of the world's most pressing challenges, such as climate change, pandemics, and poverty, are global in nature.

Figure 4 presents the pictorial international collaboration of authors across the continent of the world, while table two presents the frequency of world collaboration in the area of study. The result in table two shows that China-USA had highest frequency of collaboration of 43, follows by China-Australia with a frequency of 25, China- Canada with the 18 frequency of collaboration, Malaysia-Saudi Arabia which had frequency of collaboration of 17 is number four while other countries as presented in table 2.

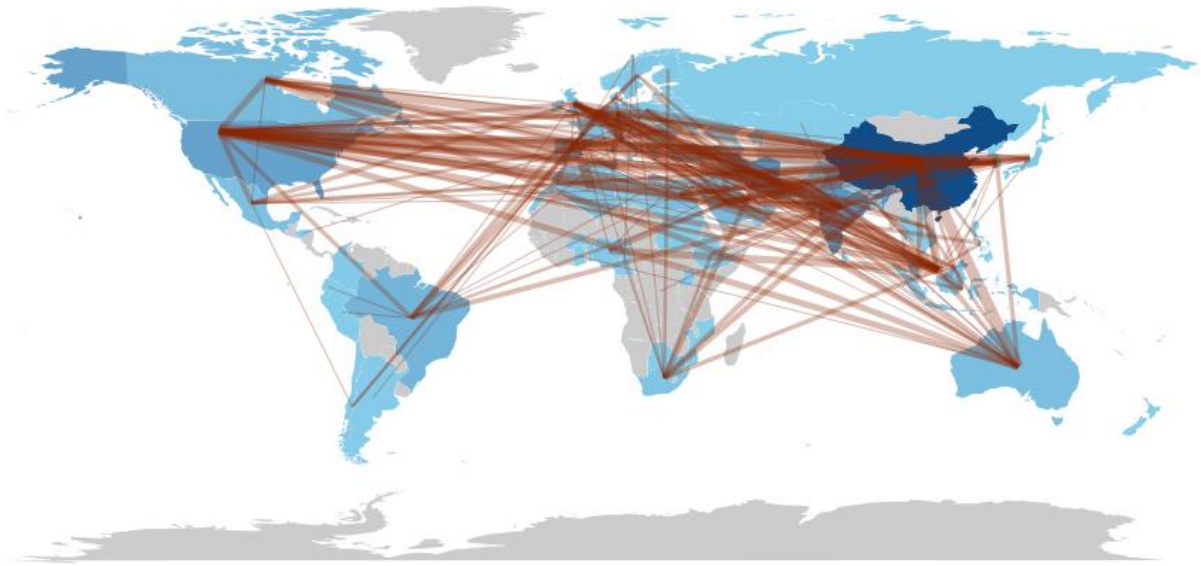

Figure 4: International Collaboration

Table 2: World collaboration

From	To	Frequency
CHINA	USA	43
CHINA	AUSTRALIA	25
CHINA	CANADA	18
MALAYSIA	SAUDI ARABIA	17
FRANCE	ALGERIA	16
CHINA	JAPAN	15
INDIA	SAUDI ARABIA	15
CHINA	INDIA	14
CHINA	MALAYSIA	14
USA	KOREA	13
IRAN	USA	12
MALAYSIA	UNITED KINGDOM	11
EGYPT	SAUDI ARABIA	10
MALAYSIA	IRAQ	10
MALAYSIA	NIGERIA	10
PAKISTAN	SAUDI ARABIA	10
CHINA	IRAN	9

6 Most Globally cited author

A globally cited author is an individual whose work, typically in the form of academic publications, research papers, books, or other scholarly contributions, has received significant recognition and citations from scholars and researchers worldwide. These authors have made substantial and influential contributions to their respective fields, and their work has had a broad impact on the global academic community. Being a globally cited author is a testament to the quality and significance of their research and the influence they have had on their field of study.
The result obtained from the data extracted from the WoS as analyzed by bibliometrix software, revealed that Zhang Y who had 15 h-index, 25 g-index, 1.5 m-index, and 665 total citation was the most productive author out of the first ten, followed by Wang J, who had 14 h-index and 22 g-index citation. Meanwhile Guo J, who had 9 h-index, 9 g g-index, 0.75 m-index was the last ten top authors as shown in table 3.

Table 3: Authors index and Citation

S/n	Element	h_index	g_index	m_index	TC	NP	PY_start
1	ZHANG Y	15	25	1.5	665	33	2014
2	WANG J	14	22	1.273	504	28	2013
3	WANG Y	14	36	1.167	1316	42	2012
4	CHEN X	12	12	1.091	430	12	2013
5	LIU Y	11	29	1	855	37	2013
6	ZHANG J	11	17	1	303	24	2013
7	LI J	10	22	0.909	513	29	2013
8	WANG X	10	18	1.111	349	18	2015
9	CAI J	9	10	0.818	344	10	2013
10	GUO J	9	9	0.75	286	9	2012

