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DOMESTIC WASTEWATER TREATMENT AT THE SINGLE-FAMILY LEVEL USING A SEPTIC TANK AND CONSTRUCTED WETLAND SYSTEM: A SCIENTOMETRIC AND SYSTEMATIC ANALYSIS

Fernando García-Ávila[1,2], César Zhindón-Arévalo[3], Lorgio Valdiviezo-Gonzales[4] , Carlos Sánchez-Alvarracín[1,2], Jéssica Criollo-Bravo[1,2], Daniela Albuja-Arias[1,2] and Edgar Vivar-Martínez[1,2]
[1]Carrera de Ingeniería Ambiental, Universidad de Cuenca, Ecuador
[2]Grupo de Evaluación de Riesgos Ambientales en Sistemas de Producción y Servicios (RISKEN), Cuenca, Ecuador
[3]Unidad Académica de Salud y Bienestar, Universidad Católica de Cuenca, sede Azogues, Ecuador
[4]Facultad de Ingeniería, Universidad Tecnológica del Perú, Lima, Perú
E-Mail: garcia10f@hotmail.com

ABSTRACT

The study of wastewater treatment at the single-family level is of great interest to researchers around the world. This study focused on making a scientometric analysis and a systematic review of the treatment of domestic wastewater at the single-family level through a septic tank (ST) and constructed wetland (CW) system. For which the publications from 2002 to 2022 registered in the Scopus database were recovered. For the systematic review, the PRISMA approach was used to verify the efficiency of the wastewater treatment system integrated by an ST and CW. After the respective exclusion, a total of 166 articles were obtained. The findings of this study revealed that the leading countries in this field of research are the USA, Brazil, China, Norway, and Poland. The most recurrent words were artificial wetlands, septic tanks, and domestic wastewater. The systematic review showed that the integration of an ST with a CW is an alternative for wastewater treatment at the single-family level. This integrated system allows the achievement of high BOD5 and COD removal efficiencies. Meanwhile, the removal of phosphorous and nitrogen has been moderate. However, research is needed on the costs and reuse of the effluent from this treatment system; as well as, to evaluate the efficiency of the application of deflectors in the STs and the use of ornamental plants in the CWs. This study helps researchers in this field to identify sanitation trends that have emerged in the last 20 years, serving as a reference for future research.

Keywords: constructed wetland, septic tank, wastewater treatment, scientometric, systematic review.

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1. INTRODUCTION

Wastewater treatment is necessary to achieve the sixth sustainable development goal which is to guarantee clean water and sanitation. One of the goals of this goal involves halving the amount of wastewater that is not treated [1]. Domestic wastewater treatment is an essential factor in the development of societies and the health of ecosystems [2]. The practices of dumping untreated or inadequately treated wastewater into bodies of water have contributed significantly to the degradation or loss of ecosystems. Domestic wastewater (black and gray water) is 99.9% water and barely 0.1% suspended, colloidal, and dissolved solids [3]. However, this small content of solids causes big problems in the treatment.

For wastewater treatment, there are conventional and unconventional systems [4, 5]. Conventional treatment systems refer to a wastewater treatment plant, which integrates primary, secondary, and tertiary treatment [6]. Through these processes, the characteristics of the polluted water are altered, allowing the pollutant load to be eliminated; however, they have a high cost, a low hydraulic retention time, and a high energy cost [7].

Therefore, unconventional treatment systems have a low cost, a high hydraulic retention time, and do not require energy expenditure; but they need a large surface area, These systems can be implemented for small populations or on an individual scale (single-family homes) [8, 9]. Non-conventional systems also known as alternative treatments can be part of the treatment response, in particular for those dispersed areas, which do not have the culture or the financial resources for it [10, 11].

Due to the above and given the extent of the problem related to untreated wastewater, it is convenient to analyze the wastewater treatment systems that have been applied at the single-family level, specifically to the treatment made up of a septic tank (ST) as primary treatment together with constructed wetlands (CW) as a secondary treatment [12,13]. In this sense, the objective of this document is to carry out a scientometric and systematic analysis of the treatment of domestic wastewater at the single-family level through a system composed of a septic tank and a constructed wetland [14, 15, 16].

Septic tanks are structures for the primary treatment of wastewater from homes, small housing complexes, schools, shops, hospitals, and sanitary services of some industries, located in urban or rural areas that lack sewerage [17, 18]. The septic tank is a biological treatment that only removes part of the suspended solids, converting the volatile suspended solids to fixed ones [19]. This system can receive both water with human excrement and that from kitchens and bathrooms (wastewater, plus sewage) [20]. Through a simple decantation and sedimentation process, it is possible to eliminate the solids present in the wastewater, thus preventing them from contaminating the soil or freshwater sources [21, 22]. The effluent from the septic tanks still contains a large amount of organic matter that has caused a high degree of contamination of the groundwater located in the first levels of the aquifer and has become a danger to public health and a serious obstacle to development. Sustainability of all population centers, whose only source of water supply for human consumption is the aquifer itself [23,24,25]. This situation makes it necessary to use a secondary treatment system for the water collected in the septic tanks, to guarantee that the quality of the treated effluent meets the discharge conditions allowed to the state aquifer [18, 21].

