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Articles

Holistic perspective of slaughterhouse wastewater from the context of the PENTApropeller: A scoping review

Perspectiva holística de las aguas residuales de los mataderos desde el contexto de la PENTAhélice: una revisión de alcance

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Abstract

The indiscriminate disposal of wastewater from slaughterhouses causes problems. This scoping review aims to identify the interest and implications of the PENTApropeller stakeholders —business, academy, government, society, and the environment— in the management of wastewater from slaughterhouses. PRISMA-ScR was used to collect and analyze studies during 2020-2024. The explicit stakeholders identified are academy, government, and industry, with a participation of 76.92, 15.39 and 7.69 %, respectively, while society and the environment are implicit stakeholders that are considered by the explicit ones. Teachers and students generate and apply knowledge that, through government funding, can develop management strategies at the laboratory level and disseminate the results. By linking with the private sector, these results can be leveraged into technological developments, with the backing of compliance with government regulations. The environment is an actor composed of academy, industry, and government, as the beneficiary of strategies that remove the physical and chemical parameters that affect it. Society does not have a direct presence, but its intervention derives from academy's intention to address risks to human health. Finally, comprehensive collaboration between stakeholders is essential in the development of sustainable multidisciplinary and transdisciplinary strategies among PENTApropeller stakeholders, for the benefit of humanity and the environment.

Keywords: literature reviews, waste water, food industry, meat, universities, government, industry, environment, society, PRISMA-ScR.

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Resumen

La disposición indiscriminada de las aguas residuales de los mataderos genera afecciones. Esta revisión de alcance tiene el objetivo de identificar el interés y las implicaciones de los actores de la PENTAhélice —empresa, academia, gobierno, sociedad y medio ambiente— en la gestión de las aguas residuales de los mataderos. *PRISMA-ScR* se utilizó para recabar y analizar estudios durante 2020-2024. Se identificó que los actores explícitos son la academia, el gobierno y la industria con una participación del 76.92, 15.39 y 7.69 %, respectivamente; mientras que la sociedad y medio ambiente son actores implícitos que son considerados por los explícitos. Los profesores y alumnos generan y aplican conocimiento que mediante el financiamiento del gobierno puede desarrollar estrategias de gestión a nivel laboratorio y divulgar los resultados; al vincularse con el sector privado, estos resultados pueden potencializarse en desarrollos tecnológicos, con el respaldo en el cumplimiento de la normatividad que enmarca el gobierno. El medio ambiente es un actor integrado por la academia, industria y gobierno, como beneficiario de las estrategias que remueven parámetros fisicoquímicos que lo afectan. La sociedad no evidencia una presencia directa, sino su intervención deriva de la intención de la academia por atender el riesgo en la salud humana. Finalmente, la colaboración integral entre los actores es fundamental en el desarrollo de estrategias sustentables multidisciplinarias y transdisciplinarias entre los actores de la PENTAhélice en beneficio de la humanidad y del medio ambiente.

Palabras clave: estudio bibliográfico, agua residual, industria alimentaria, carne, universidad, gobierno, industria, medio ambiente, sociedad, PRISMA-ScR.

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Introduction

The wastewater cogenerated in the slaughterhouses by the production process of processing and disposal of meat for human consumption contains a high organic load that favors the development of pathogenic microorganisms, it also contains parasite eggs, and pesticide residues that were present in the animal during its feeding, chlorine from the cleaning of the facilities, brine, among other components. So, wastewater from slaughterhouses turns out to be a potentially toxic contaminant of soil and water, which is presented by the decomposition of organic matter. Shi *et al*. (2023) mention that the high concentration of organic matter without sufficient treatment is a factor of serious contamination of the natural environment. In addition, wastewater, due to its rapid decomposition, releases methane, thus generating unpleasant odors that attract harmful fauna —*e.g.*, flies, cockroaches, rats— that transmit diseases; in addition to this, they generate the formation of leachate that drags pollutants into surface waters or infiltrates aquifers, which ultimately deteriorate the aquifers that are a source of water for human consumption and agriculture, thereby affecting the environment (COFEPRIS, 2006). Mainly in developing countries, the indiscriminate disposal of wastewater from slaughterhouses causes waterborne diseases (Dos Santos-Pereira *et al*., 2024).

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Worldwide, wastewater from slaughterhouses is considered to be one of the most polluted (Mkilima *et al*., 2024). In addition, due to their characteristics, they are the focus of antibiotic-resistant bacteria and antimicrobial residues (Savin *et al*., 2020). In Mexico, according to the "Agri-Food and Fisheries Information Service" (AFFIS) in its 2023 report, it mentions that there are 1 198 slaughterhouses, of which 903 are municipal (Inspection Type of the Secretary of Health, ITSH), 174 are private and 121 federal (Federal Inspection Type, FIT) (Secretaría de Agricultura y Desarrollo Rural, 2023). Depending on the type of activity to be carried out, the equipment, and the purpose for which the slaughterhouse was created, these are classified into FIT slaughterhouses and ITSH slaughterhouses. The ITSH slaughterhouses are known as "municipal slaughterhouses" for the disposal of meat for the consumption of the inhabitants of the municipality; while the FIT slaughterhouse, which in addition to complying with the basic services of the ITSH, offers an industrialization of meat products for large-scale marketing at the national level and for export (INAP, 2019).

