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Cleaner production and drinking water: Perspectives from a scientometric and systematic analysis for a sustainable performance

Fernando García-Ávila [a,b,*], Rita Cabello-Torres [c], Sergio Iglesias-Abad [d], George García-Mera [e], Cristopher García-Uzca [f], Lorgio Valdiviezo-Gonzales [g], Silvana Donoso-Moscoso [h]

[a] *Universidad de Cuenca, Facultad de Ciencias Químicas, Carrera de Ingeniería Ambiental, Cuenca, Ecuador*
[b] *Grupo de evaluación de riesgos ambientales en sistemas de producción y servicios (RISKEN), Departamento de Química Aplicada y Sistemas de Producción, Universidad de Cuenca, Ecuador*
[c] *Universidad César Vallejo. Escuela de Ingeniería Ambiental, Lima, Peru*
[d] *Universidad Católica de Cuenca, Carrera de Ingeniería Ambiental, Cuenca, Ecuador*
[e] *Universidad Laica Eloy Alfaro de Manabí, Facultad de Ciencias Agropecuarias, Manta, Ecuador*
[f] *Universidad de Cuenca, Facultad de Ingeniería, Carrera de Electricidad, Cuenca, Ecuador*
[g] *Universidad Tecnológica del Perú, Faculty of Mechanical and Industrial Engineering, Lima, Peru*
[h] *Department of Bioscience, Universidad de Cuenca, Cuenca, Ecuador*

A R T I C L E I N F O

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A B S T R A C T

Cleaner Production, as an environmental strategy, is integrated into processes, products, and services to increase efficiency and reduce risks to people and the environment. However, Cleaner Production management in water treatment services does not receive much public attention. To address this need, a scientometric analysis of the integration of Cleaner Production in water treatment was developed to investigate the efficacy and limitations of various Cleaner Production strategies applied in water treatment. A search was carried out in the Scopus database using the keywords ``Cleaner production,'' ``Wastewater treatment,'' and ``Drinking water treatment'' between January 1, 2002, and October 31, 2022. Through the scientometric analysis, it was possible to identify that Cleaner Production has been little applied in drinking water treatment. The reason for this was a systematic review of the application of Cleaner Production in drinking water treatment. The data and information obtained were filtered following the guidelines of the Preferred Reporting Declaration of elements for systematic reviews and meta-analyses (PRISMA). The PICO method was used to structure the important components of the research questions. The results of this review showed that there is currently little application of Cleaner Production in drinking water systems. This article concludes that Cleaner Production is a strategy that contributes to reducing the environmental impact generated by the different activities of treatment and distribution of drinking water. However, it is necessary to carry out research that promotes the dissemination and knowledge of the different Cleaner Production strategies, as well as highlighting the social, environmental, and economic benefits that their application could generate. Future research should aim at the application of Cleaner Production strategies such as water recycling and Good Housekeeping. Technological progress in purification processes can offer promising results for saving water, energy, waste reduction, and gaseous emissions.

1. Introduction

Cleaner Production (CP) is considered worldwide as a tool to achieve sustainable development (SD) (Kovac Kralj, 2021). The United Nations Industrial Development Organization defines Cleaner Production (CP) as the continuous application of a preventive environmental strategy, integrated into processes, products, and services; to increase overall efficiency and reduce social and environmental risks (UNIDO, 2008). These preventive practices contribute to achieving economic savings and better environmental quality for society, which are fundamentally emphasized in the description of the sustainable development goals (SDGs) (Giannetti et al., 2020).

There are studies that have related CP practices to SDGs, which focused on the efficient use of resources (Adekomaya and Majozi, 2022).

* Corresponding author.
E-mail address: fernando.garcia@ucuenca.edu.ec (F. García-Ávila).

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Regarding Objective 6, which aims to guarantee the availability of water and its sustainable management and sanitation for all, this objective can be achieved through the application of four principles: 1) separate drinking water from wastewater; 2) facilitate access to drinking water and treat it to remove chemical and biological contaminants; 3) protect and restore freshwater ecosystems; and 4) safeguard access to water and the right to use water (Weststrate et al., 2019). Cleaner Production practices could help to achieve SDG 6 (García-Ávila, et al., 2021a). However, the community does not pay enough attention to the application of CP in wastewater treatment (WWT) and in drinking water treatment (DWT) (Leite et al., 2019).

CP can be applied to any process, product or service, and ranges from simple changes in operating procedures that are easy and immediate to execute, to major changes that involve the substitution of raw materials (Adekomaya and Majozi, 2022), inputs or production lines for more efficient ones (Gianneti et al., 2020). The main objective of the CP is "to achieve the reduction of the environmental impacts of the production process, focusing on the improvement of processes and products to avoid environmental problems before they occur. For which, the CP makes use of different strategies or techniques, such as: process improvements, good operating practices, equipment maintenance, reuse and recycling, raw material changes, and technology changes (Nunes et al., 2019).

Currently, there is a strong tendency for the application of CP options by industries (Servere et al., 2017), they use various environmental management tools which guide and optimize the development of processes (Sikander et al., 2021). However, the application of environmental practices in the service sector (water treatment) is still little analyzed, normally few environmental impacts are assumed for not producing palpable products (Oliveira Santos et al., 2020). The CP application serves to provide recommendations that allow for improving the performance of the WWTP, as well as the use of treated water. This has motivated researchers to apply CP as a strategy to minimize the impact of waste and improve environmental quality (Amala et al., 2021); as well as to reduce the costs of construction and operation of the treatment plant (Rahayu et al., 2018).

The reviewed literature has focused on the application of CP in the WWT, there is very little research on the application of CP in the DWT. In the literature review prior to this study, a gap was identified in the research on the application of CP in the DWT, specifically in analyzing and evaluating the different CP strategies in various treatment processes. of drinking water. The reason for this, this study in the first instance carried out a scientometric analysis of the application of the CP in the treatment of wastewater and drinking water. In the scientometric analysis, it was possible to clearly establish that CP is currently mostly applied in the WWT, but not in the DWT. For this reason, a systematic review of the application of CP in the treatment of drinking water was subsequently carried out, due to the little application of CP strategies in the purification process.

This document has the purpose of contributing to the literature on why and how CP programs can be developed in the service sector, based on integrated approaches to CP and water treatment. Drinking water systems are an essential part of the public service, whose purpose is the treatment and distribution of drinking water suitable for human consumption (Alsaeed, 2021). The implementation of CP strategies in drinking water treatment plants (DWTP), as alternatives for improvement and efficient use of water, allows for generating a reduction in its consumption in the treatment processes, without altering the quality of drinking water (Garcia-Avila et al., 2021).

Purification causes certain impacts on the environment, such as the generation of sludge in the decantation and filtration processes (Qrenawi and Rabah, 2021), and waste that must be handled in a special way (Ruj et al., 2021). The residual chlorine in disinfection can produce toxic effects, due to the formation of chlorination by-products caused by the reaction of chlorine with the organic matter present (humic and fulvic acids) (Yang et al., 2021). The purification of water includes the use of technologies with various treatment processes, whose purpose is to remove contaminants from the water until they reach concentrations that do not represent a risk to human health (Sharma and Bhattacharya, 2017). A nonconventional DWTP refers to alternative treatments, either by advanced purification processes or by decentralized or emerging systems. Conventional DWTPs are a set of structures capable of eliminating turbidity, sediments, microorganisms, hardness, odor, color and the necessary parameters depending on the state of the original raw water (Dhar et al., 2020). Environmental phenomena have a strong impact by generating variations in the quality of water from supply sources, it is necessary that the purification processes respond to these changes to maintain quality standards and the production of safe water (Price and Heberling, 2018)

Drinking water treatment plants are made up of a series of processes whose objective is the reduction of contaminants. The high efficiency of these plants depends on the technologies implemented for water purification (Sharma and Bhattacharya, 2017), achieving the total removal of contaminants and ensuring the quality of water for human consumption (Cescon and Jiang, 2020). The synergy of the integrated approach of CP and DWT tries to improve the economic efficiency of the companies in charge of making water drinkable while guaranteeing environmental well-being (more efficient use of natural resources with less waste and pollution) and improving the quality of drinking water.

However, the literature on an integrated approach to clean production and purification is still scarce, this was verified by conducting this research. Although the reviewed literature has focused on improving drinking water treatment technologies and on the search for new alternatives for purification, it also reveals a deficiency in the analysis and evaluation of the different CP strategies in the variety of drinking water treatment processes. Table 1 presents specific cases of PC strategies and techniques that were applied in the treatment of drinking water.

Scientometrics is the study of quantitative aspects of science and seeks to investigate trends and biases in the scientific literature on a given topic (Guo et al., 2022). Through Scientometrics it is possible to know the trend of a certain branch of research, which is extremely relevant for academic society (Torcătoru et al., 2022). In view of the above, the objective of this work was to carry out a scientometric analysis of the application of CP in water treatment and a systematic review of the studies where CP was applied in drinking water treatment plants.

2. Methodology

2.1. *Scientometric analysis of the application of cleaner production in water treatment*

2.1.1. *Data sources and search strategy*

To develop the scientometric analysis, a search was carried out for literature published between 2002 and 2022 in the Scopus database, which has a strict evaluation process, therefore, this database presents relevant and reliable information. The search code was: (TITLE-ABS-KEY (``cleaner production'') AND TITLE-ABS-KEY (``water treatment'' OR ``wastewater treatment'' OR ``Drinking water treatment'' OR ``potable'')), these were searched in the title, abstract and keywords. Subsequently, purification of this literature was carried out, articles that were outside the application of the CP in water treatment were eliminated. For example, Wei et al. (2022) in their study indicate that developing adequate feeding control strategies in aquaculture is one of the most effective ways to promote CP; After reading the abstract, it was possible to show that even though the words ``cleaner production'' and ``water treatment'' were in the abstract, this article is not inherent to the topic under study.

2.1.2. *Treatment of selected articles and data analysis*

Currently, there are tools for scientometric studies that are compatible with the analysis of co-citation of literature, number of citations, main journals, analysis of co-occurrence of keywords, etc. (Bornman

Table 1
Strategies and measures of CP in drinking water treatment plants.