Within the non-conventional systems are the natural wastewater treatment systems, among the most important are the stabilization ponds, the vermifilter, and the constructed wetlands [26]. Constructed wetlands are presented as bioremediation techniques with the lowest impact on the environment, framed in phytodepuration with wetland plants [27]. Wetlands are characterized by their simple procedure, low input costs compared to conventional ones, low costs of electricity and maintenance, but mainly by their harmony with the balance of nature [28].

One of the most used processes for the treatment of effluents is the septic tank, which is a conventional treatment system and which is usually a conv system [29,30]. However, alternative technologies have been generated that essentially also clean the water of biodegradable organic compounds from the management of microorganisms, but in situ, in the same place where they are generated and on a reduced scale [31]. Given these circumstances, it was chosen to analyze alternative technologies for secondary treatment, such as the constructed wetland, which can be used in dispersed settlements that do not have a sewage system due to their topographic location. The delegation's financial resources are scarce and, above all, because they are respectful of nature [32].

Therefore, this study aimed to exhaustively search for articles in the Scopus databases that allow achieving a contextualization of the integration of the septic tank and constructed wetland used at the single-family level for wastewater treatment. To achieve this, a scientometric analysis and a systematic review of this field of research were carried out. Scientometrics consists of the quantitative analysis of scientific production, which makes it possible to investigate the development, structure, dynamics, trends, and relationships of scientific practice, as well as to identify research trends from indicators of scientific activity or production, to provide an overview of the state of research in this field. Meanwhile, the systematic review made it possible to identify, evaluate, and synthesize all the articles that met the eligibility criteria, previously specified, to answer the research questions posed.

2. METHODOLOGY

2.1 Scientometric Analysis of Single-Family Domestic Wastewater Treatment through a Septic Tank and Constructed Wetland System

2 .1.1 Data collection

For the scientometric analysis, the Scopus database was used, from where the academic literature related to articles, reviews, conference papers, and book chapters from 2002 to 2022. “Septic tanks”, and “Constructed wetlands” were used as keywords to search for them in the title, abstract, and keywords in the database. The search was further refined by excluding manuscripts that did not have the search words indicated above in the title, abstract, or keywords, for which each article was reviewed. Initially, the raw data obtained were 323 articles, after reviewing the keywords in the title and abstract, 166 records were obtained. VOSviewer software was then used to statistically examine the papers, in terms of publications per year, top journals, top-producing authors, research institutions, and countries.

2.1.2 Treatment of selected articles and data analysis

For scientometric analysis, software such as VOSviewer can be used, which allows a quantitative analysis of scientific production in this field of research [33]. VOSviewer made it possible to intuitively understand the state of the research through maps based on bibliographic data obtained from documents retrieved from Scopus.

2.2 Systematic Review of Single-Family Domestic Wastewater Treatment through a Septic Tank and Constructed Wetland System

2.2.1 Data sources and research strategy

For the systematic review of the literature, the PICO method and the PRISMA model [34] were used. The PICO method helps to structure the research questions in a systematic review through important components such as Population (relevant population), Intervention (intervention or exposure), Comparison (comparison according to intervention), and Result (output) [35]. The preferred statement reporting items for Systematic Reviews and Meta- Analyses (PRISMA), published in 2009, aims to help authors improve the writing of systematic reviews, for which a flowchart should be used that can be downloaded from https:// prisma - statement.org/PRISMAStatement/FlowDiagram .

Three research questions related to single-family domestic wastewater treatment using a septic tank and constructed wetland system were formulated for this systematic review: Q1. Does the integration of a septic tank with a wetland improve performance? Q2. What are the main characteristics of the system integrated by a septic tank and constructed wetland in houses? Q3. What is the efficiency of the treatment system integrated by a septic tank and a constructed wetland?

Based on the research questions, PICO was applied. Population: Treatment of domestic wastewater at the family level. Intervention: On-site treatment systems; Comparison: Septic tank and constructed wetland. Result: Increased treatment efficiency when using a septic tank + constructed wetland.

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3. RESULTS AND DISCUSSIONS

3.1 Scientometric Analysis of Single-Family Domestic Wastewater Treatment through a Septic Tank and Constructed Wetland System

3.1.1 Posts and documents trend by type

In total, 323 articles published in the period 2002-2022 were retrieved, after the individual review, articles whose titles, abstracts, and keywords did not have the words "Septic tank" and "Constructed wetlands" were excluded, finally obtaining 167 articles. Increases and decreases in publications in this field were observed from 2002 to 2022; evidencing a high number of publications in 2005, after which there were ups and downs, 2021 another high number of publications was presented (Figure-1). However, in general terms, it can be said that there is an interest in researching wastewater treatment on the site using a septic tank + constructed wetland (ST+CW) in single-family homes.