According to the standard "Products and services. Sanitary specifications in establishments dedicated to the slaughter and processing of animals for supply, storage, transport, and sale. Sanitary specifications for products", the slaughterhouse is considered to be any establishment intended for the slaughter and slaughter of animals for slaughter; with a slaughter capacity of at least 28 head of large livestock, 56 head of small livestock or 1 000 domestic birds per day, either individually or combined (Secretaría de Salud, 2004). The slaughter considers the livestock species: cattle, pigs, sheep, goats, horses and poultry (Secretaría de Agricultura y Desarrollo Rural, 2023). Slaughterhouses are public services, provided to individuals by municipalities; to provide facilities for

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the adequate slaughter of animals that people will later consume. The National Institute of Public Administration (INAP), defines the "municipal slaughterhouse" as an entity owned by the municipality focused on the slaughter of animals for consumption as food for part of the population; in areas such as landing pens —receives the cattle to be slaughtered— and deposit —protects the cattle for slaughter after the ownership, sanitary and fiscal requirements have been met—, and slaughter (involves the slaughter, removal of visors and the cutting of meat), through the efficient use of personnel, equipment, and necessary tools (INAP, 2019).

According to the General Law for the Prevention and Integral Management of Waste (GLPIMW, in spanish), waste is any solid or semi-solid, liquid or gas material that an owner or possessor discards. Also, throughout the production process of the slaughterhouse, various wastes are generated; in this sense, and considering the classification of the GLPIMW, it is possible to establish that special handling waste and hazardous waste are generated (PROFEPA, 2015). The main waste generated in slaughterhouses is wastewater, blood, and rumen content; these being of large volume and highly polluting; in addition to this, municipal slaughterhouses generally do not have adequate waste separation systems, which causes a mixture of waste with a high organic load, and which unfortunately in some cases is dumped indiscriminately into public drainage, aquifers or the environment. The main composition of wastewater from this sector includes blood, excrement, rumen content, fat, feathers, and bones. In the document "Risk Assessment of Municipal Slaughterhouses and Slaughterhouses" (in spanish) of the Federal Commission for the Protection against Sanitary Risks (COFEPRIS in spanish), the average values of the main components of wastewater are presented according to the COFEPRIS (COFEPRIS, 2006). The animal´s

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blood, urine, and excrement produce Nitrogen (N) in the wastewater; while the alkaline pH of the wastewater, other compounds in the wastewater, and ammonium (NH_4-N), generate ammonium hydroxide (NH_4OH); organic matter originates from water that in contact with carcasses, excrement, and blood, among other elements; from the undigested stomach contents Phosphorus (P) is produced; likewise, sodium (Na) is generated from the excrement and food present in the animal's stomach, as well as from the pickling process (Ibidem). In addition, veterinary pharmaceuticals and surfactants may be present (Sandoval *et al*., 2024) toxic to aquatic life (Sandoval & Salazar, 2021). Municipal slaughterhouses consume a large amount of water. Water is mainly used in the processes of receiving and handling livestock, in stunning and slaughter, for evisceration, in post-mortem inspection, and in carcass detailing and washing. According to Quiroga *et al*. (1994) the water needed for the slaughter and slaughter process, for larger animals is 1 000 liters; for pigs, the need is 450 liters; while 100 and 20 liters are used, for sheep goats, and poultry, respectively. The slaughterhouse is considered to be the second largest consumer of water within the livestock processing value chain (Teo *et al*., 2023).

The wastewater cogenerated by slaughterhouses has been treated from various approaches. Generally, wastewater treatment can be developed by electrocoagulation, membrane separation, advanced oxidation, physicochemical processes and biological treatments (Aziz *et al*., 2019). Biological processes have the characteristic that they are long-treatment, polymeric, include adjunct growth processes, and operate at high rates of organic load (Derakhshan *et al*., 2023). Kothari *et al*. (2024) present the treatment of wastewater from slaughterhouses is presented using a biological approach, *i.e.*, bioremediation, which includes

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phytoremediation. The Microbial Fuel Cell and Electro-Fenton schemes are combined to treat slaughterhouse wastewater; separately, the two treatments report good results; however, better efficiency is obtained with integrated treatment that improves water quality, but is not suitable for human consumption (Mkilima *et al*., 2024). Shi *et al*. (2023) describe a treatment system that uses fungi and algae, *Chlorella sp*. DT025 and *Penicillium sp*. A treatment that uses electrocoagulation with aluminum and iron electrodes is described by Sandoval *et al*. (2024). Ramírez-Montoya *et al*. (2023), anaerobic treatment is improved in the treatment of slaughterhouse wastewater using carbon as a methanogenic enhancer.

In addition, Feng *et al*. (2009), the development of an Anaerobic Carrier Reactor with Baffles, which is made with bamboo carriers in treating slaughterhouse wastewater, is described. Fedorov *et al*. (2023), the use of Hydrodynamic Cavitation in the activation of sodium percarbonate and ozone (O_3) is described, thereby degrading the recalcitrant 1.4-dioxane. A novel biochar coupled with nano-valent copper (nZVCu/BC), in wastewater remediation is described by Iqbal *et al*. (2021). De Nardi *et al*. (2008), a Dissolved Air Flotation (DAF) system and two Up-flow Anaerobic Sludge Blanket reactors are presented. Dosta *et al*. (2008), a Sequencing Batch Reactor is presented for the biological removal of Chemical Oxygen Demand (COD), Suspended Solids, and N, including a coagulation/flocculation step. Ramadan *et al*. (2023), an Anaerobic Membrane Bioreactors is used in the treatment of poultry slaughterhouse wastewater. A strategy that integrates Anaerobic Digestion and Electrocoagulation is described by Adou *et al*. (2022). Advanced oxidation processes were used in the treatment of wastewater from a poultry slaughterhouse, namely iron salts, potassium persulfate, titanium dioxide, and hydrogen peroxide (Kanafin *et al*., 2022). Two

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strategies involving the use of ozone in wastewater treatment involve: (i) preozonation followed by a UVC/H_2O_2 process, and (ii) simultaneous application of O_3/UVC/H_2O_2 (Alfonso-Muniozguren *et al*., 2021). Bingo *et al*. (2021), an integrative approach is presented that considers an Expanded Granular Sludge Bed (EGSB) bioreactor together with a submerged Ultrafiltration (UF) membrane. A simple and combined electrochemical oxidation treatment is presented by Terán-Hilares *et al*. (2021).

