The public's attitude toward recycled water: a review

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Abstract

Many locations worldwide are encountering significant obstacles to achieving economic and social sustainability due to the increasing disparity between water availability and demand resulting from population expansion. Therefore, many countries are looking for alternative water sources to increase their water supply. Water reuse has become a practical and effective method for addressing water scarcity. A systematic review and meta-analysis of water reuse are necessary to provide guidance for future studies on the impact of water reuse and to assist managers in optimizing the usage of water reuse technology for improving workplace and organizational results. This paper is studied to investigate the correlation between public acceptance and water reuse. In addition, it provides a comprehensive analysis and summary of public acceptance regarding water reuse surveys. The study compiled data based on 85 original research papers published between 2018 and August[1], 2023. The information included details such as keywords, Geographic location, Cloud of words co-occurrence, sample size, publication peer years, published journals, and affiliations. Moreover, it shows the potential avenues for future research in this area, and it offers recommendations for enhancing the public's acceptance of water reuse.

الخلاصة: تواجه العديد من المواقع في جميع أنحاء العالم عقبات كبيرة أمام تحقيق الاستدامة الاقتصادية والاجتماعية بسبب التفاوت المتزايد بين توافر المياه والطلب الناتج عن التوسع السكاني. ولذلك، تبحث العديد من البلدان عن مصادر مياه بديلة لزيادة إمداداتها من المياه. أصبحت إعادة استخدام المياه طريقة عملية وفعالة لمعالجة ندرة المياه. تعد المراجعة المنهجية والتحليل التلوي لإعادة استخدام المياه ضرورية لتوفير التوجيه للدراسات المستقبلية حول تأثير إعادة استخدام المياه ولمساعدة المديرين في تحسين استخدام تكنولوجيا إعادة استخدام المياه لتحسين نتائج مكان العمل والنتائج التنظيمية. تمت دراسة هذه الورقة لمعرفة العلاقة بين القبول العام وإعادة استخدام المياه. بالإضافة إلى ذلك، فإنه يقدم تحليلاً شاملاً وملخصًا لقبول الجمهور فيما يتعلق بمسوحات إعادة استخدام المياه. جمعت الدراسة بيانات بناءً على 85 ورقة بحثية أصلية نُشرت بين عامي 2018 و1 أغسطس 2023. وتضمنت المعلومات تفاصيل مثل الكلمات الرئيسية والموقع الجغرافي والتواجد المشترك وحجم العينة وسنوات النشر والمجلات المنشورة والانتماءات. علاوة على ذلك، فإنه يوضح السبل المحتملة للبحث المستقبلي في هذا المجال، ويقدم توصيات لتعزيز قبول الجمهور لإعادة استخدام المياه.

1. INTRODUCTION

Although water is frequently referred to as "blue gold," there is no doubt that it will be a significant challenge in the twenty-first century [1]. Freshwater is a vital resource for humanity, with only about 3% of the world's supply suitable for direct human consumption. Life depends on water for survival[2, 3]. Recent studies indicate that 385 million people, which accounts for one-fourth of the global population, rely on water systems facing strain[4]. In 2017, the United Nations reported that global freshwater consumption reached a record 32,928 km3 per year, with agriculture responsible for approximately 70% of this amount and up to 90% in less affluent countries[5-7]. Global water scarcity is becoming a significant issue as a result of rapid urbanization, climate change, population growth, and fast economic progress [8-16]. By 2030, acute water shortages are projected to rise, impacting 1.6 billion people, which is about a quarter of the global population[2, 17].

By 2050, it is projected that 1 billion individuals will reside in urban areas facing year-round water scarcity[14, 18-21]. Consequently, numerous countries are attempting to broaden their water sources by accessing alternative water suppliers[22-25]. One of the most useful ways to help combat water scarcity and promote water resilience is by using recycled water [26-28]. Wastewater reuse is seen as a possible solution to address the challenge of fulfilling decreased demand[29]. As a substitute water source for human consumption or industrial purposes, it can alleviate pressure on current systems[30-32]. Additionally, the global water supply's capacity for reuse has grown from 33.7 Gig litres per day (GL/d) in 2010 to 54.5 GL/d in 2015. Furthermore, some regions throughout the globe have recently augmented their funding for recycled water infrastructure. Between 2011 and 2018, China invested over 25 billion yuan annually in its recycled water infrastructure, according to data from the Ministry of Housing and Construction of China. In 2018, the investment reached 80.26 billion yuan; the construction of Water Factory 21, the world's largest advanced wastewater recycling facility, in the Orange County Water District of Southern California, USA, is almost finished. The plant will have a maximum capacity of 130 million gallons when completed [26]. Popular opposition has caused delays in several water recycling projects. Hence, comprehending the factors behind the acceptance and refusal of recycled water is a crucial matter[33-36].One key challenge in establishing reuse activities, especially drinking water recycling schemes, is the negative public perception[30, 37]. Public attitude, acceptance, and support are essential for the functioning, efficiency, and effectiveness of the system for wastewater reuse[38-40]. A literature evaluation on water reuse surveys has been completed. The USA, China, Spain, South Africa, and India are among the top five countries that have conducted significant research on water reuse surveys, as shown in Figure 2. In addition, in several developing regions, including Latin America, Asia, Europe, and Africa, the utilization of water reuse surveys is limited, as seen in Figure 3B[41-50].