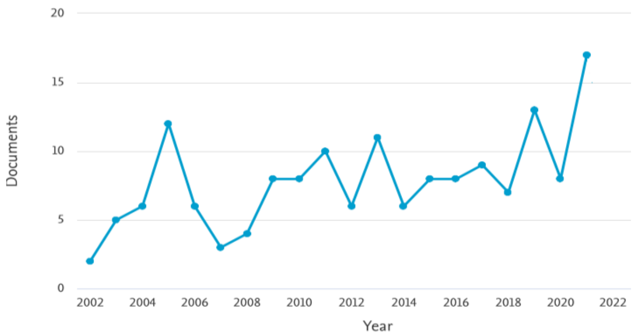

Figure-1. Number of articles published annually on.

3.1.2 Documents by type

Regarding the association of publications by type of document, this relationship is presented in Figure-2, where it can be seen that 82.5% correspond to original articles, 12% to conference articles, 3% to book chapters, and 2.4% to revisions.

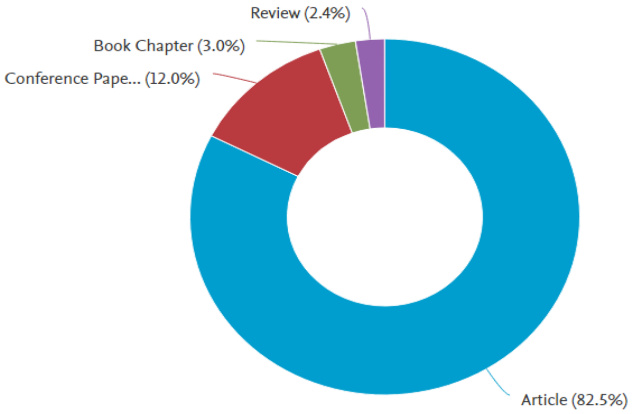

Figure-2. Type of documents retrieved from Scopus.

3.1.3 Science-mapping of journal sources

The results of the scientometric analysis involving the sources of the journals published in the field of single-family domestic wastewater treatment using a system integrated by septic tanks and constructed wetlands are reported in Figure-3. A minimum of 3 articles was established per journal for analysis in *VOSViewer*, obtaining 14 out of a total of 79 journals that met this requirement. Figure-3 shows the main journals and their interrelationships through the connected lines. Please note that not all relevant journals may be visible through Figure-3. The largest number of articles (n = 19) was published in water science and technology, in ecological engineering 17 articles were published, and eight in desalination and water treatment. These three journals published 26.5% of the papers published during the study period.

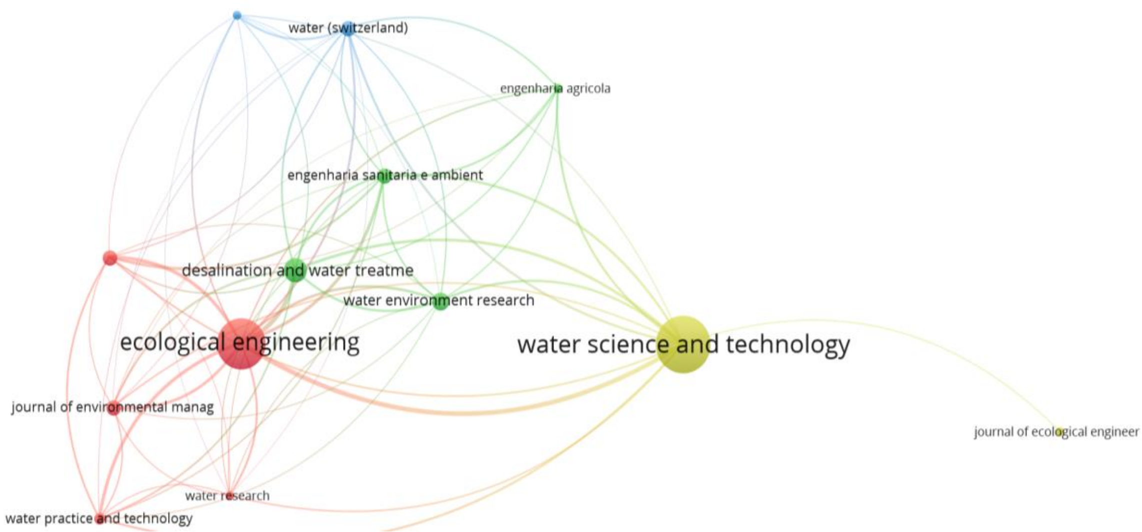

Figure-3. Relevant journals published in the field of single-family domestic wastewater treatment using a constructed wetland and septic tank system.

3.1.4 Keyword co-occurrence analysis

A keyword network provides a clear demonstration of the interrelationships and closeness between them [36]. Regarding the most recurring words in the title, keywords, or abstract, a total of 491 words were located that were used as keywords in the 166 documents. 18 words were identified that were recurring in at least 3 articles. These words were constructed wetlands with 39 appearances, constructed wetlands with 35 appearances, then wastewater treatment, septic tank, and domestic wastewater with 25, 17, and 15 occurrences respectively (Figure-4). This also indicates that wastewater treatment at the residence level has been carried out primarily using constructed wetlands.