Sandoval and Salazar (2021), the electrochemical treatment scheme for the purpose of generating electricity is described. Zahedi *et al*. (2021), methane is produced as part of anaerobic wastewater treatment. Wastewater from slaughterhouses is remediated and biomass is produced, using various concentrations of wastewater, by Azam *et al*. (2020). The treatment of wastewater from slaughterhouses and the culture of microalgae Chlorella vulgaris using acid precipitation (H_2SO_4) in both discontinuous and continuous processes, is described b Terán-Hilares *et al*. (2021). Previous studies show that there are strategies developed to address the management of solid and liquid waste, cogenerated by the process of slaughterhouses, considering strategies for the redesign of products and processes. However, it is a reality that the multiple problems derived from the generation, and management of wastewater are not isolated situations but integral.

However, a scheme that can meet this need is the context of the Mexican Innovation Model: The PENTApropeller and Open Innovation (see Figure 1), which emerged in 2019. The PENTApropeller, as a Mexican model of linkage between industry, academy, and government, scales its impact, through the incorporation of society and the environment; through the generation of innovation that transforms reality, as a

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responsible economic development scheme, with which it is possible to face priority national problems. The PENTApropeller presents a vision of the SECIHTI (Secretaría de Ciencia, Humanidades, Tecnología e Innovación) of cutting-edge technological change and open innovation in a virtuous and harmonious way of the five sectors of the innovation ecosystem. And well, the model of the PENTApropeller of Mexico can be scaled up internationally.

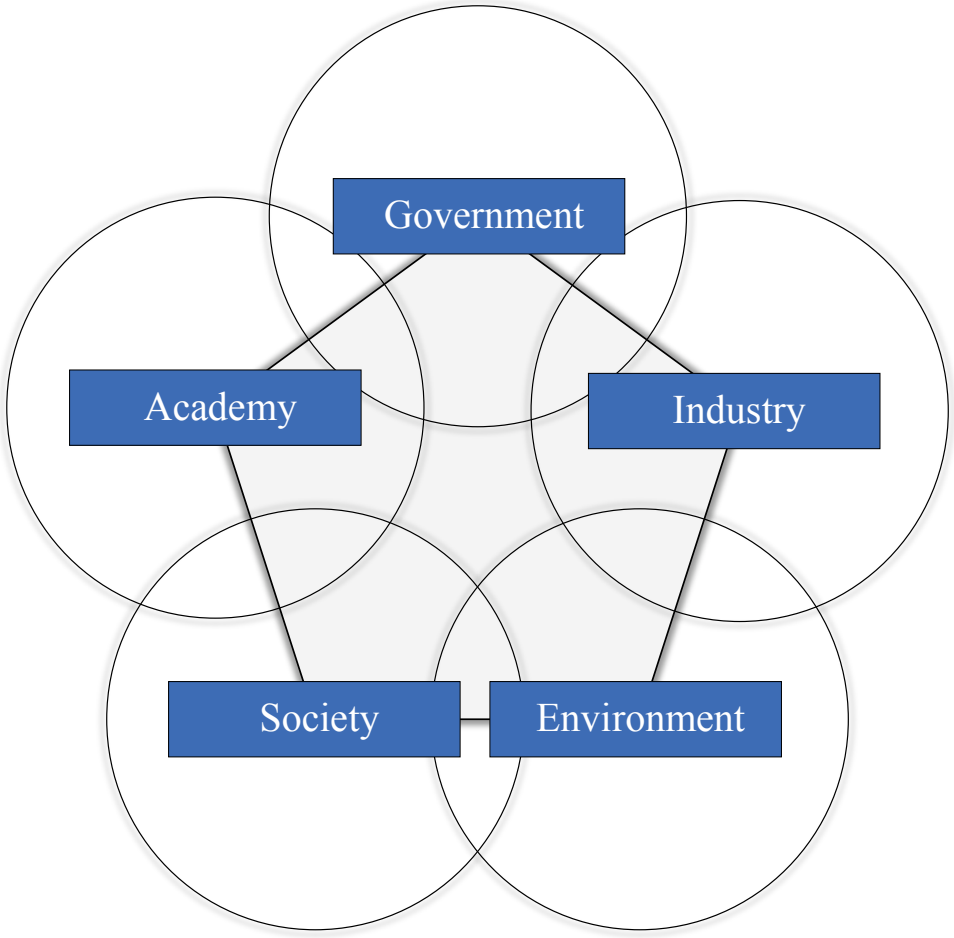


Figure 1. PENTApropeller model from SECIHTI.

So, it is a reality that there are multiple efforts that emerge from different stakeholders in wastewater management; however, it is unclear

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what kind of information is available in the literature on the holistic involvement of actors in the development of strategies for the management of slaughterhouse co-generated wastewater. That is why a scoping review was carried out to systematically map the research in this area with the aim of identifying and analyzing, if in the development of slaughterhouse wastewater remediation strategies, the main actors —PENTApropeller: academy, government, industry, society, and environment— involved and interested in the development of such strategies are considered in a holistic and integral way, that maintain and enhance the socio-economic development of humanity without compromising the environment; as well as their integration and intervention in the development of these strategies, likewise, it is interesting to identify the degree of intervention of the actors evidenced in the dissemination of results through scientific publications, and the way in which they interact with each other; as well as identifying the existing knowledge gap. The following research question was asked: What has been reported in the literature about the holistic intervention of the actors involved in wastewater management?