Title	Identified problem	Measure implemented	CP strategy used	Results	Authors
Cleaner agricultural production in drinking-water source areas for the control of non-point source pollution in China	Application of chemical fertilizers and pesticides near areas of drinking water sources.	formula fertilization through soil testing, integrated pest management, and water-saving irrigation technology	Better Process Control good operating practices	Through reasonable fertilization formula, N loss could be reduced by 714 ± 151 kg	Wang et al. (2021)
Experimental evaluation of sorptive removal of fluoride from drinking water using natural and brewery waste diatomite.	It is widely recognized throughout the world that the excessive presence of fluoride in drinking water supplies constitutes a public health problem.	Use of waste products from the brewing industry, to remove fluoride from drinking water. Brewery waste diatomite was used in a batch adsorption system.	Reuse of the wasted	Fluoride removal by 65% Safe management of industrial waste, at the same time provided a resource for water treatment.	Yitbarek et al. (2019)
Opportunities for improvement in a potabilization plant based on cleaner production: Experimental and theoretical investigations.	Inefficiencies in the use of raw material (raw water), inputs (coagulant)	Recirculation of water from the filters to the settlers. Substitution of aluminum sulfate coagulant by aluminum polychloride	Good housekeeping	Reduction in water consumption economic savings	Garcia-Avila et al. (2021a)
The role of water reuse in the circular economy	Reduce the global burden of disease and improve the health, education and economic productivity of populations	Application of various advanced treatment technologies for water supply	Good housekeeping	Water reuse closes the loop between water supply and sanitation and provides an alternative water source	Giakoumis et al. (2020)
Low-cost recycled end-of-life reverse osmosis membranes for water treatment at the point-of-use	Production of spent membrane waste from reverse osmosis systems	Recycling of reverse osmosis modules as an alternative for the treatment of groundwater for domestic use.	Recycling	Energy savings by recycling domestic reverse osmosis module. Decrease in the production of waste from used membranes	Moreira et al. (2022)
Enhancing the Assessment of Cleaner Production Practices for Sustainable Development: The Five-Sector Sustainability Model Applied to Water and Wastewater Treatment Companies	Need to improve the evaluation of cleaner production practices in this sector, in order to promote sustainable development and reduce the environmental impact of these companies.	The implementation of a sustainability model managed to quantify the levels of sustainability and served to classify the procedures and improvements in 20 water treatment plants.	Good housekeeping	Water savings, better distribution efficiencies, investments to reduce greenhouse gas emissions, and an increase in the quantity and quality of jobs	Giannetti et al. (2022)
Resilience to evolving drinking water contamination risks: a human error prevention perspective	Threats to public health, due to exposure to the presence of contaminants in water.	The application of Good Operating Practices, which included the optimization of operating and administrative procedures, made it possible to eliminate or at least reduce risks and incidents of drinking water contamination.	Good housekeeping, process reengineering	Resilience for the supply of clean drinking water. Avoid threats to public health, protection against exposure to pollutants.	Tang et al. (2013)

et al., 2018). One of these tools is VOSviewer, which allows quantitative analysis (Xue et al., 2021). In this study, VOSviewer was used as a visual tool, which made it possible to intuitively understand the state of the research through maps based on bibliographic data obtained from documents retrieved from Scopus (Van Eck and Waltman, 2010). Using VOSviewer, association networks were built that included journals, keywords, authors, citations, which allowed us to analyze the research frontiers, research critical points, gaps in this field of research, etc. (Guo et al., 2019)

2.2. Systematic review of the application of cleaner production in drinking water treatment

2.2.1. Protocol and focus questions

The research question of the study was framed based on PICO (Tobi et al., 2019) and guided by the PRISMA model (Garcia-Peñalvo, 2022). PICO format questions are often used in systematic review papers, this strategy can be used to build various types of research questions. The formulation of questions with the PICO strategy serves to improve the specificity and conceptual clarity of the problem to be investigated, as well as to carry out searches that yield results with higher quality and precision. Likewise, it allows for maximizing the location of relevant information, focusing the search objectives and rejecting unnecessary information, which will help to make the best evidence-based decisions.

The PICO method is an aid to structure the research questions in a systematic review through important components, identify and convert the problem into a structure based on Population (Problem), Intervention, Comparison and Outcome (Petticrew, and Roberts, 2005). The Population/Problem refers to ¿What is the problem to address?, this element should be thought of as a dependent variable. The intervention refers to ¿What action or change would affect the /problem/-population?, this element should be thought of as the independent variable. The comparison refers to ¿What is the alternative to the intervention?, ¿Is there a different intervention?, this item should be thought of as a 'control group'. Outcome refers to ¿What are the relevant results?, this element should be thought of as what is measured to show what the intervention has achieved or failed to solve the problem. The PICO strategy was applied and presented according to Table 2.

Based on the PICO strategy, the following questions were

Table 2
Description of the components of the PICO system.

Population	Drinking Water Treatment Plants: With the demand for water increasing day by day, drinking water treatment plants are designed to provide clean and safe water.
Intervention	Cleaner production: It is a preventive environmental protection initiative that can be applied to production processes, products or services for the control of environmental pollution.
Comparison	Strategies, techniques or opportunities for cleaner production: Process improvements, Good Housekeeping, Equipment maintenance, Reuse and recycling, Changes in inputs, Changes in technology.
Outcomes	Application of CP in DWT: The application of CP techniques to purification processes involves the reduction of raw materials and energy, the elimination of toxic raw materials, as well as the reduction of the quantity and toxicity of all emissions and wastes before their deletion.

formulated:

Q1. ¿Is there integration between cleaner production and drinking water treatment?
Q2. ¿What are the cleaner production opportunities applied in drinking water treatment?
Q3. ¿In what purification processes has cleaner production been applied?

To answer the questions formulated previously, a systematic review was applied, which was developed following the guidelines of the ``PRISMA 2020 Declaration: an updated guide for the publication of systematic reviews'' (Page et al., 2020), which has a methodology of diagrams for item selection (Garcia-Peñalvo, 2022; Petticrew and Roberts, 2005).

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement, published in 2009, was designed to help systematic reviewers transparently report why the review was done, what the authors did, and what they found (Page et al., 2021).

2.2.2. Data sources and research strategy

The articles were retrieved from the SCOPUS database and limited to the period (2002–2022). For this case, keywords such as ``cleaner production'' and ``drinking water treatment'' or ``drinking water'' or ``potable'' were used, these were searched in the title, abstract and keywords. The retrieved articles were saved in a database data in csv format for further analysis Articles published in English only were included in the search.

2.2.2.1. Inclusion and exclusion criteria. The articles were retrieved from the SCOPUS database and limited to the period (2002–2022). For this case, keywords such as ``cleaner production'' and ``drinking water treatment'' or ``drinking water'' or ``potable'' were used, these were searched in the title, abstract and keywords. The retrieved articles were saved in a database data in csv format for further analysis Articles published in English only were included in the search.

2.2.2.2. Treatment of selected articles and data analysis. The selected information was analyzed and organized in tables that included: the author, the objective of the article, the CP strategy implemented, and type of drinking water system where the CP was implemented, purification process where the CP strategy was implemented. The data collected in the table were useful to compare the results according to the contributions of different authors and thus answer the research questions (Nurbaiti et al., 2021).

3. Results and discussion

3.1. Scientometric analysis of the application of cleaner production in water treatment

3.1.1. Publication trend

Using the aforementioned search code, a total of 305 documents on CP and wastewater and drinking water treatment were found, most of which included research papers. After filtering the year of publication between 2002 and September 2022, the initial search was reduced to 278 documents.

In Fig. 1 you can see the distribution of the number of articles that investigated the application of CP in water treatment. The blue bar indicates the number of articles that applied CP to the WWT. Meanwhile, the red bar indicates the number of articles that applied CP to the DWT. It is evident that in these 20 years CP has been more applied in the WWT, evidencing a research gap on the application of CP in the DWT.

A gradual increase was observed in the number of publications that applied CP in the WWT, increasing from 3 articles in 2002 to 42 articles in 2021, in 2022 there was a decrease to 30 articles. Meanwhile, the number of articles that applied CP in the DWT has been irregular in these 20 years; In 2003 an article was published in this field, the maximum number of articles published was in 2014 and 2022 with 4 articles, there is no growing trend in these last two decades.

3.1.2. Journal analysis

The studies were published in 129 journals (Fig. 2). In 123 of them, only one article was published. The largest number of articles ($n = 100$) were published in the journal of cleaner production, eleven in the water science and technology journal, six in environmental science and pollution research. The first journal produced 35.6% of the papers published during the study period.

The main focus of these journals is the environment. Journal of cleaner production had the most citations with 3312, followed by water science and technology journal (124 citations), environmental science and pollution research (59 citations). Regarding the impact of the source, the h-index, developed by Hirsch (2005), was commonly used to describe the importance of journals (Halbach, 2011). The journal with the highest h-index, the Journal of Cleaner Production, had a score of 232. It was followed by Water Science and Technology (h-index = 145),

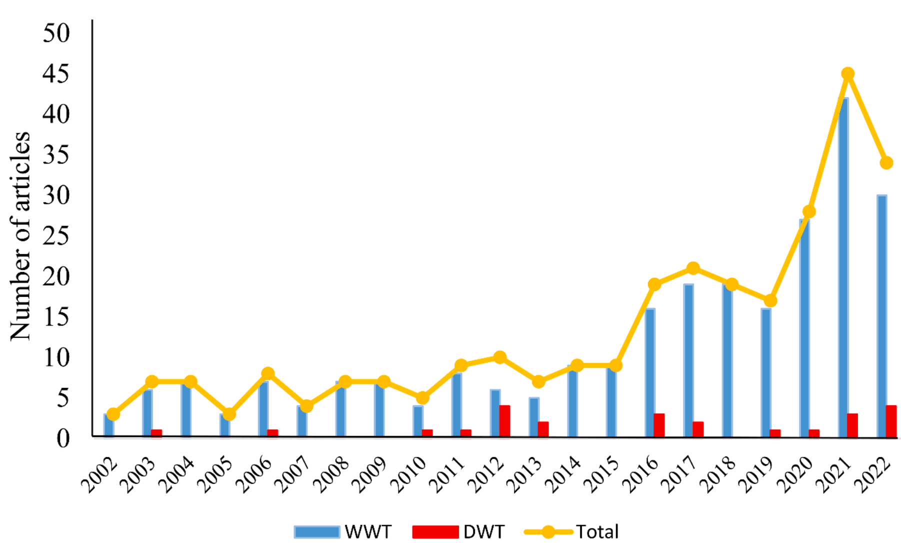

Fig. 1. Distribution of the number of articles that investigated CP in water treatment in relation to the year of publication. Blue bar: CP applied to wastewater treatment; Red bar: CP applied to drinking water treatment. Yellow line: CP applied to wastewater and drinking water treatment.