Due to the rapid expansion and interest in water reuse survey monitoring and prediction, it is necessary to continue analysing the existing literature to identify the current state and prospects in this research area. The current study presents a comprehensive systematic review of people's acceptance of water reuse between 2018 and August 1, 2023. A systematic review seeks to identify the areas where the existing literature is deficient, while also emphasizing the challenges other researchers face in their use of current assessment and benchmarking methods and procedures. Furthermore, it underscores the benefits and recommendations. The research also utilized a systematic review to comprehensively evaluate and compare water reuse survey support systems and the methodologies employed for this purpose. The manuscript is organized in the following manner: The methods used in this study, including a systematic review and meta-analysis, are outlined in Section 2. The review's results and analysis are discussed in Section 3. Section 4 delineates many constraints of this investigation. The future of this study is discussed in section 5.
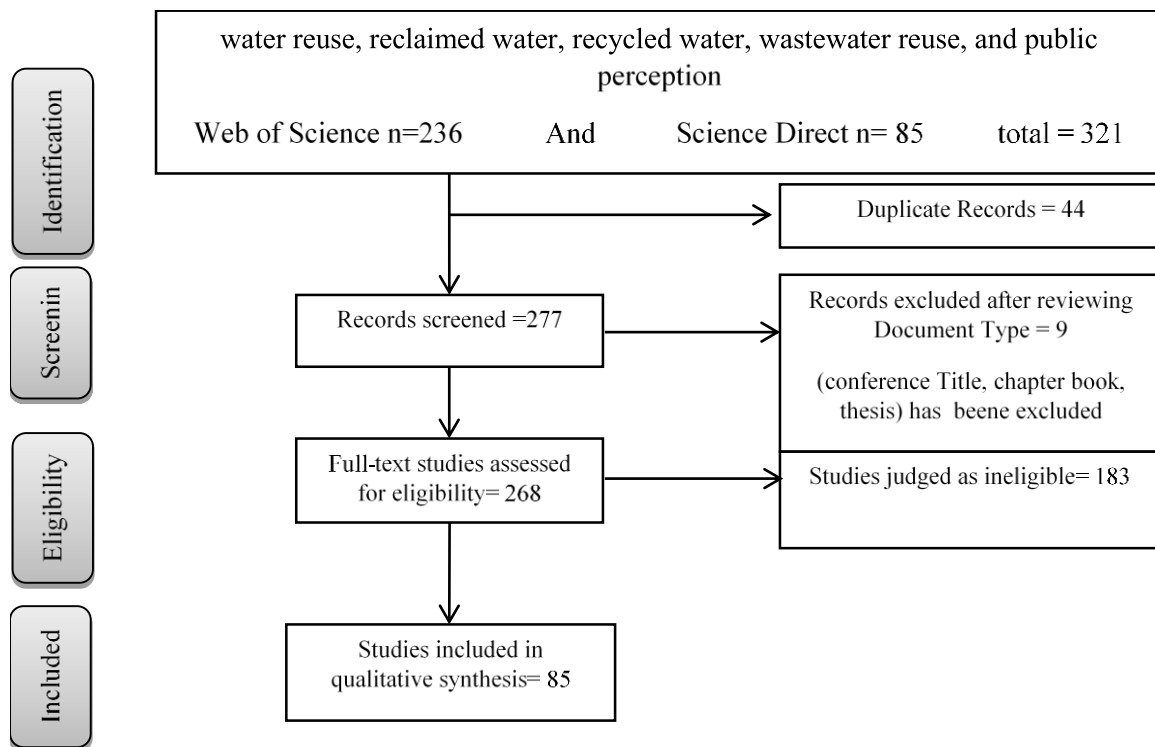
Figure.1: PRISMA flow diagram for this systematic review.

2. METHODS

Systematic reviews and meta-analyses are crucial for assessing the current state of knowledge and linkages in the subject of public perception, as well as for identifying areas for improvement and future research goals; a meticulous and carefully thought-out strategy is necessary[51-53]. The Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement was utilized in this research[54]. Previous literature reviews in several hydrological disciplines have effectively applied the PRISMA declaration[1, 55, 56]. The four basic steps of this method are as follows: (1) identification, (2) screening, (3) eligibility, and (4) inclusion [57]. The study's methodology is outlined in Figure 2 using the PRISMA flow diagram [58]. Two of the most widely used scholarly online databases had their titles, abstracts, and keywords searched using a string developed using the PRISMA architecture: Science Direct and Web of Science.

The search query covered the collective sentiment of the general population towards recycled water. The primary aims of this study are to assess individuals' understanding of the problem of water shortage and gauge public opinion about the utilisation of treated wastewater for different purposes. It determines the elements that influence acceptance and impedes the adoption of treated wastewater reuse.