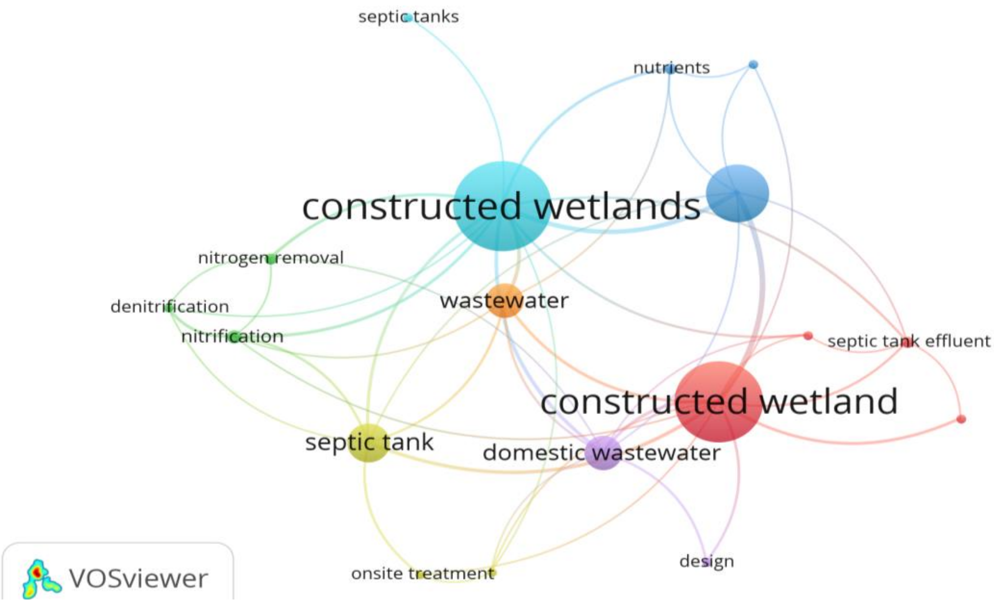

Figure-4. Relevant keywords occurred in the published literature in the domain of single-family domestic wastewater treatment by a constructed wetland and septic tank system.

3.1.5 Co-authorship analysis

a. countries

The review by countries showed that research in this field was distributed in 61 nations. The countries that produced at least 5 articles were identified, determining that 15 countries met this requirement. being United States, with 27 articles, is the most active country in publishing articles related to wastewater treatment at the household level using a septic tank together with a constructed wetland, followed by Brazil with 26 publications, China with 14, Poland with 11 and Norway with 10 publications (Figure-5).

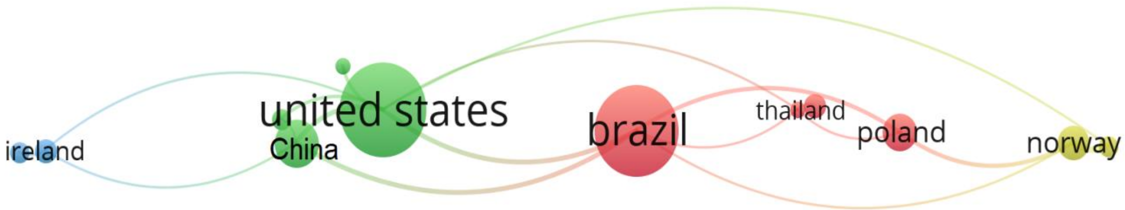

Figure-5. Main countries that published in the domain of single-family domestic wastewater treatment through a septic tank and constructed wetland system.

b. Authors

Regarding the authors who produced the most on single-family domestic wastewater treatment through a septic tank system and constructed wetland, of the 595 authors, 19 authors published more than 3 articles. The authors who published the most can be seen in Fure-6; these are Paruch, AM (n=6), De Matos, AT (n=5), Koottatep, T. (n=5), Heistad,A. (n=4), Maehlum, T. (n=4). It was possible to demonstrate a direct relationship between the contributions of these five authors (Figure-7).

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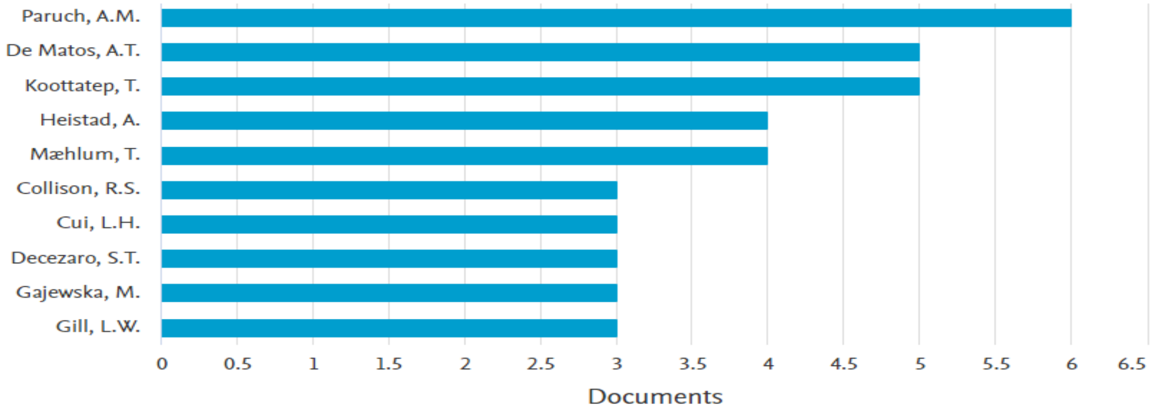

Figure-6. Number of publications by author.