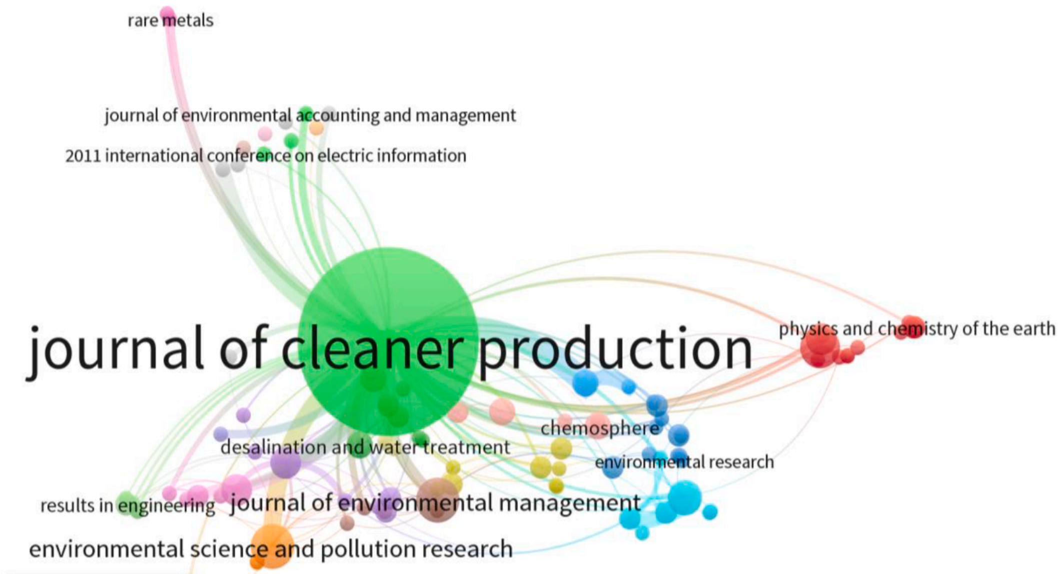

Fig. 2. Visualization of the magazine network (VOSviewer). Network of the main journals in the field of the application of CP in the treatment of residual waters.

Environmental Science and Pollution Research (h-index = 132). Over the years, the Journal of cleaner production, Water science and technology and environmental science and pollution research has been active in this area of research. The size of the circle represents the number of papers published by the journal. The larger the size of the circle, the greater the number of papers published by the journal.

3.1.3. *Analysis of concurrent keywords*

Regarding the most recurring words in the title, keywords or abstract, a total of 927 words were identified that were used as keywords in the 278 documents. Within the most recurring words, 14 words were identified that were recurring in at least 5 articles (Fig. 3). These words were cleaner production with 75 occurrences, wastewater treatment with 25 occurrences, wastewater with 21 occurrences.

After that, VOSviewer divided the co-occurrence network into several color groups via its grouping function. The more relevant the keywords are, the more likely they are to be grouped together. As seen in the visual network map (Fig. 3), all these keywords were classified into five groups. The size of the circle represents the occurrence of the keywords. The larger the circle, the more times the keyword has appeared in publications in this field of research. The keywords cleaner production and wastewater treatment exhibit the strongest link. The relative strength and similarity between the topics are exhibited by the distance between the two keywords. Circles of the same color show the similarity of topics between different published articles. The co-keyword network clearly illustrates five distinct groups. Each group represents a subfield of a CP field in water treatment. Even though the words ``drinking water treatment'' and ``drinking water'' were used in the search for articles, in Fig. 3 drinking water does not appear as a keyword. Therefore, as mentioned above, there is no current application of CP in the DWT once again demonstrating that there is a gap in this field of research.

3.1.4. *Co-authorship analysis*

3.1.4.1. Countries. With the bibliographic data retrieved from Scopus, the visualization map of the co-authored network of the countries was

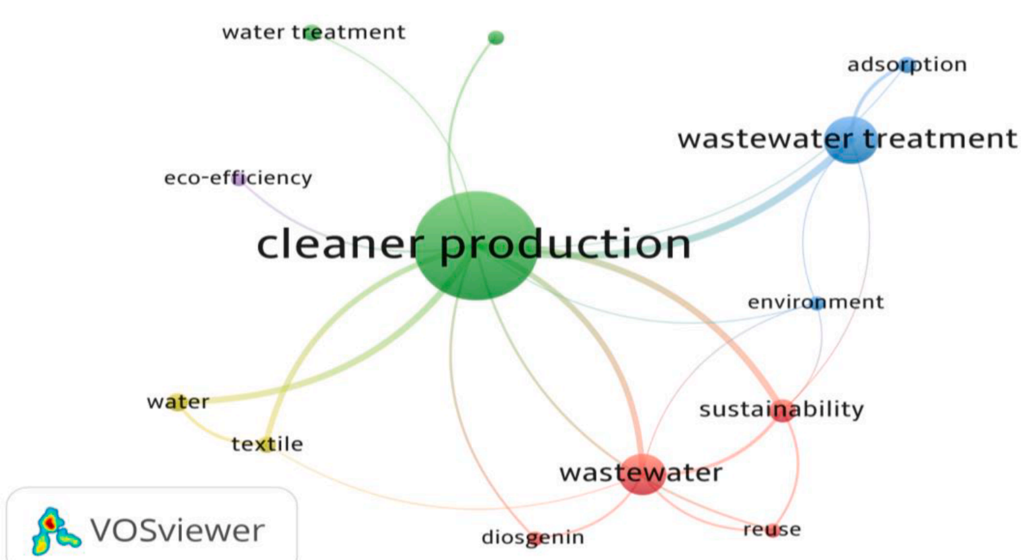

Fig. 3. Network of the most recurring words in the field of application of the CP in wastewater treatment. The words cleaner production, wastewater treatment and wastewater were the most used; textile, diosgenin, and reuse were the least used.

created with VOSviewer. The review by countries showed that research in this field was distributed in 61 nations, with the largest number for China with 91 articles, followed by 19 for India, 19 for United States (46.40% of these three countries together), as well as 18 articles for Australia and 21 for Brazil (Fig. 4).

The size of the circles represents the number of documents, the larger the circle, the more documents a country has published in this field. By using five different colors, five clusters of cross-country links on CP research in water treatment could be distinguished. For example, China, the United States, Canada, and Chile co-authored many articles; while Australia, Poland, Iran and Thailand were deeply involved in cooperation with CP's research on water treatment. The third team in red brings together countries like Brazil, Spain, France, Finland, etc. India maintains extensive cooperation in this field of research with other countries like Germany, Italy, Ireland.

3.1.4.2. Authors. The VOSviewer co-authoring visualization functions module was applied to analyze the cooperation pattern of the authors, who published on the application of CP in water treatment. Regarding the authors who wrote the most about the application of CP in water treatment, of the 1005 authors, 8 authors published more than 5 articles (Fig. 5). The authors who published the most are Wang Y. ($n = 10$), Zhang Y. ($n = 9$), Liu Y. ($n = 8$), Zhang C. ($n = 8$), Li X. ($n = 7$).

It was found that 16.21% of the authors ($n = 163/1005$) were accredited in two publications on the subject of CP and water treatment, 4.77% ($n = 48/1005$) were accredited in at least three publications, 1.99% ($n = 20/1005$) were credited in four publications, and 0.79% ($n = 8/1005$) were credited in five publications. It was observed that some of the 1005 authors were not connected with the other authors in the network. The lines between the authors represent their cooperative links, while the eight different colors seen in Fig. 5 represent the collaborative group of the authors. The size of the circles represents the average publication by one author; thus, the larger size that some authors have indicates that these authors have a greater number of publications in this field of research, the smaller circles show fewer documents produced by authors.

3.1.4.3. Institutions. Collaboration between institutions is necessary to disseminate and create knowledge according to (Cardoso et al., 2020). Collaborations between academic organizations are concerted scientific efforts that help solve impossible global problems (Ding et al., 2000). A total of 619 organizations participated in the publication of the 278 articles. Regarding the number of documents by institutions, it was identified that five organizations had the highest number of publications (3 documents) in this field, these organizations are presented in Table 3. The organization that had the most citations in this period was the Department of polytechnic education and community college, ministry of higher education, Putrajaya, Malaysia with 66 citations.

Organizations from Asian countries, except for China and African institutions, did not appear among the main organizations investigating CP in water treatment. This trend suggests the need for developing countries to mobilize their own limited resources to carry out research through their own initiatives or seek links with institutions in developed countries.

3.1.5. Publications with the greatest impact

The publications with the greatest impact are presented in Fig. 6, where the investigations with the greatest impact can be observed. In this regard, articles with a minimum number of 100 citations were considered, with 14 documents out of the 278 that fulfilled this purpose. The top five papers with the most citations are presented in Table 4. The paper entitled ``Green synthesized iron nanoparticles by green tea and eucalyptus leave extracts used for removal of nitrate in aqueous solution'' has to date 307 citations, it was developed by Wang et al. (2014) and was published by the Journal of Cleaner Production.

3.1.6. Discussion and limitations of the research

Using the previous results of the scientometric analysis, it was possible to extract many new findings in this field, the same ones that cannot be determined by other types of reviews, but which are very useful to analyze the information in a more objective way (Chen and Song, 2019). Thus, it can be revealed how research in the field of CP has played a role in the efficiency of water treatment. The CP should be a priority to help companies in charge of water treatment to analyze and measure the efficient and sustainable use of resources (Barón et al., 2020). Most water treatment plants aim to reduce emissions by optimizing the use of chemicals and treatment processes (Torcătoru et al., 2022).