Only journal publications published in English from 2018 to August 1, 2023, were included in the literature sample. 321 articles matched the search criteria. Several articles were duplicated due to the utilisation of two databases. Mendeley's "Check for Duplicates" feature resolved the problem. After eliminating duplicates and doing a manual inspection of each item, 277 were selected for the screening of their titles and abstracts. Two reviewers precisely evaluated the title to determine which articles would be retained or eliminated. If both reviewers reached a consensus to either keep or delete a record, that agreement was considered the ultimate judgment. In disputed instances, a third reviewer analysed the record and rendered the ultimate judgment. After excluding titles such as Conference Title, Chapter book, and thesis, the final abstract screening involved 268 articles. Five reviewers were assigned to meticulously evaluate the abstracts of the papers according to the inclusion criteria. Following the abstract screening, 94 articles were retained. 85 studies completed the systematic review.

3.RESULTS AND DISCUSSION

This section offers a summary of publication patterns, covering the year of publication, publishing journals, geographic area, and co-occurrence of keywords. The affiliations and sample sizes were also provided and analysed.
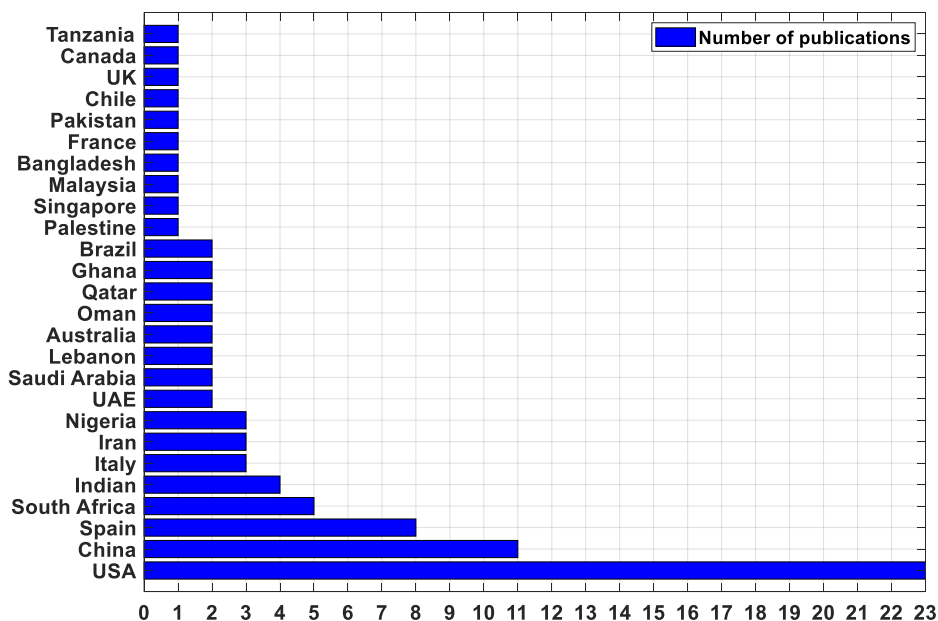

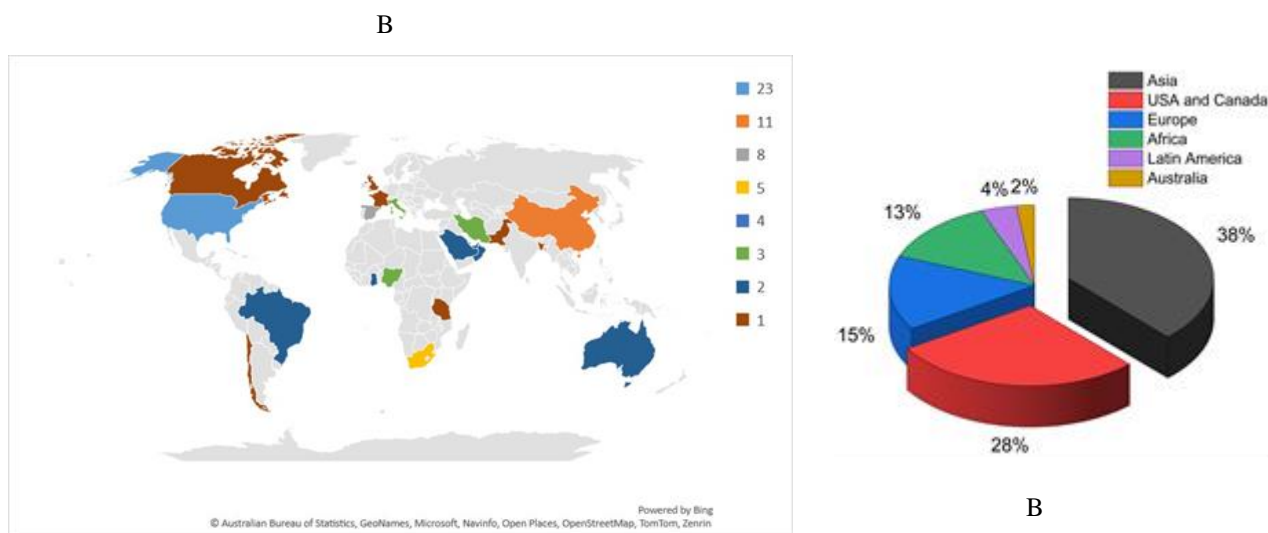Figure 2. shows the geographic distribution of the 85 papers collected for each country.