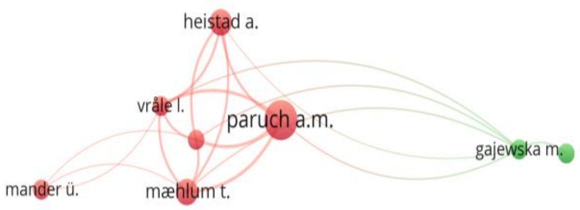

Figure-7. Main authors who published in the field of single-family domestic wastewater treatment using a septic tank and constructed wetland system.

c. Affiliations

Regarding the number of documents by affiliation, it was identified that three of the 390 institutions published 6 documents in this field; another three institutions published 5 articles (Figure-8). The affiliations that had more articles in this field were the Federal University of Vicosa, South China Agricultural University, and the Norwegian Institute of Bioeconomy Research with 6 publications each. Meanwhile, Norges Miljø - og Biovitenskapelige Universitet, Asian Institute of Technology Thailand, and Trinity College Dublin had 5 posts each one.

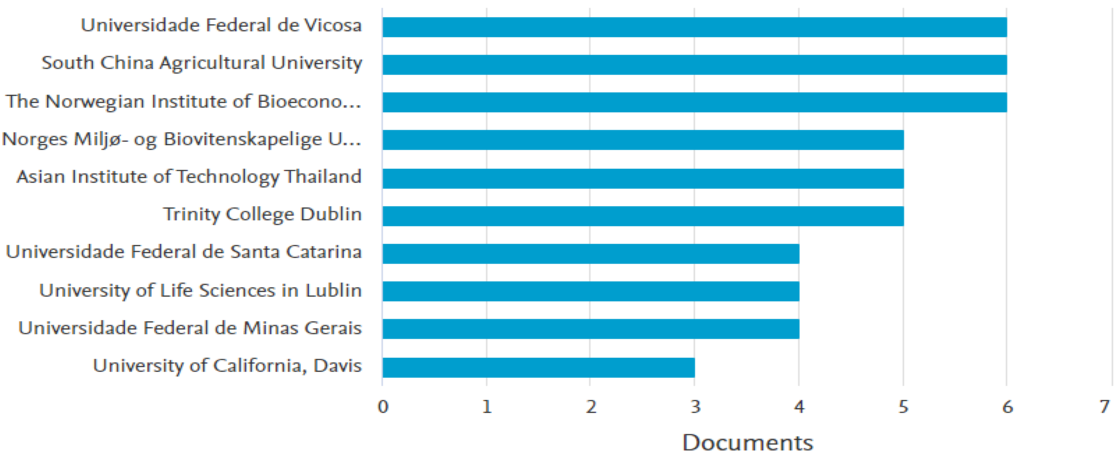

Figure-8. Main published affiliations in the field of single-family domestic wastewater treatment using a constructed wetland and septic tank system.

3.1.6 Publications with the greatest impact

The most influential articles published in the domain of single-family domestic wastewater treatment using a constructed wetland and septic tank system were reviewed on *VOSViewer. In* Figure-9, the network of authors who wrote the most cited articles in the field of single-family domestic wastewater treatment using a septic tank and constructed wetland system is presented.

A minimum of 50 citations were set for the research, which resulted in 13 articles, of which the 5 most important are presented in Table-1. The document entitled "Efficiency of small constructed wetlands for subsurface treatment of single-family domestic effluent" has to date 117 citations, was developed by Steer [37] and published by Ecological Engineering Journal; this article was one of the first investigations carried out on the treatment of residual water in homes. Other research papers published not many years ago, such as the study by Jahangir et al. [38] and Resende *et al.* [39] have 63 and 52 citations to date, showing a high citation score in this field compared to the other articles, therefore, relatively new articles have higher citations than comparatively older articles. This indicates that newer articles are gaining more importance in a shorter duration of time.