This study provides timely and valuable information on the application of CP in water treatment and allows researchers to better analyze current research progress in this field, highlighting potential future research and collaborations.

It must be emphasized that the results of scientific research cannot be included and analyzed in a scientometric investigation, which is why it has not been possible to easily explore it in this investigation. Thus, in practice, the factors that most influence the wastewater treatment process are undoubtedly its composition, considering that the water treatment process consists of a succession of physical, chemical and/or biological processes that eliminate contaminants (Thomas et al., 2020). Being difficult to make a further analysis, because the authors have signed a confidentiality agreement regarding the data, or they cannot be published for other reasons.

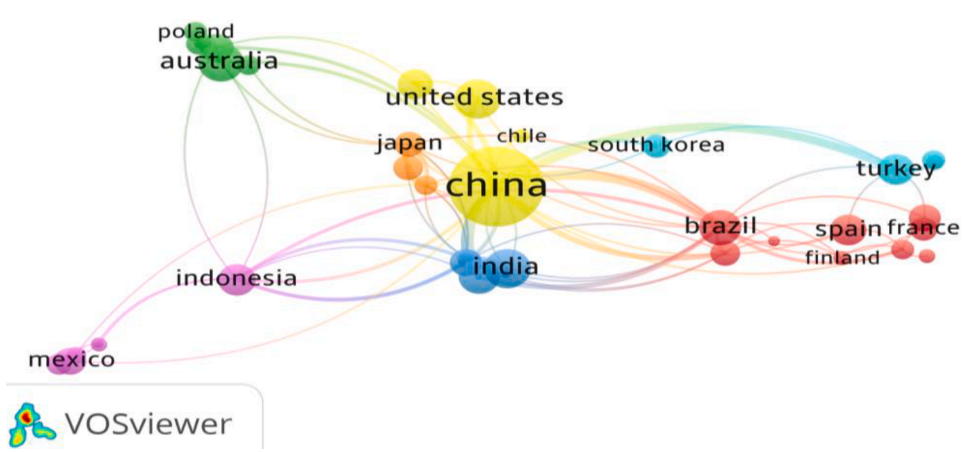

Fig. 4. Visualization of the network of countries (VOSviewer). Network of countries with more publications in the field of application of the CP in wastewater treatment. China is the country that has published the most in this field.

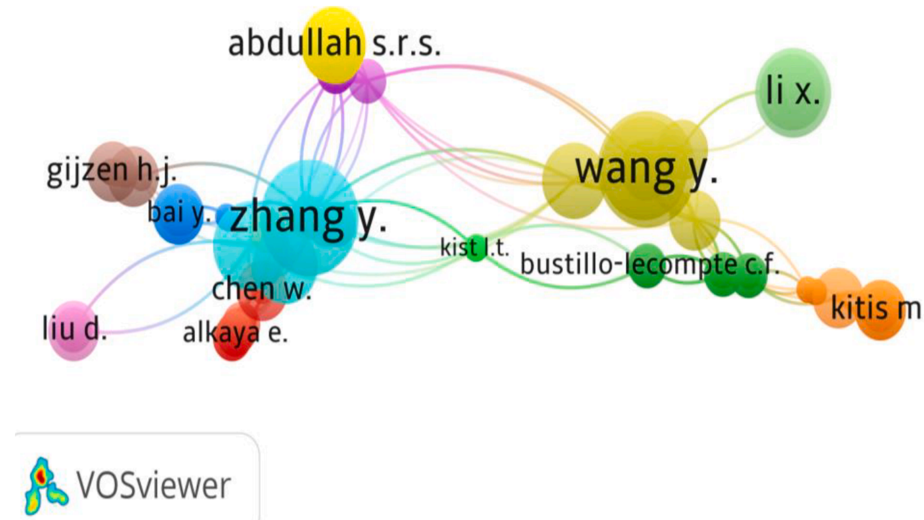

Fig. 5. Network of authors with more publications in the field of the application of the CP in wastewater treatment. Wang and Zhang had more publications in this field of research.

Table 3
Institutions with more publications in the field of application of the CP in wastewater treatment.

Organization	Documents	Citations
Department of polytechnic education and community college, ministry of higher education, Putrajaya, Malaysia	3	66
Laboratory of industrial biotechnology, ministry of education, school of biotechnology, Jiangnan University, China	3	45
Co-innovation center of green building, Jinan, China	3	31
School of municipal and environmental engineering, Shandong Jian zhu University, Jinan, China	3	31
School of minerals processing and bioengineering, central south university, Changsha, China	3	16

Being this study the only scientometric analysis on the application of CP in water treatment to our knowledge, the main journals, countries, institutions and authors involved in related research were identified along with the trend in the growth of publications in this field.

This scientometric analysis established trends and gaps in this field of research. Regarding the trends, it was possible to identify that the application of the CP in the WWT is growing, because the researchers consider it essential to invest efficiently in wastewater and other sanitation infrastructures, which will allow to achieve benefits for public health, improve the environment and the quality of life of the population. This has allowed us to determine that research has focused so far on the field of CP related to WWT. Meanwhile, investigations of the application of the CP in the DWT have been scarce, since of the 278 articles recovered that relate the CP to water treatment, only 27 articles are related to the treatment of drinking water, so there is a gap in this field. For this reason, a systematic analysis of the application of the CP in

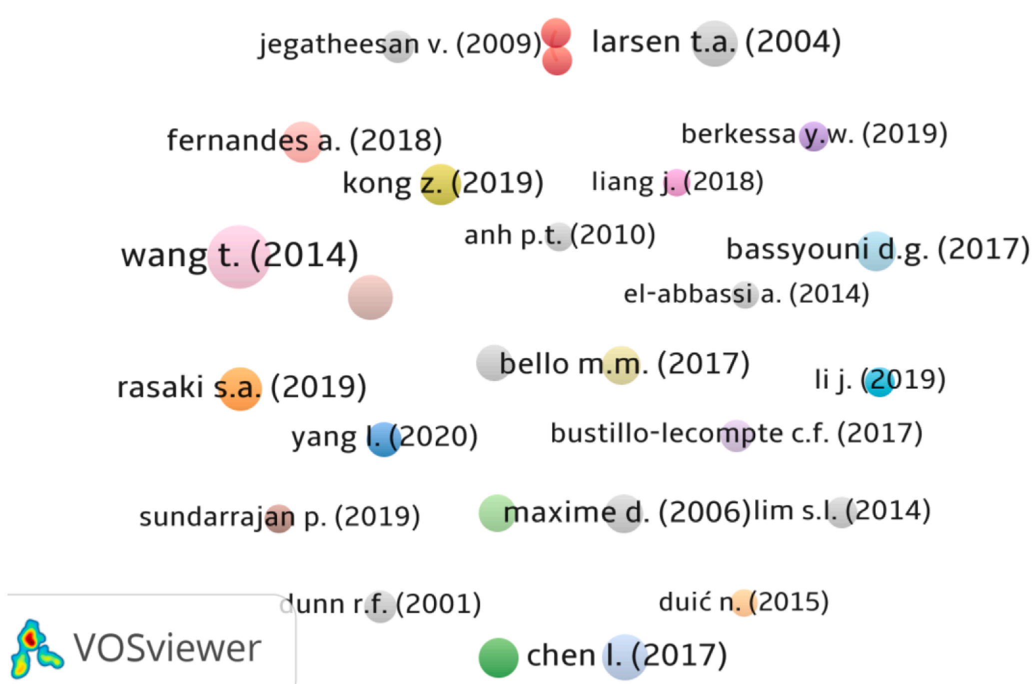

Fig. 6. Network of authors of the most cited publications in the field of CP application in wastewater treatment.

Table 4
The five most cited articles in the field of CP application in wastewater treatment.

Author	Title of the publication	Number of citations
Wang et al. (2014)	Green synthesized iron nanoparticles by green tea and eucalyptus leaves extracts used for the removal of nitrate in an aqueous solution	316
Larsen et al. (2004)	How to avoid pharmaceuticals in the aquatic environment	162
Chen et al. (2017)	Environmental-friendly montmorillonite-biochar composites: Facile production and tunable adsorption-release of ammonium and phosphate	154
Ahmed et al. (2019)	Production of biogas and performance evaluation of existing treatment processes in palm oil mill effluent (POME)	151
Rasaki et al. (2018)	Geopolymer for use in heavy metals adsorption, and advanced oxidative processes: A critical review	141

the treatment of drinking water was carried out below.

Limitations of the scientometric analysis

One of the limitations of this study could be the words used to retrieve the articles on this topic, which could be subject to bias. Another limitation is the exclusive use of articles from the Scopus database, therefore, future studies should focus on expanding the search to other databases such as WoS.

3.2. Systematic review of the application of cleaner production in drinking water treatment

3.2.1. Search results

A search of scientific literature was carried out in the SCOPUS database, with the following keywords: ``cleaner production'', ``drinking water'', ``potable water''. The keywords were searched in the title, abstract and keywords of the article.

For the initial identification of articles, the search string: (TITLE-ABS-KEY (``Cleaner Production'') AND TITLE-ABS-KEY (``drinking water treatment'') OR TITLE-ABS-KEY (``drinking water'') OR TITLE-ABS-KEY (``potable'')). In this first search, 27 articles were obtained.

Subsequently, the publications were filtered, considering articles from the years 2002 to 2022, written in English, with the following search criteria in Scopus: (TITLE-ABS-KEY (``Cleaner Production'') AND TITLE-ABS-KEY (``drinking water treatment'') OR TITLE-ABS-KEY (``drinking water'') OR TITLE-ABS-KEY (``potable'')) AND PUBYEAR > 2002 AND PUBYEAR < 2022 AND (LIMIT-TO (DOCTYPE, ``ar'')) AND (LIMIT-TO (LANGUAGE, ``English'')). With this new search, eighteen articles were obtained.