B

A

B

Figure 3. Geographic distribution of the 85 articles conducted per country: A) world map, and B) Distribution of continents

3.1 Geographic location

Figure 3 displays the geographical distribution of the papers by nation. The study includes publications from 26 nations across Asia, North America (USA and Canada), Europe, Africa, Latin America, and Australia, as shown in Figure 2. Asia ranked first with 38%, followed by North America with 28%, Europe with 15%, Africa with 13%, Latin America with 4%, and Australia with 2% of the world's land area. These countries are recognised as prominent areas for water reuse due to factors including global population expansion and the impacts of climate change, as stated by several experts [14, 59-66]. The systematic review revealed that the United States of America, China, Spain, South Africa, and India have the highest number of publications, with 23, 11, 8, 5, and 4 correspondingly. The results displayed in Figure 2 suggest that these countries prioritize water recycling due to rising population growth and escalating water consumption. In 2006, the United States had the highest total volume of recycled water production yearly. Florida led with 663 million gallons per day (mgd), followed by California with 580 mgd, Texas with 31.4 mgd, Virginia with 11.2 mgd, Arizona with 8.2 mgd, Colorado with 5.2 mgd, Nevada with 2.6 mgd, and Idaho with 0.7 mgd[67]. Also, agricultural water demands heavily strain water supplies, consuming 36% of freshwater in the USA[68-71].

In addition, China is among the 13 countries most impacted by water shortages, with over 660 cities facing this issue due to the country's fast economic growth and urbanization in recent decades[14, 72-75]. It is evident from Figure 2 that the usage of water reuse surveys in emerging regions like Latin America, Asia, Europe, and Africa is limited and needs further exploration[33, 47, 76-84]. For example, Arab homeland countries such as the United Arab Emirates, Saudi Arabia., Lebanon, Oman, Qatar, and Palestine have less research; in the future, the number of publications could rise because Arab countries are primarily situated in arid to semiarid environments and face severe water scarcity challenges due to growing populations, urbanization, and climate change impacts such as decreasing precipitation [73, 85-89]. The Gulf Cooperation Council (GCC) countries are among the countries with the most water scarcity in the world. They depend on increasing amounts of desalinated water and Treated Sewage Effluents (TSEs) to fulfill their rising water needs[90-92]. No publications on water reuse were identified in countries facing severe water shortages, such as Iraq. This suggests that there are considerable gaps in knowledge regarding water reuse surveys, highlighting the need for additional study.

Figure 4. The key terms regarding the water reuse.

3.2 Cloud of Words

The most common and significant terms found in the keywords of previous research cloud highlights. Figure 4 emphasizes the key terms found in the research literature to summarize and restructure the data. Words can range significantly in size from minuscule to substantial. Larger word sizes in the research indicate higher occurrence frequencies. Less common terms are often those that have a lower frequency of occurrence in formal literature. The main components of the existing body of knowledge include water reuse, reclaimed water, recycled water, wastewater reuse, and public perception. Water reuse is the most commonly used term, indicating its significance and prevalence.
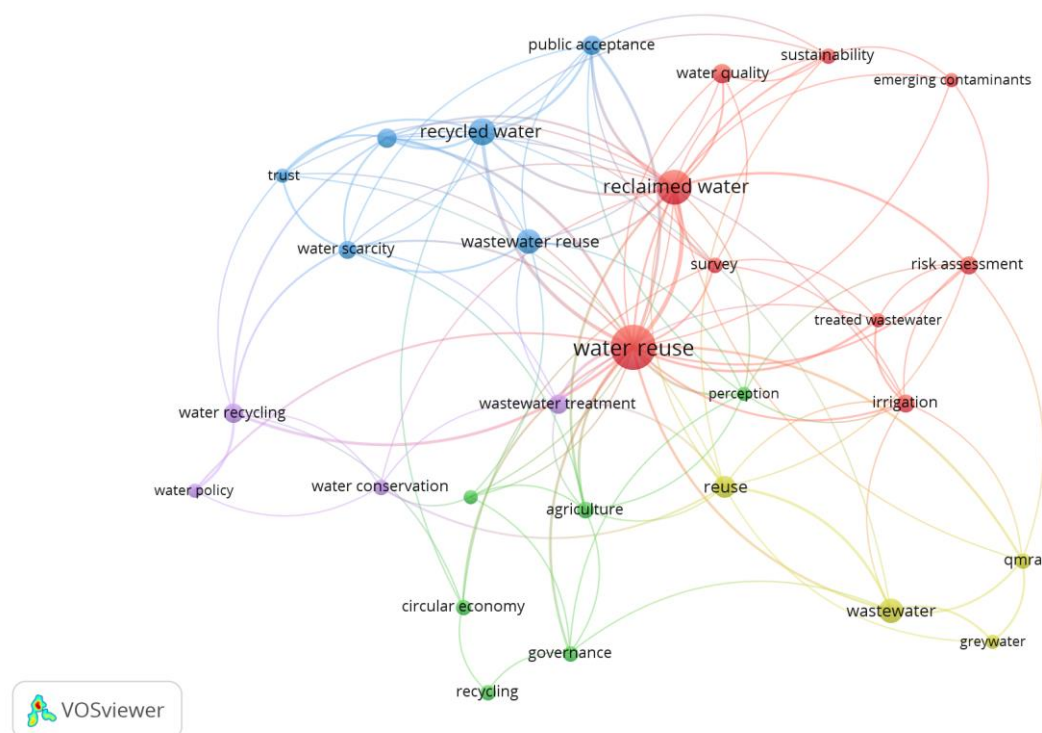

Figure 5. VOS viewer author's keyword co-occurrence.