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Table-1. Journals with the highest citations.

author	Title of the publication	number of citations
Steer D.N. (2002) [37]	Efficiency of small constructed wetlands for subsurface treatment of single-family domestic effluent	117
Alvarez JA (2008) [38]	Anaerobic digesters as a pretreatment for constructed wetlands	98
Olson MR (2004) [39]	Effects of freezing and storage temperature on MS2 viability	89
Sim CH (2008) [39]	Nutrient removal in a pilot and full-scale constructed wetland, Putrajaya City, Malaysia	86
Heistad (2006) [40]	A high-performance compact filter system treating domestic wastewater	80

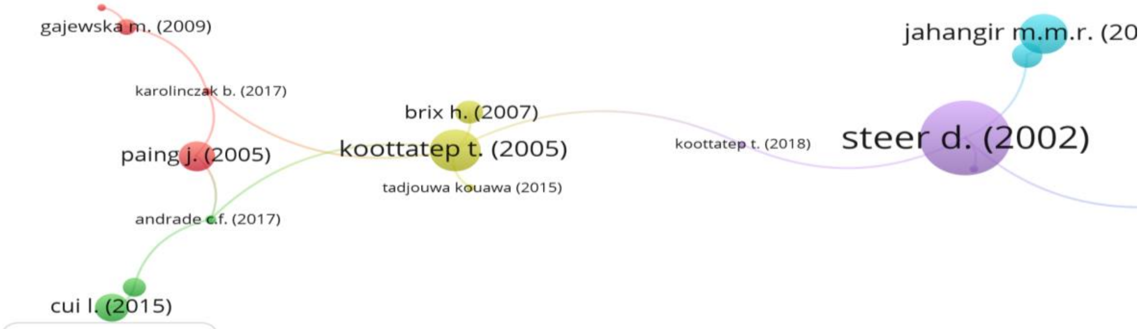

Figure-9. Authors of the most cited articles in the field of single-family domestic wastewater treatment using a septic tank and constructed wetland system.

3.2 Systematic Review of the Application of Cleaner Production in Drinking Water Treatment

3.2.1 Search results

The PRISMA model (Figure-10) was used for the identification, filtering, and inclusion of articles that were used for the systematic review. The final product of the initial search yielded a database of 315 articles, 2 articles were discarded for being notes and 313 articles remained. Of the 313 articles, 146 were removed as the search words were not found after reading the title and abstract. Subsequently, 145 articles were excluded because they were not related to the objectives of the research, studies were found where only septic tanks were investigated, or septic tanks with other secondary treatments different from CWs, some articles investigated the use of only wetlands, all the above were excluded. Finally, 10 articles were excluded after the complete reading because they were not related to the criteria established in the questions, resulting in 10 articles for the systematic review.

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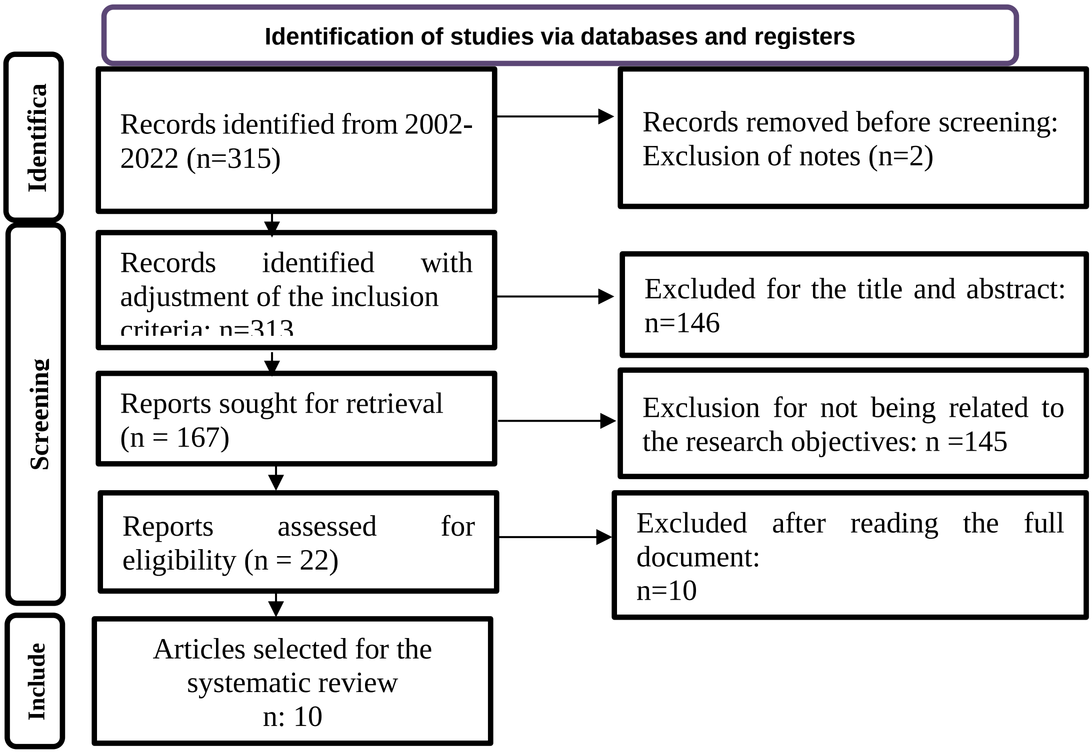

Q1. Does the integration of a septic tank with a wetland improve performance?

The implementation of a septic tank is necessary in homes that do not have access to a centralized sewerage network, however, the septic tank alone is not enough to purify domestic wastewater, therefore, and a secondary treatment is needed: constructed wetland. Constructed wetlands play a super interesting role in the decentralization of wastewater systems [30].