This scoping review is aimed at researchers and technology developers, who design and generate wastewater management strategies; and at all those interested in the development of environmental conservation policies and schemes, from a holistic perspective. This review can be the basis for developing more in-depth and detailed reviews. The review adopts a strategy of backward analysis of secondary data from the published contributions. Scoping review, as a strategy, allows for systematic search, selection, and synthesis of existing knowledge to map key concepts, types of evidence, and knowledge gaps of this phenomenon. The approach used guarantees a formal and

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structured review, which allows for the extraction and analysis of reliable information on the implications of the stakeholders that must be considered in the development of strategies for remediation and conservation of natural resources considering a revaluation of treated wastes, under a holistic perspective of the stakeholders. Finally, Section I contains the Introduction; the rest of the document is organized as follows: Section II Material and Methods, describes the methodology used to identify and collect the studies; Section III Results, presents the findings identified in the studies reviewed; Section IV Discussion, presents the main reflections of the evidence of the studies; finally, Section V concludes the scoping review study of the implications of stakeholders in the development of strategies for the maintenance and conservation of the ecosystem, under a holistic perspective.

Material and methods

A Scope Review (Gómez, 2023; Mak & Thomas, 2022) was carried out as a systematic methodological framework aligned with the statement of the Preferred Reporting Items for Systematic reviews and Meta-Analyses PRISMA for Scoping Reviews (PRISMA-ScR) (Tricco *et al*., 2018). It is not the objective of the scoping review to assess the quality of the literature, but to identify the depth and breadth of the literature on the interest and involvement of the actors of the PENTApropeller. The protocol was prospectively registered in the Open Science Framework on December 31, 2024 (https://osf.io/eu63v/) (Montiel-Rosales *et al*., 2024); while the PRISMA-P Preferred Reporting Items for Systematic review and Meta-Analysis Protocols (PRISMA-P) were used for its drafting, and it was reviewed by the research team.

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The inclusion and exclusion criteria of the studies were aligned with the PICO scheme (P: population, I: intervention, C: comparator, O: outcome) (Prill *et al*., 2021). The studies, to be included in the review, had to consider the development of strategies for the management of cogenerated wastewater by the production process of the slaughterhouses, considering the incorporation of at least three actors identified by the PENTApropeller. The review considered articles published in peer-reviewed journals, during the period from January 2020 to December 2024, that were written in English, in addition to including the perspective of stakeholders in wastewater management. Experimental studies at laboratory and field level were included, with quantitative results of the efficiency of the contaminant removal system. On the other hand, studies that did not fit into the conceptual framework of the study were excluded, *e.g.*, simulation models, and evaluation of hypothetical cases. The literature search for the scoping review was not limited by discipline or subdiscipline; but review studies, conference proceedings, books, book chapters, non-peer-reviewed articles, and intellectual property registrations were not considered.

The identification of the studies was carried out by searching the databases: Web of Science (WoS), Scopus, ScienceDirect, SpringerLink and Google Academic; during the period from January 2020 to December 2024. The search strategies were designed and perfected by the research team, through discussions. On December 23, the following databases were consulted: WoS (Clarivate, 2024), Scopus (Elsevier, 2024b), ScienceDirect (Elsevier, 2024a), SpringerLink (SpringerNature, 2024), and Google Academic (Google, 2024). With the intention of considering relevant studies within the review, the authors decided to include several

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databases. The search results were exported to Mendeley Cite v1.67.0 (Elsevier Ltd., 2024), where duplicates were removed.

The search strategy was peer-reviewed, using the Peer Review of Electronic Search Strategies (McGowan *et al*., 2016). Key terms were used in the search closely related to the study framework; this selection of terms was made jointly and in agreement by the authors. Similarly, the search strategy for each database was designed and reviewed by the authors; for this purpose, the Boolean operators "AND", "OR" and "NOT", were used to define the search code made up of keywords. Due to the characteristics of each database, codes were designed for each one (see Table 1).

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Table 1. Search strategies.

Database	Search Algorithm
WoS	ABS-KEY ("Slaughterhouses" AND "Wastewater" OR "Water Treatment" OR "Water Treatment System" OR "Water Treatment Technologies") AND NOT TITLE ("Review" OR "Literature" OR "Bibliometric") AND ALL FIELDS ("Academy" OR "Government" OR "Industry" OR "Society" OR "Environment")
Scopus	ABS-KEY ("Slaughterhouses" AND "Wastewater" OR "Water Treatment" OR "Water Treatment System" OR "Water Treatment Technologies") AND NOT TITLE ("Review" OR "Literature" OR "Bibliometric") AND ALL ("Academy" OR "Government" OR "Industry" OR "Society" OR "Environment") AND PUBYEAR AFT 2020
ScienceDirect	ABS-KEY ("Slaughterhouses" AND "Wastewater" OR "Water Treatment" OR "Water Treatment System" OR "Water Treatment Technologies") AND NOT TITLE ("Review" OR "Literature" OR "Bibliometric") AND ALL FIELDS ("Academy" OR "Government" OR "Industry" OR "Society" OR "Environment")
SpringerLink	("Slaughterhouses" AND "Wastewater" OR "Water Treatment" OR "Water Treatment System" OR "Water Treatment Technologies") AND ("Academy" OR "Government" OR "Industry" OR "Society" OR "Environment") AND NOT ("Review" OR "Literature" OR "Bibliometric")
Google Scholar	("Slaughterhouses" AND "Wastewater" OR "Water Treatment" OR "Water Treatment System" OR "Water Treatment Technologies") AND ("Academy" OR "Government" OR "Industry" OR "Society" OR "Environment")

With the intention of obtaining an objective review, all authors individually reviewed all studies. We selected only those studies that were relevant to the scoping review; to do this, the authors sequentially evaluated titles, abstracts, and keywords. Only those studies that met the inclusion criteria were considered as part of the review; while all those studies irrelevant to the PICO scheme were excluded. Once the potential studies were defined, the full text was read individually by each author.

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However, when there were disagreements about study selection and data extraction, the authors agreed to include or exclude them.