3.3 co-occurrence

Keywords are particular terms that are crucial to articles since they can convey themes and ideas from a given body of literature and how a study topic has evolved. [93]. VOS viewer software, which creates a visual and multidimensional representation of the data, was applied to evaluate and display the network of co-occurring keywords, illustrated in Figure 5. Co-occurrence networks are constructed by selecting frequently used terms from the current corpus of literature. The network structure uncovered by co-occurrence analysis can shed light on the theoretical foundations of a certain discipline, making it beneficial for researchers, academicians, and practitioners in that area; it displays the co-occurrence networks of widely used terms for easier comprehension. The overlapping of these themes reflects the network of ideas explored in the previous literature. Larger knots represent more widespread concepts discussed in the literature. Additionally, the proximity of nodes shows the degree to which particular keywords are related to one another; the closer two nodes are, the more often they appear together [94, 95]. The five most common search keywords in the selected literature are water reuse, reclaimed water, recycled water, wastewater reuse, and public perception. These keywords represent research hotspots in the field of water reuse surveys.
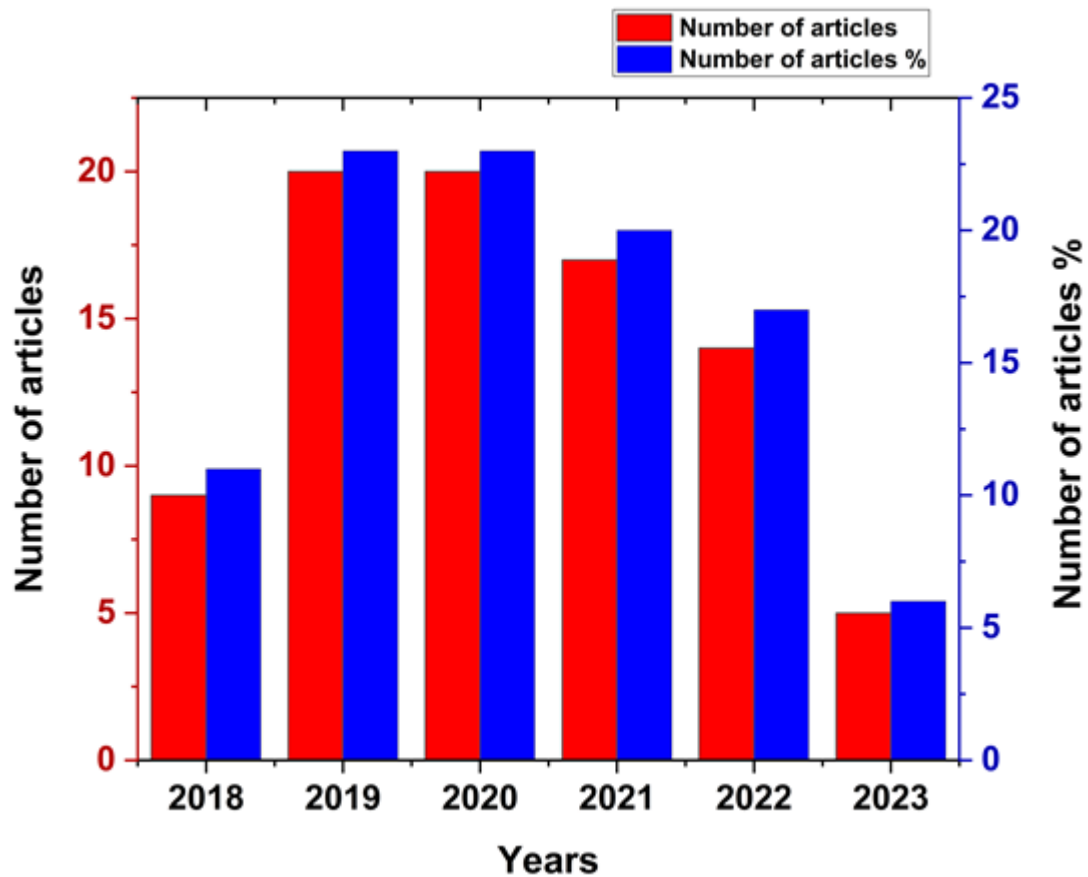
Figure 6. Research shows how many publications over the previous six years addressed a survey on water reuse