Implementing a properly designed CW, as well as an efficient primary treatment system improves the quality of the wastewater effluent (WW).

Despite the wide use of the septic tank as a domestic wastewater treatment system, it does not remove enough BOD_5 and COD to comply with regulations [41]. Some authors have incorporated other types of secondary treatment other than CWs into the septic tank.

Q2. What are the main characteristics of the system integrated by septic tank and constructed wetlands in houses for the treatment of residual water?

Most septic tanks constructed of concrete and brick are rectangular, have a baffle that divides the tank, and access points that allow inspection and cleaning. The first chamber occupies approximately two-thirds of the total volume of the tank. However, the use of dividers in septic tanks has been applied in a small number of investigations.

Among the advantages of the septic tank are appropriate for rural communities, infrequent cleaning, low cost of construction and operation, and minimum degree of difficulty in operation and maintenance if there is sludge removal infrastructure. Among the disadvantages we can mention: are limited use for small populations, it requires facilities for sludge removal (pumps, trucks with vacuum pumps), they require additional systems for the treatment of their effluents, and possible water leaks.

Authors such as Nasr and Mikhaeil [41] have studied the benefits of using modifications in septic tanks, their study consisted of the implementation of baffles inside the septic tank, and they found improvements in some parameters such as BOD5, COD, and total suspended solids (TSS).) compared to conventional septic tanks, in their study they took three different hydraulic retention times of 24, 48 and 72h, reaching the best results at 72h, the SST had a percentage reduction of 62.5% in the conventional tank while with baffles had removal of 76%, for DBO5 the removal in conventional tanks was 68.4% while in the septic tank with the baffle, it was of the order of 76.5%, for COD it had a variation of 65.3% in conventional tanks and for the one with the deflector installed it was 74%.

Anila [42] installed vertical baffles in a pit and found at the end of his study the elimination of 99% of total coliforms, 99.57% of TSS, 46.83% of ammoniacal nitrogen, 31.08% of nitrate nitrogen, 48.39% of total Kjeldahl nitrogen, 94.4% of BOD and 71.74% phosphates. This indicates that the implementation of baffles improves the performance of septic tanks.

On the other hand, to treat wastewater from a house based on constructed wetlands we need to know that we always need a primary treatment, which is given by the septic tank. Wetlands are used as a secondary treatment. Subsurface flow wetlands are characterized because the circulation of water within the system is carried out through a granular medium, where they are in contact with the roots of plants.

Constructed wetlands have been studied for the past two decades as a new treatment alternative for on-site domestic wastewater. The removal of contaminants within these systems occurs through complex physicochemical and microbiological interactions that occur by slowly passing wastewater through a bed of substrate (sand, gravel, clay) and emergent vegetation. The vegetation used in this type of wetlands is the same that colonizes natural wetlands: emergent aquatic plants (reeds, rushes, cattails, etc.), helophytes that develop in shallow waters, rooted in the subsoil, and whose stems and leaves emerge out of the water.

Q3. What is the efficiency of the treatment system integrated by a septic tank and a constructed wetland?

The parameters monitored in the reviewed articles were COD, BOD, Nitrogen, Phosphorus, and fecal coliforms, whose values are presented in Table-2. Evidencing high removal of COD and, BOD; while there has been between a moderate and low removal of nitrogen and phosphorus. The total coliforms measured in some studies indicated a removal between 90 and 99% [43, 44,45]

Table-2. Efficiencies obtained in the septic tank + wetland systems.

COD	BOD	Nitrogen	Phosphate	Author
93	95		44	Vargas et al. (2022) [43]
72	82	70	70	Koottatep et al. (2021) [16]
87	87	97	91	Calheiro et al. (2019) [44]
90				Paulo et al. (2019) [46]
83	88	82	fifteen	Garzón Zúñiga et al.2016 [45]
71.3-91.4	75.3-91	29.5-77.2	12.8-58.3	Avelar et al., (2019) [47]
		29	10	Gill and Luanaigh (2011) [48]
		35	28-45	Gill et al. (2011) [49]
74.9-95.5	78.5-95.9			Gajewska et al. (2099) [50]
	58-99	11-82		Zaytsev et al. (2007) [51]

4. DISCUSSIONS

Choosing an adequate system to treat domestic wastewater from rural communities is not an easy task, since several factors must be considered, from costs to environmental sustainability and durability over time, therefore, to give a recommendation the factors mentioned above and what is recommended by the literature studied must be taken into account. The systems analyzed in this review are composed of a septic tank for the removal of suspended solids and to avoid clogging problems in constructed wetlands.

The research carried out by Calheiros *et al.* [44] aimed to investigate the reduction of the toxicity of domestic wastewater after passing through a biosystem composed of a system integrated by ST and CW. This system was implemented in a tourist house located in a rural area. This system was able to remove carbon and nutrients from the water with a marked reduction in its toxicity.

Paulo *et al*. [46] in their study used an evapotranspiration tank that functioned as a natural hybrid system, based on soil and plants, which is a combination of an incorporated septic tank with a constructed wetland, which was used for sewage treatment. The results indicated that the evapotranspiration tank could receive 740 L d−1 providing a COD removal of around 90 %.