The PRISMA model (Fig. 7) was used for the identification, filtering and inclusion of articles (Thomas et al., 2020). The final product of the search produced a database of eighteen articles, six articles that did not correspond to the objective of the systematic review were discarded and twelve articles remained. Of the twelve articles, four were eliminated after reading the abstract, because they did not meet the criteria established in the questions. Subsequently, of the eight studies chosen, three articles were eliminated after the complete reading because they were not related to the objectives of this work, resulting in five articles for the systematic review.

Most of the articles were excluded because they were not related to ``cleaner production'' and because they were not related to the term ``drinking water treatment''. In many articles, an adequate description of the CP strategies that were implemented in a drinking water treatment system was lacking. For example, the abstract indicated the application of CP, but the methodology did not establish the CP strategy applied, nor was the application of CP in the potabilization processes indicated. The results also did not provide precise information on the saving of raw materials, water and energy, it was not indicated if there was an elimination of toxic raw materials, a reduction of toxicity of waste and emissions, among other aspects.

Finally, only five articles were analyzed, clearly noting how the

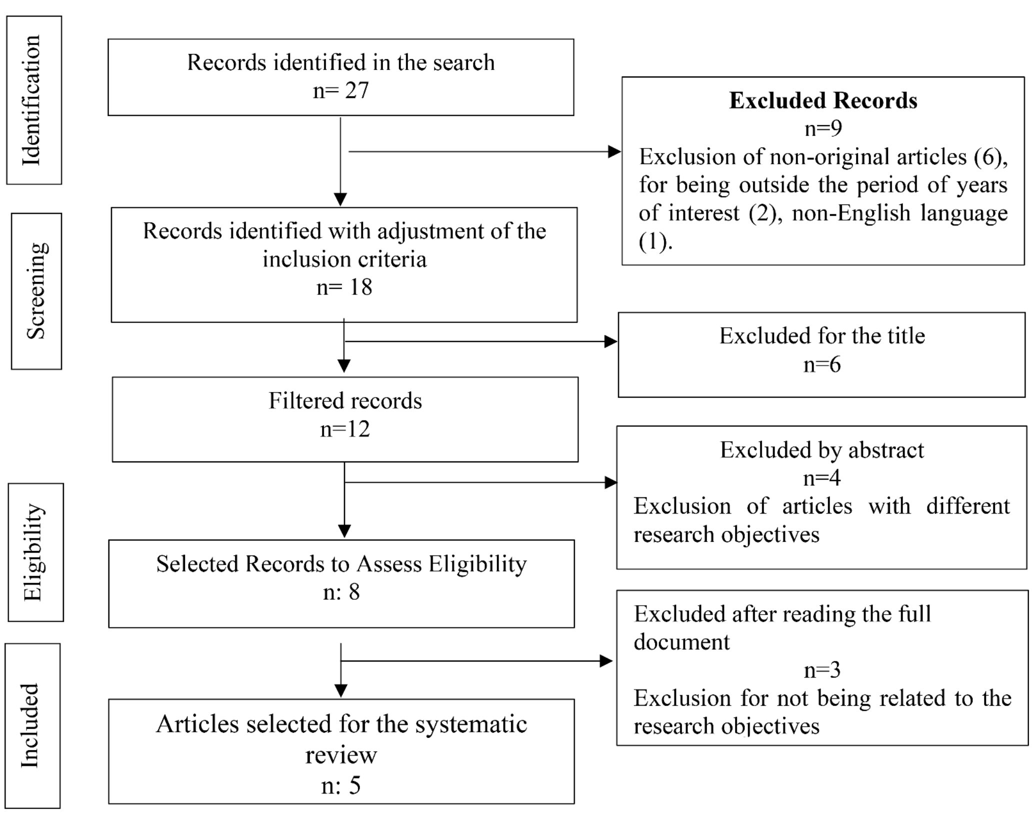

Fig. 7. Selection of relevant articles for the systematic review on the integration of CP in drinking water treatment.

number of articles initially identified was low, indicating that there is currently no integration of CP strategies in drinking water systems. Despite the fact that water (raw material) is used in purification, energy for the different processes, chemical inputs necessary for the treatment, no CP studies have been carried out that save water, energy and inputs, as well as reduction of waste and greenhouse gasses.

3.2.2. Q1. Is there an integration between cleaner production and drinking water treatment?

Currently, it is not only necessary to implement environmental programs, but also to involve concepts of quality, competitiveness and saving of raw materials, to environmental management. This is how the development of CP tools begins, aimed at promoting the development of programs and projects in a more efficient and economically viable way (Hens et al., 2017). For the specific case of service provider institutions, such as drinking water service providers, these companies aim to supply drinking water using resources efficiently and avoiding generating a large volume of waste, reducing water consumption and energy, ensuring the quality of drinking water. This goal can only be achieved with clear objectives, well-applied tools, and a concrete understanding of the processes within the treatment plants (Alsaeed, 2021).

According to the reviewed documents, the CP involves the application of knowledge, the improvement of technologies and, above all, the change of attitudes in many processes of a drinking water treatment plant. In addition to achieving a lower level of pollution and environmental risks. CP is a good proposal to reduce the costs of producing drinking water (Nunes et al., 2019). More efficient use of water and energy and optimization of processes in a treatment plant result in less waste and lower operating costs (Giannetti et al., 2022). This leads to increased productivity, with less water and energy loss, due to good operating practices.

According to the different CP alternatives, it is necessary to integrate the improvement options into the different existing processes in a purification system. However, the low number of documents in which the CP is clearly integrated into the DWTP, indicates that there is still a lack of studies in this field. Table 5 shows the main objective of each of the five selected articles, highlighting the application of preventive and integrated strategies to the processes of purification and distribution of drinking water; this allows for increasing global efficiency and reducing the risks for the human being and the environment.

The evidence demonstrates the need to know the scope of the CP, its implementation allows the saving of water, materials and energy, becoming a strategy for the fulfillment of national and international commitments, related to sustainable development objectives (SDG), especially on clean water and sanitation (SDG: 6); and on Responsible Consumption and Production (SDG:12).

3.2.3. Q2. What are the cleaner production opportunities applied to drinking water treatment?

Table 6 shows of the five articles reviewed, the Good housekeeping (GHK) approach, as the most used opportunity. This is a strategy related to a series of measures to prevent the inefficient use and loss of raw materials; minimization of unspecified products; water conservation; energy savings, accident prevention and improvement of the company's operational and organizational procedures of goods or services. The GHK is associated with changes in procedural, administrative and institutional actions; with the purpose of preventing the generation of waste, improving organizational and labor safety, preventing the loss of materials and resources, improving production programs, among others. The implementation of the GHK is relatively easy and can be achieved at low cost, even without investment cost.

Another CP opportunity that was applied according to the selected items is recycling, which aims to convert waste into new products or raw material for later use. Recycling is an eco-friendly practice that consists of subjecting a waste or unusable thing to a transformation process, in order to use it as a resource that allows it to be reintroduced into the life cycle; without having to resort to the use of new natural resources.

Table 5
The main objective of each of the documents reviewed.

Author	The purpose of the study
Moreira et al. (2022)	Energy savings through the recycling of reverse osmosis modules as an alternative for the treatment of groundwater for domestic use. The advantages of using recycled membranes could extend towards environmental aspects, preventing the production of waste from spent membranes and focusing on CP of technical processes.
Giannetti et al. (2022)	Through a sustainability model, it was possible to quantify the levels of sustainability, which served to classify the procedures and establish reference points for improvements in 20 water treatment plants. CP practices were related to water savings, better distribution efficiencies, investments to reduce greenhouse gas emissions, and an increase in the quantity and quality of jobs.
García-Avila et al. (2021a)	The processes of a treatment plant were evaluated to identify CP opportunities. The causes of the inefficiencies in the use of raw material (raw water), supplies (coagulant) and the causes of the generation of liquid effluents were identified and finally the CP options were considered. The CP options identified were good cleaning, substitution of inputs (coagulants), recycling of water from the filters.
Chang et al. (2013)	To achieve the objective of the CP, the placement of sensors in municipal drinking water networks in response to possible threats to public health becomes one of the most important challenges currently facing drinking water companies, especially in communities small scale. The implementation of sensors made it possible to guarantee that the concentration of microorganisms, disinfection by-products, disinfectants, inorganic chemical products, organic chemical products and/or radionuclides is below the permissible limits; except for residual chlorine concentration, which must meet the minimum concentration requirement of 0.2 mg/L but not exceed 4 mg/L, regulated by the EPA.
Tang et al. (2013)	Drinking water contamination risks and incidents were managed through prevention, reduction and mitigation. Measures were identified to prevent human error causing related incidents throughout the drinking water life cycle. Human error is a major contributing factor in amplifying the risk of drinking water-related incidents. Therefore, the Good Operational Practices that include the optimization of the operational and administrative procedures allow to reduce or eliminate the possible causes of drinking water incidents based on the established parameters.

Table 6
Main objective of each one of the reviewed documents.

Author	CP strategy used	Drinking water system
Moreira et al. (2022)	Recycling	decentralized plant
Giannetti et al. (2022)	Good housekeeping, use of indicators	Centralized plant (conventional plant)
Garcia-Avila et al. (2021a)	Good housekeeping, change of supplies	Centralized plant (conventional plant)
Chang et al. (2013)	Technology implementation (sensor placement)	Distribution network
Tang et al. (2013)	Good housekeeping, process reengineering	Plant and distribution network

Moreira et al. (2022) investigated the recycling of end-of-life domestic reverse osmosis modules as an alternative for point-of-use groundwater treatment. The systems operated without external energy requirements for permeation, only the hydraulic force provided by the water network was used. The system was effectively converted to ultrafiltration. A safe drinking water supply will be obtained through a technology accessible to different socioeconomic realities.

Giannetti et al. (2022) specifies the application of the SUSTAINABILITY OF THE FIVE SECTORS (5SEnSU) model to water treatment companies, this model refers to a holistic framework that can show the relationships between the human being and the natural environment.