3.4 Publication peer years

Figure 6 displays the number and percentage of publications in red and blue, respectively, relative to the total number of collected articles for a given year. The figure displays publications from 2018 to August 1, 2023. The number of published articles rose from 9 (11%) in 2018 to 20 (23%) in both 2019 and 2020. In 2021, the number declined somewhat to 17 (20%), and in 2022, it decreased further to 14 (17%). In the first half of 2023, 5 articles were published, accounting for 6% of the total amount of articles. This may be due to the year not being over yet. The decrease and increase in published papers on water reuse exited during the period from 2018 to 2023. Enhancement was recognized up to 2021, and then the reduction occurred in the publication papers until 2023.
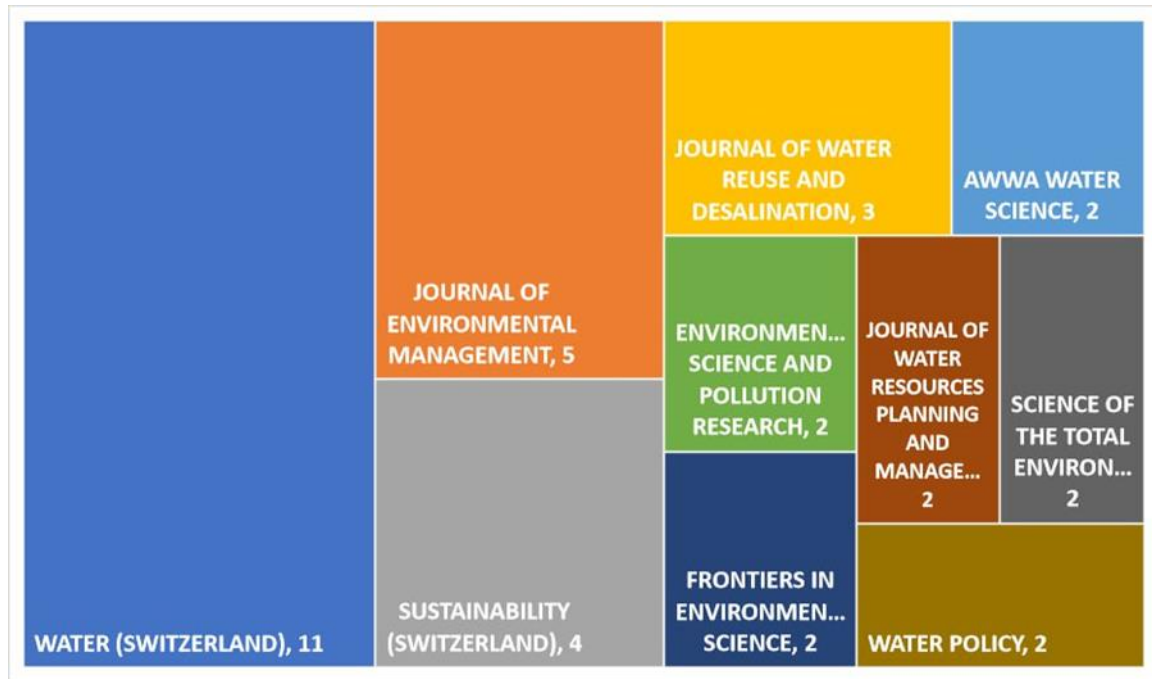
Figure 7. The best 10 journals are shown as a tree diagram based on the number of records.

3.5 Published journal

This systematic review includes papers published in 52 distinct journals. Figure 7 shows a tree map of the top ten publishing journals. The Journal of Water (Switzerland) has the highest number of articles, with 11, followed by the Journal of Environmental Management (Switzerland), with five articles, and Sustainability (Switzerland), with four articles. Each of the remaining journals has fewer than four articles. The rising water shortages may lead to a further increase in the number of publications.
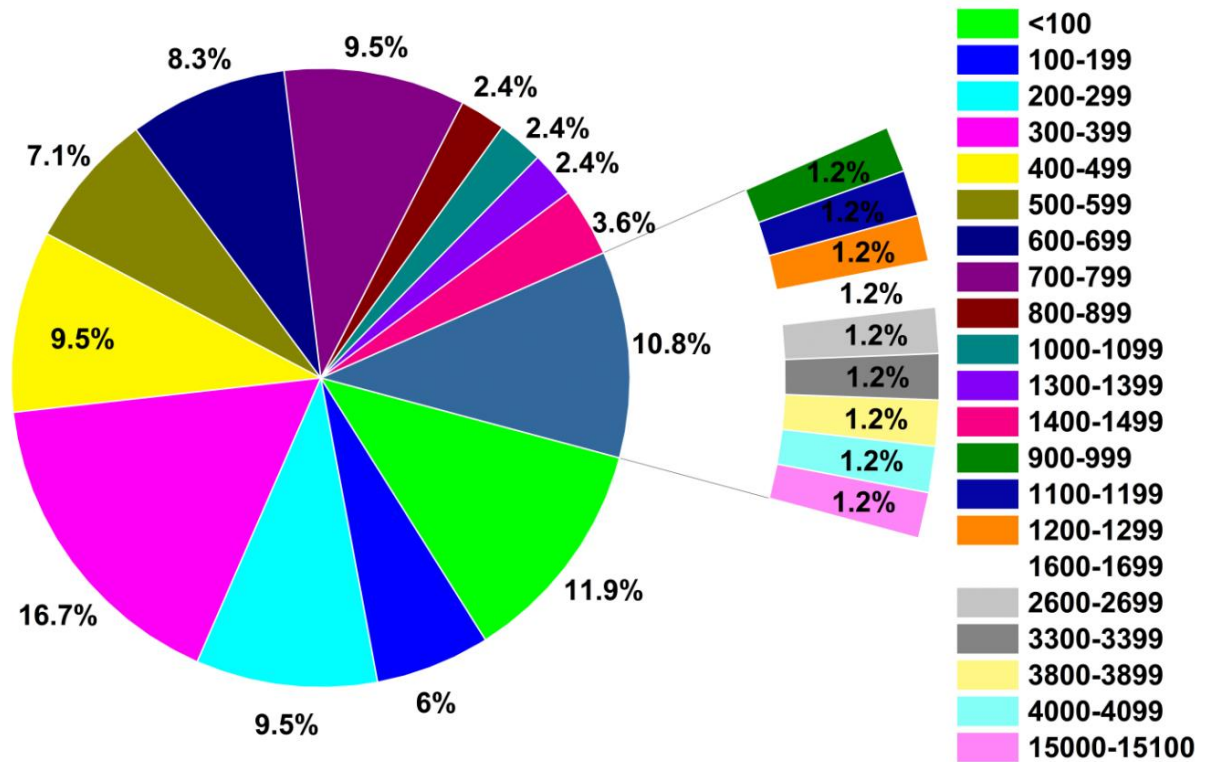
Figure 8. Graphs displaying the distribution of sample sizes used in practical applications