6.1 Globally Cited Documents

Globally cited documents, often referred to as highly-cited documents or influential papers, are research publications that have garnered significant attention and recognition in the scientific community. These documents are frequently cited by other researchers and are considered to have made a substantial impact on a particular field of study. High citation counts indicate that the work has influenced subsequent research, contributed to the development of theories or methods, and is considered seminal in its area.
There are several ways to measure and identify globally cited documents, including using citation databases such as Web of Science, Scopus, and Google Scholar. These databases track the number of times a specific publication is cited in other scientific articles, making it possible to identify highly-cited documents. Researchers and institutions often use this information to evaluate the impact and significance of individual publications (Ioannidis & Klavans, 2018 ; Waltman & Costas 2014).
The most global cited documents on wastewater treatment optimization was Chen D, 2020 who had 616 articles, followed by Awual MR, 2018, who had 327 articles and Luo J. 2019 who had 270 articles while Chin, 2016, who had 172 articles was the last first ten cited documents.
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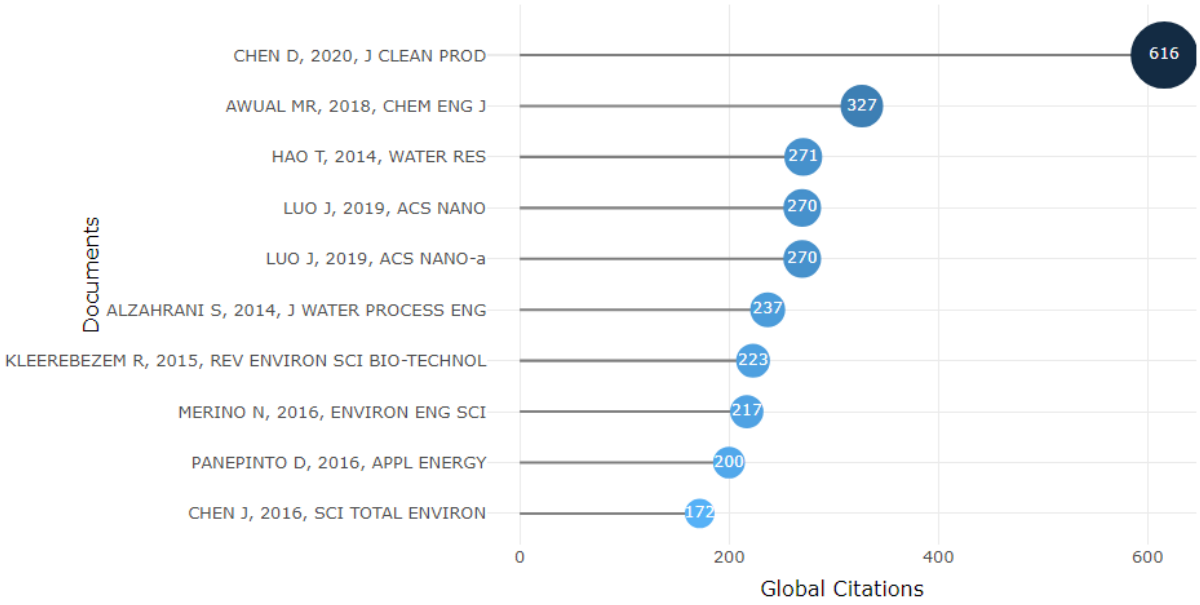


6.2 Most Relevant Source

A journal source typically refers to information or data derived from a scholarly or academic journal. Journals are periodical publications that contain articles, research papers, and reviews on various topics. These sources are often written by experts, researchers, or scholars in a particular field and are intended to disseminate new research findings, share knowledge, and contribute to the academic discourse.

Journal source productivity refers to the measure of how productive or influential a specific academic journal is within its field of study. It is an important metric for academics, researchers, and institutions to assess the quality and impact of a journal's published articles. Understanding a journal's source productivity can help researchers decide where to submit their work, evaluate the reputation of journals, and make informed decisions when seeking sources for their research (Smith & Johnson 2019 ; Smith, & Johnson 2019).

Considering the sources of journal production on wastewater treatment optimization extracted from WoS and analysed by bibliometrix, has been established that desalination and water treatment who had 149 articles within the time span considered is the most productive source, next to it was journal of water process engineering who had 78 published articles as the second top ten journal source while environmental science and research was the last top journal sources.