For this purpose, environmental indicators, economic indicators and social indicators were used in 20 treatment plants in Brazil. The application of the 5SEnSU model made it possible to classify the plants according to their levels of sustainability, as well as to highlight the sectors where improvements are essential to achieve management strategies that are more aligned with the SDGs. It was possible to identify the water treatment companies that adopted the best available practices for their operations, which left closer relationships with the environment, society and economic capital. Specifically, CP practices were related to water savings, better efficiencies in water distribution, investments to reduce greenhouse gas emissions, and an increase in the quantity and quality of jobs.

Garcia-Avila et al. (2021) used the methodology recommended by UNIDO to identify CP opportunities in a DWTP. Good housekeeping was applied, which allowed saving water (29,400 m^3/year) by reducing the number of filter washings, without any investment. CP's second opportunity achieved water savings (23,256 m^3/year) by recirculating the water from the filters to the decanters. The investment was small and the payback period was 2.4 months. The third option of CP was based on the change of coagulant, which allowed an annual economic saving of 5361.12 USD, with an immediate recovery period, at the same time this CP strategy allowed to reduce the production of sludge.

Chang et al. (2013) developed a rule-based decision support system (RBDSS) as a methodology to generate sensor implementation strategies in municipal drinking water networks in response to possible threats to public health. The CP strategy identified in this study was the implementation of technology in the distribution network, which detected the migration of contaminants such as microorganisms, disinfection by-products, disinfectants, inorganic chemical products, organic chemical products and/or radionuclides, as well as monitoring the residual color, verifying it within the corresponding standards. The profitability of this CP strategy implied the protection of the health of the population that consumes drinking water.

Tang et al. (2013) considers CP from the perspective of preventing human errors. The author identified four types of human error: unsafe acts, design errors, maintenance errors, and poor operating skills. These errors are mainly related to the behavior of operators and administrators. The identification of human errors made it possible to establish resilience-oriented management mechanisms for the supply of cleaner drinking water; and it is essential to guarantee the successful practice of managing the risks of contamination of drinking water. Consequently, it was proposed to develop Good Housekeeping for risk management for drinking water companies.

3.2.4. Q3. What purification processes apply cleaner production?

The operational objective of the purification process is to produce drinking water in adequate quantity and quality for human consumption, following the established goals. The importance of this process lies in the fact that water acts as a health barrier: it guarantees, on the one hand, that it will not be a vehicle for disease and, on the other, that its use for personal, household or food intake and hygiene helps prevent them (Valdiviezo Gonzales et al., 2021). A so-called conventional treatment integrates a pretreatment, coagulation, flocculation, sedimentation, filtration and disinfection (Parvini et al., 2015). There are more advanced water purification techniques such as reverse osmosis, ion exchange, advanced oxidation. Advanced treatments make it possible to reduce the organic load, presence of metals and pathogens in the water. In the different purification processes, energy and chemical inputs are used.

Meanwhile, for the maintenance of the different treatment units, water and energy are used. It should be noted that the processes and maintenance of the purification process oversee human personnel.

Due to the aforementioned, the implementation of the different CP opportunities in the different purification processes would allow savings in water, energy, and chemical inputs; which could be achieved by implementing good operating practices, process improvements; equipment maintenance; reuse and recycling; changes in the raw material; technology changes. In the documents reviewed, it can be highlighted that the main purification processes where CP techniques were implemented were mainly: coagulation and filtration, which allowed water savings and reduction of greenhouse gas emissions. CP options were also implemented in the distribution network, which was able to ensure the quality of drinking water (Table 7).

According to the literature review, it was observed that the organizational culture is essential to achieve the objective of the implementation of CP. To the extent that the directors or administrators of the drinking water companies adopt a CP, a full awareness of the environmental aspects and impacts involved in the processes and services provided will be developed.

Therefore, it is important to identify CP opportunities to reduce costs and favor the responsible and sustainable growth of the companies that provide this service. Implementing CP strategies in a water treatment plant implies innovating. A process requires an attitudinal change of managers and workers, which will result in efficient and sustainable performance with respect to water resources.

The ability to adapt CP practices also depends on continued knowledge in managing the demand and supply of materials and resources in the supply chain.

3.3. *Environmental and economic benefits of cleaner production in drinking water treatment*

The cleaner production is applied in various drinking water treatment processes, such as filtration, disinfection and the removal of organic and inorganic substances (Maama et al., 2021). Some cleaner production practices include the use of more efficient technologies, the reduction of the use of chemical products, the optimization of the use of resources, the prevention of pollution and the use of renewable energy (Giannetti et al., 2022)

Some studies have shown that cleaner production in drinking water treatment can reduce the emission of greenhouse gasses and other pollutants, such as chlorine and ozone, which can be harmful to human health and the environment (Zib et al., 2021)

Reducing chemical and energy use can lower greenhouse gas emissions and costs associated with producing and treating drinking water (García-Ávila et al., 2021b). In addition, reusing sludge from drinking water treatment can reduce the amount of waste generated and therefore lower waste disposal costs (Nguyen et al., 2022).

The application of cleaner production can reduce the carbon footprint and water footprint associated with the drinking water treatment

Table 7
Processes of drinking water with CP application.

Reference	Processes of drinking water	CP Objectives
Moreira et al. (2022)	Inverse osmosis	Energy savings by recycling domestic reverse osmosis modules
Giannetti et al. (2022)	Coagulation, flocculation, decantation, filtration, disinfection and distribution	Water savings, better distribution efficiencies, investments to reduce greenhouse gas emissions, and an increase in the quantity and quality of jobs
Garcia-Avila et al. (2021a)	Coagulation, filtration	Reduction in water consumption, greenhouse gas emissions
Chang et al. (2013)	Chlorination and distribution of water	Avoid threats to public health, protection against exposure to pollutants
Tang et al. (2013)	Coagulation, filtration, chlorination and distribution	Resilience for the supply of clean drinking water. Avoid threats to public health, protection against exposure to pollutants.

(Qi, and Chang, 2012). In addition, these authors highlight that cleaner production in drinking water treatment can improve the efficiency of the processes and, therefore, reduce production costs.

In drinking water treatment, cleaner production implies the use of techniques and technologies that minimize the generation of waste and emissions, reduce energy and water consumption, and optimize the use of natural resources (Capocelli et al., 2019). These practices not only benefit the environment but also generate economic advantages for the companies that implement them.

A benefit of the application of cleaner production is the improvement in the quality of the treated water (Moreira et al., 2022). Cleaner production makes it possible to obtain higher-quality water with fewer chemicals, which can improve the perception of the population and increase the demand for drinking water (Boretti and Sosa, 2019). This can translate into an increase in sales for companies in charge of water treatment.

Tang et al. (2013) highlights the importance of implementing cleaner production practices in drinking water treatment to reduce environmental impact and obtain economic benefits.

The implementation of the CP in a drinking water treatment plant reduces the generation of sludge (Sorlini et al., 2015). Additionally, CP can also help reduce the amount of chemicals used in the water treatment process, which in turn can decrease the amount of hazardous waste generated (Ahmad et al., 2016).

Due to the aforementioned, the application of cleaner production in the treatment of drinking water can generate environmental and economic benefits by reducing pollution, energy use and waste generation. The articles reviewed support the claim that cleaner production can be an effective strategy to improve the sustainability of drinking water treatment.

3.4. Limitations of the systematic review

It should be noted that, for this systematic review, manuscripts retrieved from the Scopus database with the keywords ``Cleaner production'', ``drinking water treatment'', ``drinking water'' and ``drinking'' between January 1, 2002 and October 31, 2022. The biggest limitation of this systematic review and for which it has not been possible to draw clear scientific conclusions is that after applying the inclusion and exclusion criteria, only five articles were obtained, this due to that these 5 documents had a direct and precise articulation between CP and DWT. However, future studies should expand the search to other databases where there may be more articles in this specific field of research.

3.5. Gaps and future research

The bibliographic references selected in this systematic review allow us to observe that, although the frequency of studies related to the application of CP in drinking water has increased slightly in recent years; however, the number of studies is still insufficient to obtain effective scientific evidence. One of the gaps found during this investigation corresponds to the greater application of: reuse and recycling, changes in supplies, changes in technology in the different purification processes.

Alumina-containing water purification sludge (WPS) is the most important waste produced in purification. This sludge accumulates after the processes of flocculation, sedimentation and filtration due to the application of coagulants based on alumina or iron generally. This sludge could be used as raw material in the construction materials industry for concrete works, such as for making bricks. Therefore, research is needed to determine the percentage that could be used in construction materials. In this way, the problem of generating purification sludge can be eliminated, instead of sending a receiving body or a landfill, with which the reuse opportunity would be applied.

Some of the CP strategies related to the change of input pending investigation is the replacement of sunlight with ultraviolet light (UV) or the application of some technique that facilitates greater elimination of microbiological contamination from dirty water, to reduce or eliminate the use of a chemical disinfectant. Likewise, it is important to continue investigating more about the elaboration and application of organic coagulants that replace inorganic coagulants.

For the water services sector, the implementation of the CP is aligned with the Sustainable Development Goals (SDG) of the United Nations, by achieving SDG 6 it allows to achieve other related SDGs, such as SDG 12 (Zvimba et al., 2021).

Future research is suggested to analyze CP indicators as a tool for the different purification processes. It remains to investigate how CP allows formulating strategies for treatment plants to adapt to climate change. There are several future research directions in the application of Cleaner Production in drinking water treatment that are important to explore. Below are some of these research directions and their justifications: Investigate the technical and economic feasibility of applying Cleaner Production in drinking water treatment plants; this is because there are few studies that evaluate the technical and economic feasibility of its implementation in drinking water treatment plants. These studies can help determine the cost-benefit of Cleaner Production in terms of reducing operating costs and environmental improvements.

Investigate the relationship between the application of Cleaner Production and the quality of drinking water; although it is expected that the application of Cleaner Production will have a positive impact on the quality of drinking water, there are not many studies that examine this relationship. Investigating this relationship can help determine whether Cleaner Production can be used to improve the quality of drinking water and ensure public health.