3.6 Sample sizes

When designing an empirical study, it is crucial to provide a rationale for the sample size that will be gathered. An essential consideration when determining sample sizes is identifying the effect sizes that are considered significant and how well the obtained data can support conclusions regarding these effect sizes. Collecting a greater amount of data will enhance the study's ability to achieve its inferential objectives. The chart displays the sample sizes of papers published from 2018 to August 1, 2023. 16.7% of the total goes to sample sizes ranging from 300 to 399. 11.9% of the publications had a sample size of less than 100, with the bulk (9.5%) of them focusing on the interview technique. There are similar sample sizes between the ranges 200-299, 400-499, and 700-799, with 9.5% and 8.3% for the range 600-699. Figure 8 depicts the distribution of the remaining percentage numbers.
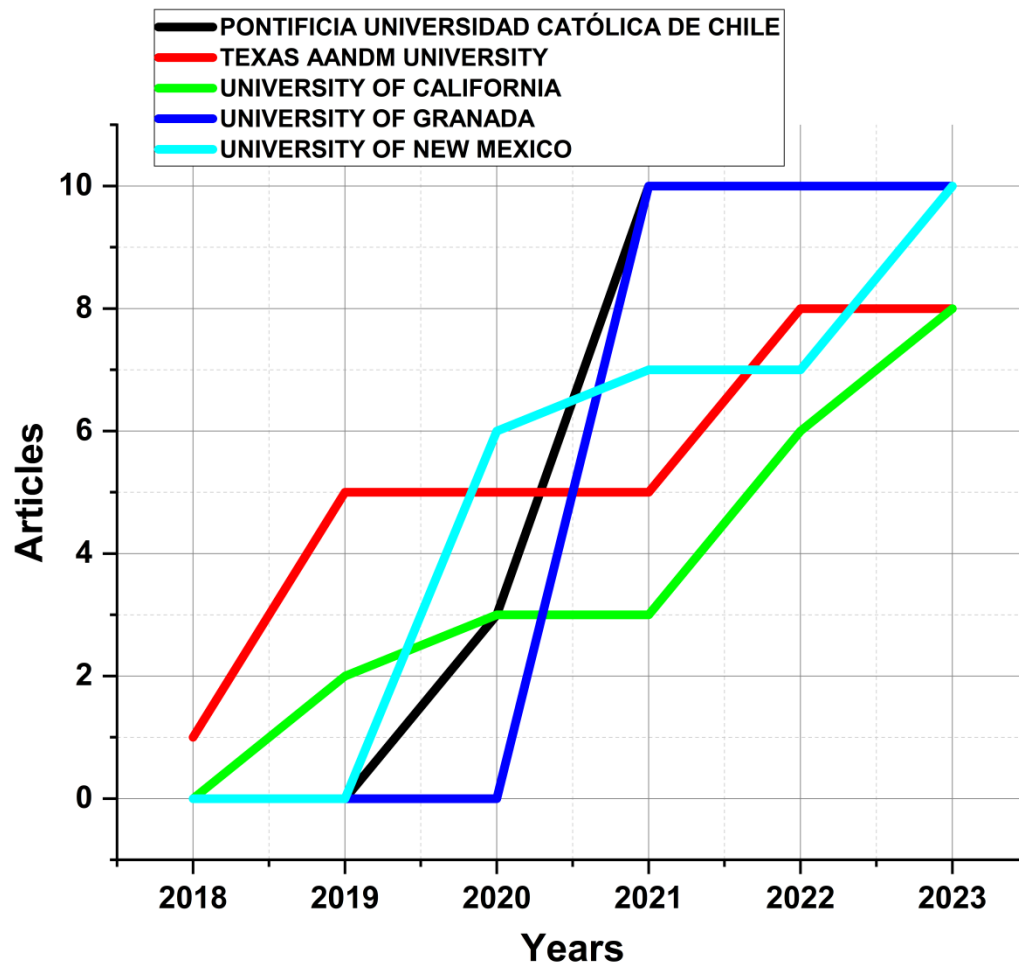
Figure 9. The publication trend from 2018 to 2023.