Subsequently, data from the studies were extracted equally among the authors with double verification. To do this, a knowledge management foundation was built in Microsoft® Excel® for Microsoft 365 MSO (version 2411 build 16.0.18227.20082) of 64-bit (Microsoft Corp., 2024). While managing the references of the retrieved studies, Mendeley Cite v1.67.0 was used (Elsevier Ltd., 2024). The authors jointly developed a form that resulted in a knowledge management base on the characteristics of the studies, integrated into categories, namely, "Publication characteristics", "Slaughterhouse and wastewater treatment system features", "Actors involved in the PENTApropeller", "Physicochemical parameters reported", "Biological parameters reported", and "Other". All authors independently recorded data extracted from studies in the database, the results were discussed, and the form was iteratively updated.

The objective of the scoping review is to explore the implications and interactions of stakeholders in the development of waste management strategies. In this sense, hermeneutics was used as a method of text interpretation to interpret the information from the studies, while the quality of the knowledge synthesis method was evaluated collaboratively among the authors. The information concentrated in the knowledge management base was synthesized according to its relevance and presented in the form of tables and graphs using Microsoft® Excel® for Microsoft 365 MSO (version 2411 compilation 16.0.18227.20082) of 64 bits.

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Results

The parameters for screening were defined jointly by the authors. The inclusion and exclusion criteria were defined based on the PICO framework (Table 2); this approach improved the quality of study selection.

Table 2. Inclusion and exclusion criteria.

PICO	Inclusion Criteria	Exclusion Criteria
Population	Studies that evaluate the performance of wastewater management systems, cogenerated from slaughterhouses	Studies that evaluate the performance of wastewater management systems, cogenerated from processes other than slaughterhouses, *e.g.*, agro-industrial, alcohol, textile, mining
Intervention	Studies that show the measurement of physicochemical and/or biological parameters, the interest in reducing the implications of wastewater on the environment and society	Studies that show hypothetical results based on assumptions
Comparator	Efficiency of the treatment system for co-generated wastewater from slaughterhouses	None
Outcome	Studies developed in direction and collaboration by the main actors of the —PENTApropeller: academy, government, industry, society, and environment—	None

The search parameters and the inclusion and exclusion criteria have been established. Search algorithms based on Boolean operators (Table 1) were entered into the databases. Initially, 31 009 studies were identified —WoS with 9 969, Scopus with 7 781, ScienceDirect with 30, SpringerLink with 7 049, and Google Scholar with 6 180—. Duplicate articles were removed and removed for other reasons, such as 30 863

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studies. In addition, 53 were excluded. While 11 studies could not recover. Finally, 37 paper reviews, 3 empirical studies, and 29 not relevant were excluded. Therefore, 13 articles were considered for the review because, during the screening process, the objective was to identify studies that showed an explicit or implicit interrelationship between at least two actors in the PENTApropeller.

To this end, each article was read in its entirety and, working in pairs, the actors and their involvement were identified. Any disputes were resolved with the intervention of a third author. The 13 studies were considered for scoping review —WoS with 4, Scopus with 3, ScienceDirect with 2, SpringerLink with 2, and Google Scholar with 2—. Figure 2 shows the selection process of the studies considering previously established search strategies and eligibility criteria.

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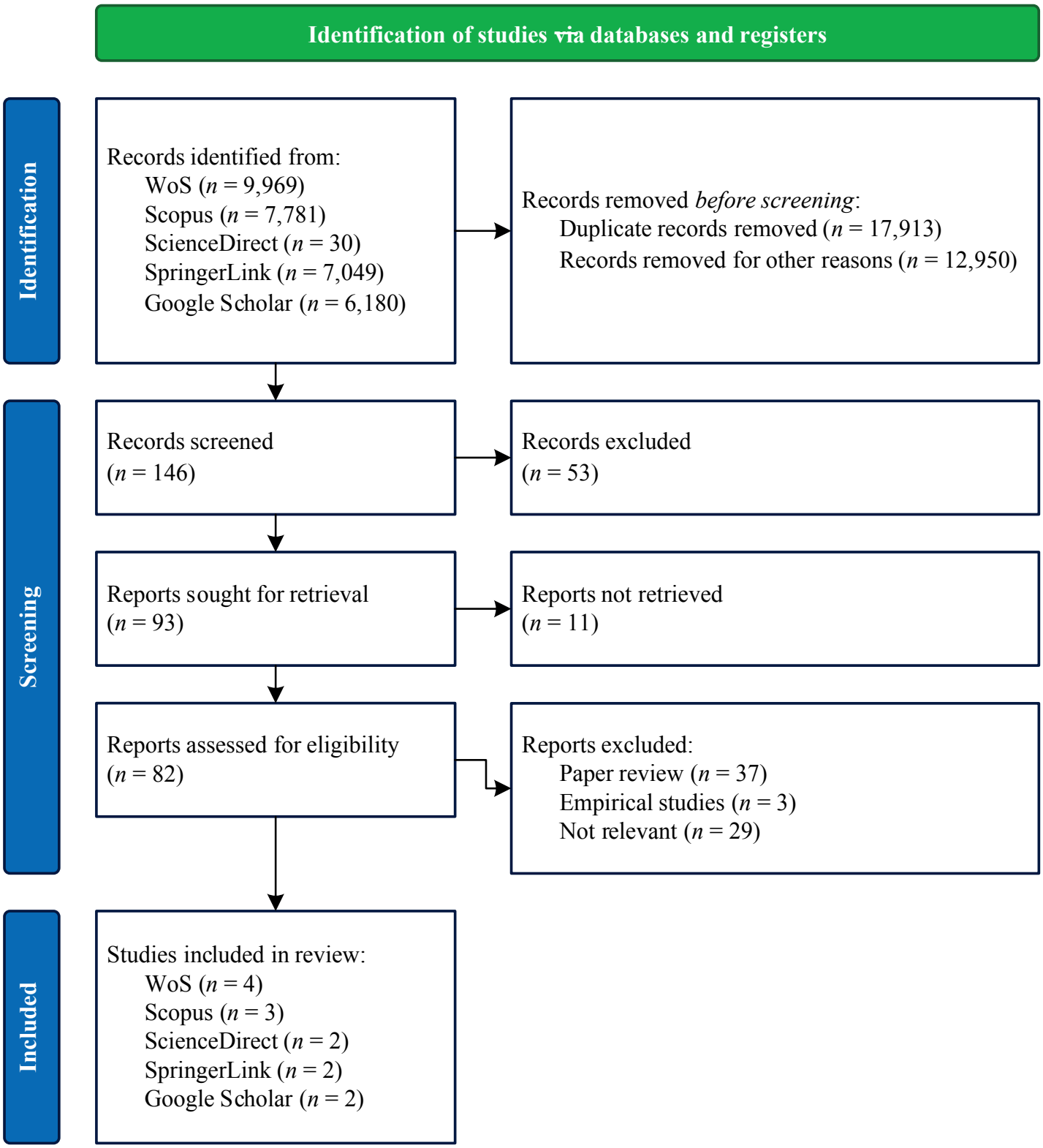