Evaluate the environmental and public health impacts of Cleaner Production in drinking water treatment. The evaluation of these impacts can help better understand the environmental and public health benefits of Cleaner Production in drinking water treatment. Research on different Cleaner Production strategies applied in drinking water treatment; this is justified because broader and deeper research is needed on the different Cleaner Production strategies that can be applied in drinking water treatment, such as water reuse and proper maintenance.

Research on the application of Cleaner Production in large-scale drinking water treatment systems: while Cleaner Production has been successfully used in some small-scale drinking water treatment systems, more research is needed on its application in large-scale systems. This would allow decision makers and drinking water treatment professionals to determine the feasibility of applying Cleaner Production strategies in larger systems and develop scalable solutions.

Due to the aforementioned limitations of the systematic review, for future studies related to cleaner production management in water treatment, it is suggested to analyze documents based on the Life Cycle Assessment (LCA), which can provide more scientific clarification in this field of research, since the CP addresses the reduction of negative impacts throughout the product's life cycle.

4. Conclusions

Studies regarding the application of CP in water treatment were compiled and reviewed through a scientometric analysis. The VOSviewer software allowed a visual analysis of 278 publications retrieved from the Scopus database and the following results were obtained: The literature in the field of the application of CP in water treatment has been increasing year after year, has increased notably since 2012. The journals that published the most in this field are Journal of cleaner production, Journal of environmental management and Environmental science and pollution research.

In the field of research on the application of CP in water treatment there are some outstanding countries such as China, India, Brazil, etc. The author collaboration network showed that a small number of researchers and countries have close and concentrated collaborative relationships. Most researchers and countries are still scattered, with little collaboration with other researchers and countries. The most recurring words were cleaner production, wastewater and waste treatment. The last indicated allowed to identify that the different CP strategies have been integrated in the various water purification processes; however, CP has not been integrated into the DWT to the same extent as it has been integrated into the WWT. Reason for which a systematic review of the application of the CP in the DWT was carried out. Only five studies explicitly evaluated the interactions or relationships between CP and DWT. The systematic review provided satisfactory answers to the research questions posed. Regarding the first research question, a weak integration of CP opportunities in drinking water systems was evidenced. The implementation of CP strategies may be the right path for drinking water treatment plants. It is important to stress that CP has not yet reached many service companies, including drinking water supply companies. Responding to research question 2, it was found that the main opportunities for CP applied in drinking water systems were Good cleaning and recycling. Regarding question 3, the main purification processes where PML has been applied have been the coagulation and filtration processes. These results provide academics and businessmen with a clear picture of the benefits generated by the implementation of CP in drinking water companies. Academics can use the results as a starting point to develop new research and managers of drinking water companies as guidelines to facilitate the implementation of CP projects. The needs and gaps based on this review indicate that more research is still needed on the topic addressed in this review. This research suggests tracing a path and the steps that can be taken to achieve each of the CP benefits and developing proposals for management models and indicators that help to achieve CP goals; deepen the studies of the synergies and correlations of each CP strategy and each purification process.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Adekomaya, O., Majozi, T., 2022. Promoting natural cycle and environmental resilience: a pathway toward sustainable development. South African J. Chem. Eng. 42, 229–240. https://doi.org/10.1016/j.sajce.2022.09.002.

Ahmad, T., Ahmad, K., Alam, M., 2016. Sustainable management of water treatment sludge through 3`R` concept. J. Clean. Prod. 124, 1–13. https://doi.org/10.1016/j.jclepro.2016.02.073.

Ahmed, M.B., Johir, M.B.H., Zhou, l., Ngo, H.H., Nghiem, L.D., Richardson, C., Moni, M. A., Bryant, M.R, 2019. Activated carbon preparation from biomass feedstock: clean production and carbon dioxide adsorption. J. Clean. Prod. 225, 405–413. https://doi.org/10.1016/j.jclepro.2019.03.342.

Alsaeed, R., 2021. Modelling turbidity removal by poly-aluminium chloride coagulant using gene expression. Adv. Environ. Technol. 7 (4), 263–273. https://doi.org/10.22104/aet.2022.5303.1433.

Amala, K., Soesilo, B., Kusnoputranto, H., 2021. Implementation of cleaner production to improve wastewater treatment performance. IOP Conf. Ser.: Earth Environ. Sci. 739, 012018.

Barón, A., de Castro, R., Giménez, G., 2020. Circular economy practices among industrial EMAS-registered SMEs in Spain. Sustainability. 12 (21), 9011. https://doi.org/10.3390/su12219011.

Boretti, A., Rosa, L., 2019. Reassessing the projections of the world water development report. npj Clean Water 2, 15. https://doi.org/10.1038/s41545-019-0039-9.

Bornmann, L., Haunschild, R., Hug, S.E., 2018. Visualizing the context of citations referencing papers published by Eugene Garfield: a new type of keyword co-occurrence analysis. Scientometrics 114, 427–437. https://doi.org/10.1007/s11192-017-2591-8.

Capocelli, M., Prisciandaro, M., Piemonte, V., Barba, D., 2019. A technical-economical approach to promote the water treatment & reuse processes. J. Clean. Prod. 207, 85–96. https://doi.org/10.1016/j.jclepro.2018.09.135.

Cardoso, L., Silva, R., Almeida, G.G.F.D., Lima Santos, L., 2020. A bibliometric model to analyze country research performance: SciVal topic prominence approach in tourism, leisure and hospitality. Sustainability 12, 9897. https://doi.org/10.3390/su12239897, 2020.

Cescon, A., Jiang, J.Q., 2020. Filtration process and alternative filter media material in water treatment. Water (Basel) 12, 377. https://doi.org/10.3390/w12123377.

Chang, N., Pongsanone, N.P., Ernest, A, 2013. A rule-based decision support system for sensor deployment in small drinking water networks. J. Clean. Prod. 60, 152–162. https://doi.org/10.1016/j.jclepro.2012.10.036.

Chen, C., Song, M., 2019. Visualizing a field of research: a methodology of systematic scientometric reviews. PLoS ONE 14 (10), e0223994. https://doi.org/10.1371/journal.pone.0223994.

Chen, L., Chen, L., Zhou, C.H., Yang, Ji., Tong, D.S., Zhong, Z.K., Yu, W.H., Chu, M.Q., 2017. Environmental-friendly montmorillonite-biochar composites: facile production and tunable adsorption-release of ammonium and phosphate. J. Clean. Prod. 156, 648–659. https://doi.org/10.1016/j.jclepro.2017.04.050, 2017.

Dhar, P., Naznin, A., Ara, M., 2020. Health risks assessment of heavy metal contamination in drinking water collected from different educational institutions of Khulna city corporation, Bangladesh. Adv. Environ. Technol. 6 (4), 235–250. https://doi.org/10.22104/aet.2021.4932.1331.

Ding, Y., Chowdhury, G., Foo, S., Qian, W., 2000. Bibliometric information retrieval system (BIRS): a web search interface utilizing bibliometric research results. JASIST 51 (13), 1190–1204. https://doi.org/10.1002/1097-4571.

García-Ávila, F., Avilés-Añazco, A., Sánchez-Cordero, E., Valdiviezo-Gonzáles, L., Tonon Ordoñez, M., 2021b. The challenge of improving the efficiency of drinking water treatment systems in rural areas facing changes in the raw water quality. South African J. Chem. Eng. 37, 141–149. https://doi.org/10.1016/j.sajce.2021.05.010.

Garcia-Avila, F., Valdiviezo-Gonzales, L., Iglesias-Abad, S., Gutierrez-Ortega, H., Cadme-Galabay, M., Donoso-Moscoso, S., Arevalo, C.Z., 2021a. Opportunities for improvement in a potabilization plant based on cleaner production: experimental and theoretical investigations. Results Eng. 11, 100274 https://doi.org/10.1016/j.rineng.2021.100274.

Garcia-Peñalvo, F.J., 2022. Developing robust state-of-the-art reports: systematic literature reviews. Educ. Knowl. Soc. 23, e28600. https://doi.org/10.14201/eks.28600.

Giakoumis, T., Vaghela, C., Voulvoulis, N., 2020. Chapter six - the role of water reuse in the circular economy. Adv. Chem. Pollut. Environ. Manage. Prot. 5, 227–252. https://doi.org/10.1016/bs.apmp.2020.07.013.

Giannetti, B.F., Agostinho, F., Eras, J.J.C., Yang, Z., Almeida, C.M.V.B., 2020. Cleaner production for achieving the sustainable development goals. J. Clean. Prod. 271, 122127 https://doi.org/10.1016/j.jclepro.2020.122127.

Giannetti, B.F., Sevegnani, F.;., Garcia, R.;., Agostinho, F.;., Almeida, C., 2022. Enhancing the assessment of cleaner production practices for sustainable development: the five-sector sustainability model applied to water and waste water treatment companies. Sustainability 14, 4126.

Guo, P., Li, Q., Guo, H., Li, H., Yang, L., 2022. A bibliometric and visual analysis of global urban resilience research in 2011–2020: development and hotspots. Sustainability. 14 (1), 229. https://doi.org/10.3390/su14010229.

Guo, Y.-.M., Huang, Z.-.L., Guo, J., Li, H., Guo, X.-.R., Nkeli, M.J., 2019. Bibliometric analysis on smart cities research. Sustainability. 11, 3606. https://doi.org/10.3390/su11133606.

Halbach, B.O., 2011. How to judge a book by its cover? How useful are bibliometric indices for the evaluation of “scientific quality” or “scientific productivity”? Ann. Anat. 193, 191–196. https://doi.org/10.1016/j.aanat.2011.03.011 (2011).

Hens, L., Block, C., Hair-Eras, J.J., Sagastume-Gutierez, A., Garcia-Lorenzo, D., Chamorro, C., Herrera Mendoza, K., Haeseldonckx, D., Vandecasteele, C, 2017. On the evolution of “Cleaner Production” as a concept and a practice. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2017.11.082.

Hirsch, J.E., 2005. An index to quantify an individual's scientific research output. Proc. Natl. Acad. Sci. U.S.A. 102, 16569–16572. https://doi.org/10.1073/pnas.0507655102.

Kovac Kralj, A., 2021. Using key-component techniques for production of different products from wastes. South African J. Chem. Eng. 36, 142–150. https://doi.org/10.1016/j.sajce.2021.03.003.