Garzón- Zuñiga *et al.* [45] in their study evaluated a system to treat wastewater from a house. This system combined the serial operation of a septic tank (ST), a biofilter (BF), and a constructed wetland (CW). The BF used wood chips as the filter medium (FM). The CW worked with a horizontal subsurface flow, and it was packed with gravel and planted with papyrus and other ornamental plants, the quality of the effluent obtained was good enough to be directly reused in patios, washing activities, irrigation of green areas and use of sanitary [52]. The parameters analyzed were biochemical oxygen demand, fecal coliforms, helminth eggs, oil, and fats.

Gill and O'Luanaigh [48] for their study built a system consisting of a septic tank and two horizontal groundflow wetlands in Ireland, one wetland functioned as secondary treatment and the other as tertiary treatment for domestic effluents from a single house. N removal was found to be low, with only 29% TN removal in the secondary wetland and 41% removal in the tertiary wetland.

Gill *et al.* [49] in a study applied to single-family homes, implemented septic tanks followed by artificial wetlands for wastewater treatment. Total N removal was only 29% and 30% in secondary and tertiary treatment wetlands; meanwhile, the removal of total P in the wetlands averaged from 28% to 45%.

Gajewska *et al*. [50] tested a system consisting of a septic tank followed by multistage (hybrid) constructed wetlands, with horizontal and vertical flow for wastewater treatment. The average efficiency removal of BOD_5 was 86.7%.

Brix *et al*. [53] designed a system consisting of conventional septic tanks for the treatment of sewage from individual households in Thailand. They also designed a system for the treatment of effluents from the septic tank and gray water, made up of constructed wetlands in several stages, specifically subsurface wetlands with vertical flow, subsurface with horizontal flow, and surface flow of free water. These authors indicate that the Danish Embassy will finance the operation and maintenance of the described systems for 5 years. As system performance data becomes available, knowledge about how to design and build appropriate low-tech systems will increase.

The present systematic review seeks to make a contribution to research in this field, allowing knowledge and dissemination of this domestic wastewater treatment integrated by ST and CW, which allows for improving the health conditions of dispersed rural populations. The results were obtained through an exhaustive search in the Scopus databases for articles that allow for a contextualization of the conditions of the septic tank and wetland systems used at the single-family level.

Future Investigations

According to the different documents consulted, the septic tanks used have a single chamber or two chambers separated by a baffle. Therefore, research should continue on modifications in the septic tank, in such a way that it is provided with several baffles forming several anaerobic chambers to remove and degrade organic matter, improving the quality of the treatment. These modifications guarantee that the wastewater is forced to pass through the sludge by the arrangement of the baffles, avoiding the resuspension of microorganisms; the anaerobic bacteria present in the sludge degrade part of the suspended organic matter present in the wastewater. It is suggested that pilot studies be carried out testing flowering ornamental plants planted in the CWs, in such a way that the wetland landscape can be improved [54]. Likewise, research should be done to develop theoretical models to predict the degree or levels of efficiency of the ST + CW system. Likewise, there is a lack of research to assess whether the effluent produced by an ST+CW system can be reused for agriculture or any other specific use.

CONCLUSIONS

The results of the scientometric analysis indicate that there is an increasing number of annual publications from January 2002 to November 2022. This increase is mainly due to the concern on the part of researchers in evaluating wastewater treatment on site. The United States is the country with the highest published production on the use of ST with CWs for the treatment of domestic wastewater at the single-family level. The largest number of articles published on this topic were published mainly in high-impact journals, including Water Science and Technology, Ecological Engineering, and Desalination and Water Treatment. The article with the highest number of citations is called "Efficiency of small constructed wetlands for subsurface treatment of single-family domestic effluent" and was published by Steer *et al.* (2002) in the Ecological Engineering journal. Additionally, the affiliations with the largest number of published documents are the Federal University of Vicosa, South China Agricultural University, and the Norwegian Institute of Bioeconomy Research with 6 publications in each institution. The most recurring words as keywords are constructed wetland, wastewater treatment, septic tank, and domestic wastewater. Therefore, world research on this subject depends on scientific results produced in the USA, Brazil, and China. This study used bibliometric data that is readily available in Scopus. The integrated septic tank-constructed wetland system is an option for the treatment of domestic wastewater since it achieves high BOD5 and COD removal efficiencies. Meanwhile, the removal of phosphorus and nitrogen has been moderate. With these efficiencies, the integrated system complies with the Maximum Permissible Limits for domestic effluent discharges. This integrated system proves to be efficient in the treatment of household wastewater. The systematic study revealed that constructed wetlands are a viable and environmentally friendly natural wastewater management technology. Constructed wetlands are effective wastewater treatment mechanisms that are ideal for developing countries as they involve minimal operating costs as well as simple technology. Other aspects in this field that should be investigated include the reuse of effluents in the agricultural field and the irrigation of green spaces. Furthermore, it is important to investigate the kinetics of the treatment systems. Published studies on the potential financial cost of the ST+CW system are still limited.

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