Figure 2. Selection of studies.

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Once the studies were identified, a knowledge management base was built with the features of interest for the recovery of the studies (Table 3).

Table 3. Variables of interest by category.

Category	Variables
Publication characteristics	"Year", "Publisher", "Journal", "CiteScore", "Impact Factor", "Title", and "Objective"
Features of the slaughterhouse and wastewater treatment system	"Treatment Technology", "City", "Country", and "Type of Animal"
Actors involved in the PENTApropeller	"Academy", "Government", "Industry", "Society", and "Environment"
Reported physicochemical parameters	"Temperature", "Electrical Conductivity (EC)", "Total Solids (TS)", "Volatile Solids (VS)", "Total Suspended Solids (TSS)", "Totally Dissolved Solids (TDSs)", "Total Chemical Oxygen Demand (tCOD)", "Soluble Chemical Oxygen Demand (sCOD)", "Fats, Oils, and Grease (FOG)", "Alkalinity", "Turbidity", "pH", "Biological Oxygen Demand (BOD)", "Total Organic Carbon (TOC)", "Total Nitrogen", "Total Phosphorus", "Ammonium nitrogen (NH_4-N)", "Nitrate-nitrogen (NO_3-N)", "Ammonia (NH_3)", "Sulphate", "Nickel", "Zinc", "Copper", "Cadmium", "Sludge", "Sludge (normalised per functional unit)", and "Wastewater"
Reported biological parameters	"ESKAPE Bacteria", "ESBL-producing *E. coli*", "Antimicrobial residues", "Total microbial number", "Total Coliform Count (TCC)", "Fecal Coliform Count (FCC)", "Thermo-tolerant coliform bacteria", "Pathogenic flora", "*Salmonella coliphages*", "Spores of sulfite-reducing clostridia", "*Pseudomonas aeruginosa*", "*Staphylococcus aureus*", and "*Enterococcus*"
Others	"^{1}H NMR (Nuclear Magnetic Resonance) relaxometry", "^{1}H NMR diffusometry", and "Methane"

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The objectives of the 13 retrieved studies, as well as the main features describing the cogenerated wastewater treatment system, are shown in Table 4. From this table, it can be seen that 30.77 % report wastewater from poultry slaughterhouses, 15.38 % from buffalo, 7.69 % from a slaughterhouse that slaughters cattle and pig, chicken, and pig, and finally 30.77 % of the studies do not specifically report the type of animal slaughtered in the slaughterhouse under study.

Table 4. Identification of the scope of each study.

No.	Objective	Treatment Technology	Type of Animal	Reference
1	Evaluate the performance of a laboratory-scale, multi-stage integrated plant for Poultry Slaughterhouse Wastewater (PSW) treatment	An eco-flush dosed bio-physico pre-treatment unit for fats, oil, and grease (FOG) hydrolysis prior to the PSW being fed to a Down-flow Expanded Granular Bed Reactor, coupled to a Membrane Bioreactor	Poultry	Dyosile *et al*. (2021)
2	Pre-treated in conventional aerobic biological Wastewater Treatment Plant (WWTP) on-site; and additionally operates a physical-chemical WWTP using flotation and precipitation (flocculation)	Assess the presence of ESKAPE *bacteria*, ESBL-producing *E. coli*, and antimicrobial residues in wastewater and process water that accumulates in the delivery and dirty areas of two pig slaughterhouses, as well as in their internal wastewater treatment plants. In addition, its subsequent dissemination through municipal wastewater treatment plants to receiving water bodies was investigated	Pig	Savin *et al*. (2020)
3	Model alternative wastewater treatment technologies and evaluate their performance from an environmental perspective in the context of decentralized wastewater management in a slaughterhouse	Screening; Coagulation & Flocculation; Dissolved Air Flotation; Membrane Bioreactor; and Advanced Oxidation Process	NA*	Teo *et al*. (2023)