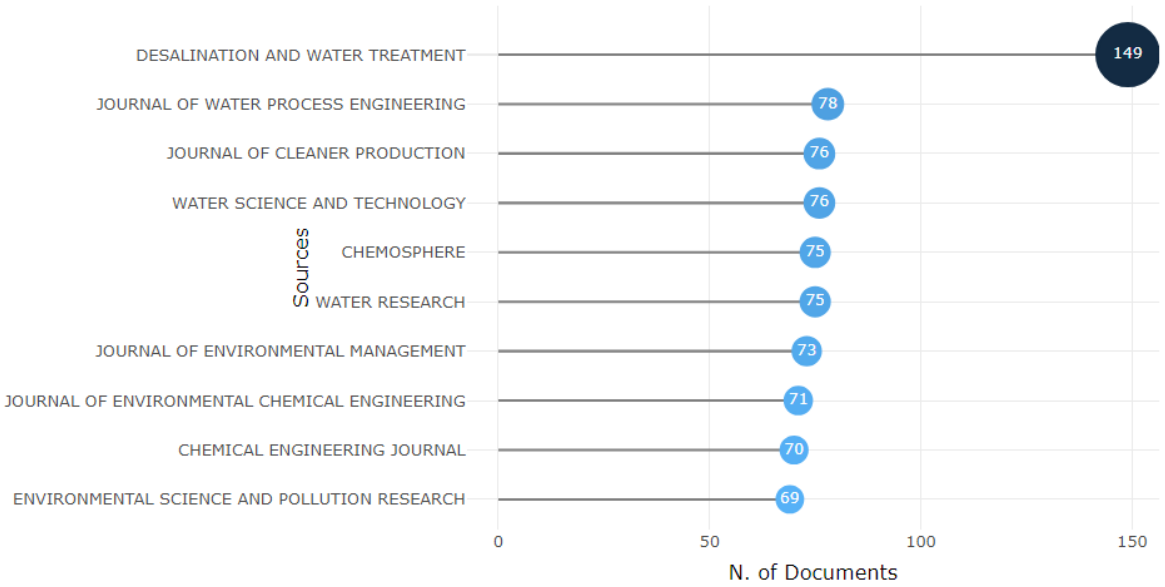
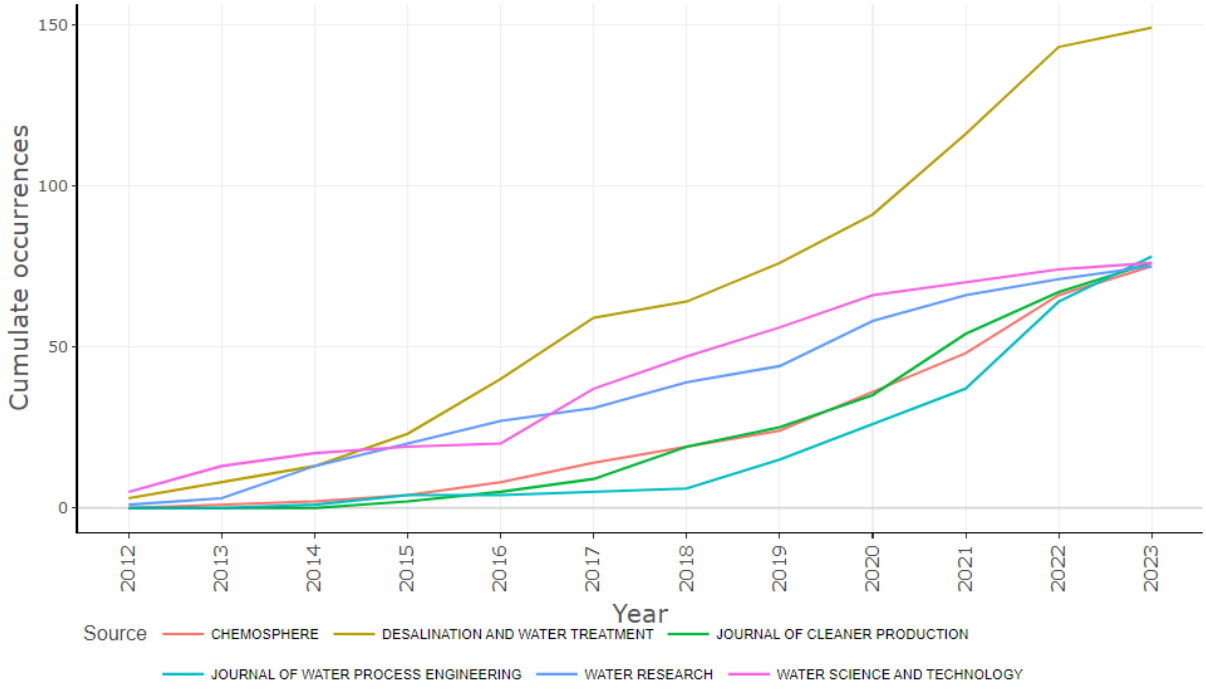


Figure 5: Journal Sources Productivity



7 Conclusion

The analysis of the issues surrounding wastewater, the treatment process, and its usage in daily life is the main goal of this study. Both the bibliometric and broad literature review methods are urged by the research. The literature review's conclusions show that wastewater poses threats to human health and the environment, including eutrophication, water pollution, environmental harm, and infrastructural issues related to climate change. From our analysis, the bibliometric data extracted from Web of Science between 2012 and 2023 revealed that Zhang and Wang, with respective h-index citations of 15 and 14, are the most globally recognized authors, while China and the United States had the highest frequency of worldwide international collaboration. In the meantime, the bibliometric literature review revealed that optimization, removal, and wastewater are the most commonly used terms.

Recommendation

We recommended that stakeholders should install more wastewater treatment facilities in Nigerian companies in order to mitigate the health and industrial threats causes by wastewater.

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