Larsen, T.A., Lienert, J., Joss, A., Siegrist, H., 2004. How to avoid pharmaceuticals in the aquatic environment. J. Biotechnol. 113 (1–3), 295–304. https://doi.org/10.1016/j.jbiotec.2004.03.033. Sep 30PMID: 15380662.

Leite, R., Amorim, M., Rodrigues, M., Oliveira Neto, G., 2019. Overcoming barriers for adopting cleaner production: a case study in Brazilian small metal-mechanic companies. Sustainability 11 (17), 4808. https://doi.org/10.3390/su11174808.

Maama, H., Doorasamy, M., Rajaram, R., 2021. Cleaner production, environmental and economic sustainability of production firms in South Africa. J. Clean. Prod. 298, 126707 https://doi.org/10.1016/j.jclepro.2021.126707, 2021.

Moreira, V.R., Rocha, Y.A., Souza, L.V., Amaral, M.C.S, 2022. Low-cost recycled end-of-life reverse osmosis membranes for water treatment at the point-of-use. J. Clean. Prod. 362, 132495 https://doi.org/10.1016/j.jclepro.2022.132495.

Nguyen, M.D., Thomas, M., Surapaneni, A., Moon, E.M., Milne, N.A., 2022. Beneficial reuse of water treatment sludge in the context of circular economy. Environ. Technol. Innov. 28, 102651 https://doi.org/10.1016/j.eti.2022.102651.

Nunes, J.R.R., Silva, J.E.A., Morris, V.A., Giannetti, B.F., 2019. Cleaner production in small companies: proposal of a management methodology. J. Clean. Prod. 218, 357–366. https://doi.org/10.1016/j.jclepro.2019.01.219.

Nurbaiti, G.A., Rachmanto, T.A., Farahdiba, A.U., 2021. Cleaner production strategy as a supporting analysis of environmental impact on drinking water treatment process using life cycle assessment approach. In: 2nd International Conference Eco-Innovation in Science, Engineering, and Technology. NST Proceedings, pp. 171–174. https://doi.org/10.11594/nstp.2021.1427.

Oliveira Santos, H., Alves, J.L., de Melo, F.J., de Medeiros, D.D., 2020. An approach to implement cleaner production in services: integrating quality management process. J. Clean. Prod. 246 https://doi.org/10.1016/j.jclepro.2019.118985.

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., 2021. The PRISMA 2020 statement: an updated

guideline for reporting systematic reviews. Syst. Rev. 10 (1), 1–11. https://doi.org/10.1186/s13643-021-01626-4.
Parvini, M., Golestanbagh, M., Salwani bt Ahamad, I., 2015. Studying effect of water quality parameters on coagulation efficiency by Moringa Oleifera seeds. Adv. Environ. Technol. 1 (1), 41–47. https://doi.org/10.22104/aet.2015.120.
Petticrew, M., Roberts, H., 2005. Systematic Reviews in the Social sciences: A practical Guide. John Wiley & Sons.
Price, J.I., Heberling, M.T., 2018. The effects of source water quality on drinking water treatment costs: a review and synthesis of empirical literature. Ecol. Econ. 151, 195–209. https://doi.org/10.1016/j.ecolecon.2018.04.014.
Qi, C., Chang, N.-.B., 2012. Integrated carbon footprint and cost evaluation of a drinking water infrastructure system for screening expansion alternatives. J. Clean. Prod. 27, 51–63. https://doi.org/10.1016/j.jclepro.2012.01.009.
Qrenawi, L.I., Rabah, F.K.J., 2021. Sludge management in water treatment plants: literature review. Int. J. Environ. Waste Manag. 27 (1), 93–125. https://doi.org/10.1504/IJEWM.2021.111909.
Rahayu, S.S., Budiyono, B., Purwanto, P., 2018. Integration of cleaner production and waste water treatment on Tofu small industry for biogas production using AnSBR reactor. E3S Web Conf. 31 (2018), 03010. https://doi.org/10.1051/e3sconf/20183103010.
Rasaki, S.A., Bingxue, Z., Guarecuco, R., Thomas, T., Minghui, Y., 2018. Geopolymer for use in heavy metals adsorption, and advanced oxidative processes: a critical review. J. Clean. Prod. 213, 42–58.
Ruj, B., Chakrabortty, S., Nayak, J., Chatterjee, R., 2021. Treatment of arsenic sludge generated from groundwater treatment plant: a review towards a sustainable solution. South African J. Chem. Eng. 37, 214–226. https://doi.org/10.1016/j.sajce.2021.06.003.
Severe, E., Guimaraes, J.C., Dorion, E.C.H., 2017. Cleaner production and environmental management as sustainable product innovation antecedents: a survey in Brazilian industries. J. Clean. Prod. 142 https://doi.org/10.1016/j.jclepro.2016.06.090.
Sharma, S., Bhattacharya, A., 2017. Drinking water contamination and treatment techniques. Appl. Water Sci. 7, 1043–1067. https://doi.org/10.1007/s13201-016-0455-7.
Sikander, M., Kumar, L., Naqvi, S.A., Arshad, M., Jabeen, S., 2021. Sustainable practices for reduction of environmental footprint in tanneries of Pakistan. Case Stud. Chem. Environ. Eng. 4, 100161 https://doi.org/10.1016/j.cscee.2021.100161.
Sorlini, S., Collivignarelli, M.C., Castagnola, F., Crotti, B.M., Raboni, M., 2015. Methodological approach for the optimization of drinking water treatment plants' operation: a case study. Water Sci. Technol. 71 (4), 597–604. https://doi.org/10.2166/wst.2014.503.
Tang, Y., Wu, S.;., Miao, X.;., Pollard, S.;., Hrudey, S., 2013. Resilience to evolving drinking water contamination risks: a human error prevention perspective. J. Clean. Prod. 57, 228–237. https://doi.org/10.1016/j.jclepro.2013.06.018.
Thomas, M.L.H., Channon, A.A., Bain, R.E.S., Nyamai, M., Wright, J.A., 2020. Household-reported availability of drinking water in Africa: a systematic review. Water 12 (9), 2603. https://doi.org/10.3390/w12092603.
Tobi, R.C.A., Harris, F., Rana, R., Brown, K.A., Quaife, M., Green, R., 2019. Sustainable diet dimensions. Comparing consumer preference for nutrition, environmental and social responsibility food labelling: a systematic review. Sustainability 11, 6575. https://doi.org/10.3390/su1123657.
Torcătoru, C., Săvescu, D., Repanovici, A., 2022. Literature review by scientometric methods on the impact of the circular economy on sustainable industrial products. Sustainability. 14 (9), 5084. https://doi.org/10.3390/su14095084.
UNIDO, Cleaner production toolkit, Available in, https://www.unido.org/resources/publications/safeguarding-environment/industrial-energyefficiency/cp-toolkit-engl, 2008.
Valdiviezo Gonzales, L., García Ávila, F., Cabello Torres, R., Castañeda Olivera, C., Alfaro Paredes, E., 2021. Scientometric study of drinking water treatments technologies: present and future challenges. Cogent Eng. 8 (1), 0–38. https://doi.org/10.1080/23311916.2021.1929046.
Van Eck, N.J., Waltman, L., 2010. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics 84, 523–538. https://doi.org/10.1007/s11192-009-0146-3.
Wang, R., Wang, Q., Dong, L., Zhang, J, 2021. Cleaner agricultural production in drinking-water source areas for the control of non-point source pollution in China. J. Environ. Manage. 285, 112096 https://doi.org/10.1016/j.jenvman.2021.112096.
Wang, T., Lin, J., Chen, Z., Megharaj, M., Naidu, R., 2014. Green synthesized iron nanoparticles by green tea and eucalyptus leaves extracts used for removal of nitrate in aqueous solution. J. Clean. Prod. 83, 413–419. https://doi.org/10.1016/j.jclepro.2014.07.006.
Wei, D., Ji, B., Li, H., Zhu, S., Ye, Z., Zhao, J., 2022. Modified kinetic energy feature-based graph convolutional network for fish appetite grading using time-limited data in aquaculture. Front. Mar. Sci. 9, 1021688 https://doi.org/10.3389/fmars.2022.1021688.
Weststrate, J., Dijkstra, G., Eshuis, J., et al., 2019. The sustainable development goal on water and sanitation: learning from the millennium development goals. Soc. Indic. Res. 143, 795–810. https://doi.org/10.1007/s11205-018-1965-5.
Xue, J., Reniers, G., Li, J., Yang, M., Wu, C., van Gelder, PHAJM., 2021. A bibliometric and visualized overview for the evolution of process safety and environmental protection. Int. J. Environ. Res. Public Health 18 (11), 5985. https://doi.org/10.3390/ijerph18115985, 2.
Yang, B., Fang, H., Chen, B., Yang, S., Ye, Z., Yu, J., 2021. Effects of reductive inorganics and NOM on the formation of chlorite in the chlorine dioxide disinfection of drinking water. J. Environ. Sci. 104, 225–232. https://doi.org/10.1016/j.jes.2020.11.033.
Yitbarek, M., Abdeta, K., Beyene, A., Astatkie, H., Dadi, D., Desalew, G., Van der Bruggen, B., 2019. Experimental evaluation of sorptive removal of fluoride from drinking water using natural and brewery waste diatomite. Process Saf. Environ. Prot. 128, 95–106. https://doi.org/10.1016/j.psep.2019.05.052.
Zib, L., Byrne, D.M., Marston, L.T., Chini, C.M., 2021. Operational carbon footprint of the U.S. water and wastewater sector's energy consumption. J. Clean. 321, 128815. https://doi.org/10.1016/j.jclepro.2021.128815.
Zvimba, J.N., Musvoto, E.V.;., Nhamo, L.;., Mabhaudhi, T.;., Nyambiya, I.;., Chapungu, L.;., Sawunyama, L., 2021. Energy pathway for transitioning to a circular economy within wastewater services. Case Stud. Chem. Environ. Eng. 4, 100144 https://doi.org/10.1016/j.cscee.2021.100144.