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No.	Objective	Treatment Technology	Type of Animal	Reference
4	To evaluate the efficiency, relaxometry and diffusometry of ^{1}H low-field NMR and VIS-nearIR spectroscopy in the analysis of contaminated wastewater during the treatment process in the slaughterhouse	Advanced ^{1}H NMR relaxometry and diffusometry methods and VIS-nearIR spectroscopy	Chicken	Crainic and Fechete (2024)
5	Investigate the performance of a three-stage PSW treatment system at the laboratory scale	Multi-stage PSW treatment system consisting of an aerobic pre-treatment tank, an EGSB bioreactor coupled with a submerged UF membrane	Poultry	Bingo *et al*. (2021)
6	Finding the most effective photochemical system for the treatment of real wastewater with complex matrix, considering the total removal of organic carbon	Advanced oxidation processes	Poultry	Kanafin *et al*. (2022)
7	Remove microbial from poultry slaughterhouse wastewater	Electrolysis, ultrafiltration, and ultraviolet radiation	Poultry	Meiramkulova *et al*. (2021)
8	Evaluate the feasibility of livestock slaughterhouse wastewater treatment by integrating chemical coagulation processes and the electro-Fenton process	Chemical Coagulation and Electro-Fenton	NA	Bazrafshan *et al*. (2022)
9	Evaluate the performance and suitability of the slaughterhouse wastewater treatment plant design, and propose upgrades to improve the efficiency of the treatment process	Rotary and static screens, an equalization tank, a DAF system, aeration tanks, and clarifiers	Buffalo	Rajpal *et al*. (2022)
10	Evaluating a Pilot-Scale FBBR (Fixed-Bed Biofilm Reactor) for Slaughterhouse Wastewater Treatment in Rural Communities	FBBR	Cattle, Pig	Marín-Peña *et al*. (2024)
11	Evaluate the efficiency of using carbonized sawdust as a low-cost natural adsorbent for slaughterhouse wastewater treatment and determine optimal conditions to achieve maximum efficiency	The treatment process involves three stages: adsorption using activated carbon, which is derived from sawdust, followed by sedimentation, and finally, a slow sand filter with a modified layer of woven textile cotton	NA	Elkady *et al*. (2024)

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No.	Objective	Treatment Technology	Type of Animal	Reference
12	Separate wastewater streams from individual slaughter processes/operations based on the nature of the similarity; and, design, implement, and evaluate the performance of an improved primary wastewater treatment system	Hydrasieve (500 µm) and externally fed rotary drum filter (EFRDF, 200 µm); a primary clarifier; a skimming tank; and dissolved air flotation	Buffalo	Shende *et al*. (2022)
13	Evaluate the efficiency and performance of Internal Circulation Anaerobic Granular Sludge Reactor (ICAGSR) in terms of organic contaminant removal and biogas production using granular anaerobic sludge	ICAGSR	NA	Hellal *et al*. (2024)

* Not Available.

Furthermore, Figure 3 shows the behavior of the number of publications per year, depending on the established search period (5 years). From the graphic analysis, it is possible to identify that 61.54 % of the studies reviewed were published in 2022; this situation reflects that the PENTApropeller model is related to the interests of the scientific community and that at the end of the review period this approach is strengthened.

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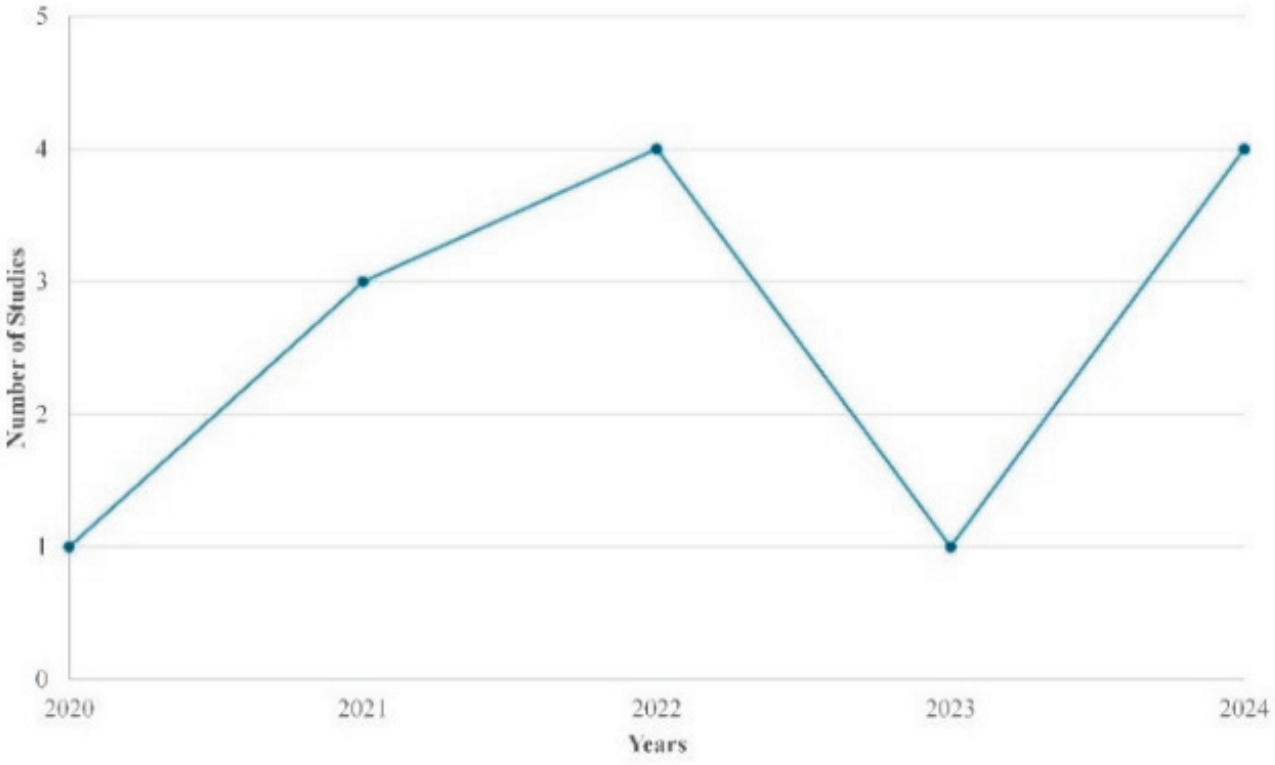
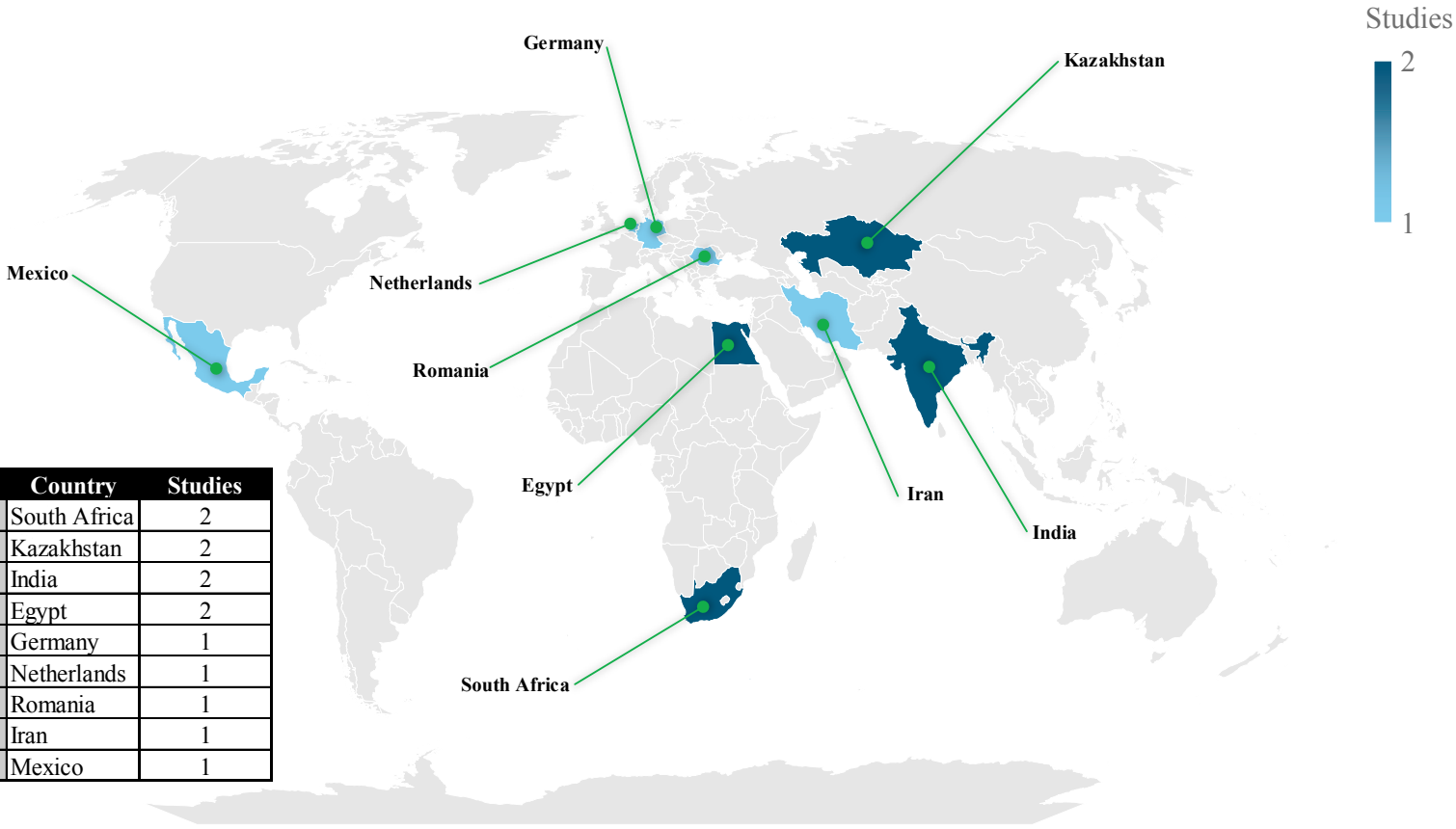