3.7 AFFILIATIONS

There are probably significant connections among articles, universities, and publication years. Various affiliations are associated with the publication. Figure 9 illustrates the publication trend from 2018 to August 1 2023, highlighting the top five affiliations that published works on water reuse. Both PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE and the UNIVERSITY OF NEW MEXICO had no publications in 2018 and 2019. The UNIVERSITY OF NEW MEXICO had a higher publication rate in 2020, with six articles, compared to PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE, which had three articles. PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE saw a significant increase in publications from 2021 to 2023, maintaining 10 articles. In contrast, the UNIVERSITY OF NEW MEXICO experienced a little increase in publications in 2021 and 2022, reaching 10 publications in 2023. TEXAS A&M University and the University of California followed a similar trend in publication growth. However, the University of California had no publications in 2018, while Texas A&M University had one. By 2023, both universities had published eight articles. The University of Granada did not have any publications from 2018 to 2020. Following that, the publication trend escalated quickly to ten articles and sustained that number of publications until 2023. Publishing rates are expected to climb post-2023 due to the escalating global water scarcity issue and the rising water demand. The notable aspect of this data is the overall rise in publications across all universities, particularly post-2020.

1. STUDY LIMITATIONS

Despite the fact that this study followed a rigorous approach, it cannot be considered without significant restrictions. Through the utilisation of the databases of Web of Science and Science Direct, review papers were obtained. It is possible that we will overlook certain papers that are accessible through databases such as JSTOR, ERIC, IEEE, and ACM if we restrict ourselves to only two databases during our research. On the other hand, due to the limitations imposed by the institution, certain manuscripts that fulfilled the inclusion criteria could not be accessed. For the purpose of maintaining high standards for the articles, we only accepted article submissions that were the result of original research and rejected conference papers, chapter books, and technical reports. In spite of the fact that not all groups are likely to agree with the findings of this study, it places an emphasis on the public's perspective on water reuse. Because of the significance of this research topic and the quick growth of the field, it is essential for this kind of work to continue identifying gaps, obstacles, and possibilities throughout the research process.

2. RESEARCH DIRECTION AND PROSPECTS

The problem of public acceptance of recycled water has been the subject of a significant amount of research, as was briefly discussed before. Most of these studies have relied on correlational survey research as their primary method of investigation. On the other hand, despite the fact that there are some variables for which there is little evidence, more survey research that focuses on variables with little research is not likely to produce useful insights for those who are attempting to implement recycled water projects. Case studies, on the other hand, do a wonderful job of presenting the dynamic and detailed implementation of recycled water initiatives in the "real world," but I couldn't tell you which aspects are the most critical for getting people on board with the project. After taking all of these factors into consideration, it is significant to suggest the following directions for future research.

3. Conclusion

This study aimed to conduct a comprehensive evaluation of public opinion on wastewater reuse. It is evident that although certain nations have extensive experience with the circular economy (CE) in the water and wastewater industry, its application is insufficient, and there is a dearth of knowledge regarding the necessity of developing consensus indicators to support its application more thoroughly. Different sectors of the five global motivations—economic, technological, and environmental—were examined in the publications of the current study. Water reuse is a promising scenario for modern cities to ensure their water supply during a water crisis. This systematic study focused on a public opinion survey on water reuse. The survey was conducted from 2018 to 2023. The main research papers were obtained from the Science Direct and Web of Science databases. It was shown that the majority of the articles were released in Europe, America, and Asia in order of publication. Most research papers were conducted in semi-arid and arid regions that are experiencing water scarcity as a result of climate change, population growth, and rapid economic development. This study's experimental results offer a fresh perspective on continental and country-level research on water reuse. America, China, and Spain were among the leading countries in terms of the quantity of research articles produced on water reuse. Asia, America, Canada, and Europe were the continents that published the most. Throughout this investigation, the term "water reuse" was identified as the most significant and prevalent. The study found that the most popular publishing years for publications on water reuse surveys were 2019, 2020, and 2022. The papers discussed in this systematic review were published across 52 distinct journals. The Journal of Water (Switzerland) has the highest number of papers, with 11, followed by the Journal of Environmental Management (Switzerland) with five articles and Sustainability (Switzerland) with four articles. The study found that the optimal sample size for the questionnaire was between 300 and 399 individuals, resulting in a percentage of 16.7%. An analysis of publication rates per affiliation revealed a notable rise in publishing across all affiliations, particularly post-2020. The increasing importance of finding alternative solutions to water shortages may lead to a growth in the number of publications on the topic as water shortages and demands become more frequent and severe. The current data highlight the importance of water reuse. The empirical findings in this study provide a new understanding of Public acceptance. Whilst this study did not confirm public acceptance has not been demonstrated, it did partially substantiate Supported acceptance of recycled water.

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