Figure 3. Behavior of study publications during the search period.

Figure 4 shows the distribution of recovered studies in various countries around the world. In this sense, South Africa, Kazakhstan, India, and Egypt, report 15.38 % each; while Germany, Netherlands, Romania, Iran, and Mexico contributed 7.69 % of the studies retrieved, each. While at the continental level, Asia accounts for 38.46 % of the contributions, followed by Africa with 30.77 %, Europe with 23.08 %, and finally America with 7.69 %.

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No.	Country	Studies
1	South Africa	2
2	Kazakhstan	2
3	India	2
4	Egypt	2
5	Germany	1
6	Netherlands	1
7	Romania	1
8	Iran	1
9	Mexico	1

Figure 4. Distribution of studies in the world.

The retrieved studies were analyzed by identifying the interest and involvement of the actors of the PENTApropeller —academy, government, industry, society, and environment—, for each study (Figure 5). From this analysis, it was identified that it is directly the academy, made up of professors-researchers, students and academic entities, who is the main actor interested and involved in the development of strategies for the efficient management of wastewater from slaughterhouses. In collaboration with the academy, there is evidence of a close relationship with the industry, in this case the slaughterhouses, who allow the studies to be developed in their facilities by improving their processes, with a

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clear goal: to improve production efficiency without affecting the environment or society —in some cases—. Likewise, the actors; academy, government and industry directly consider the environment as a main actor on which the strategies that are developed, by remedying the aversions that humanity generates for its socioeconomic development activity on the environment. In addition, some of the studies reflect that the development of strategies indirectly considers society, because they seek to improve the wastewater treatment process of slaughterhouses with the intention of reducing the risk of occupationally exposed personnel to the bacteria that are generated by exposure to the effluent. In the same way, there is evidence of an intrinsic participation of government entities in the development of strategies, their main participation being through calls on which research projects are financed. Finally, it is evident that to date there is no direct interest in the part of society in collaboration, in the development of strategies that contribute to a more sustainable society.



Figure 5. Direct and indirect interest and implications of the actors of the PENTApropeller.

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Figure 6 shows the relationship identified of the actors of the PENTApropeller, in each of the studies. As mentioned above, some studies reflect a direct interest and involvement; while, in other cases, this relationship is indirect but exists; likewise, there is evidence of a lack of consideration of actors in some studies. It was clearly identified that no study holistically considers the actors of the PENTApropeller, in the development of strategies. Only two studies, 15.38 %, when indirectly considering some actors, achieve an approach to a holistic approach.

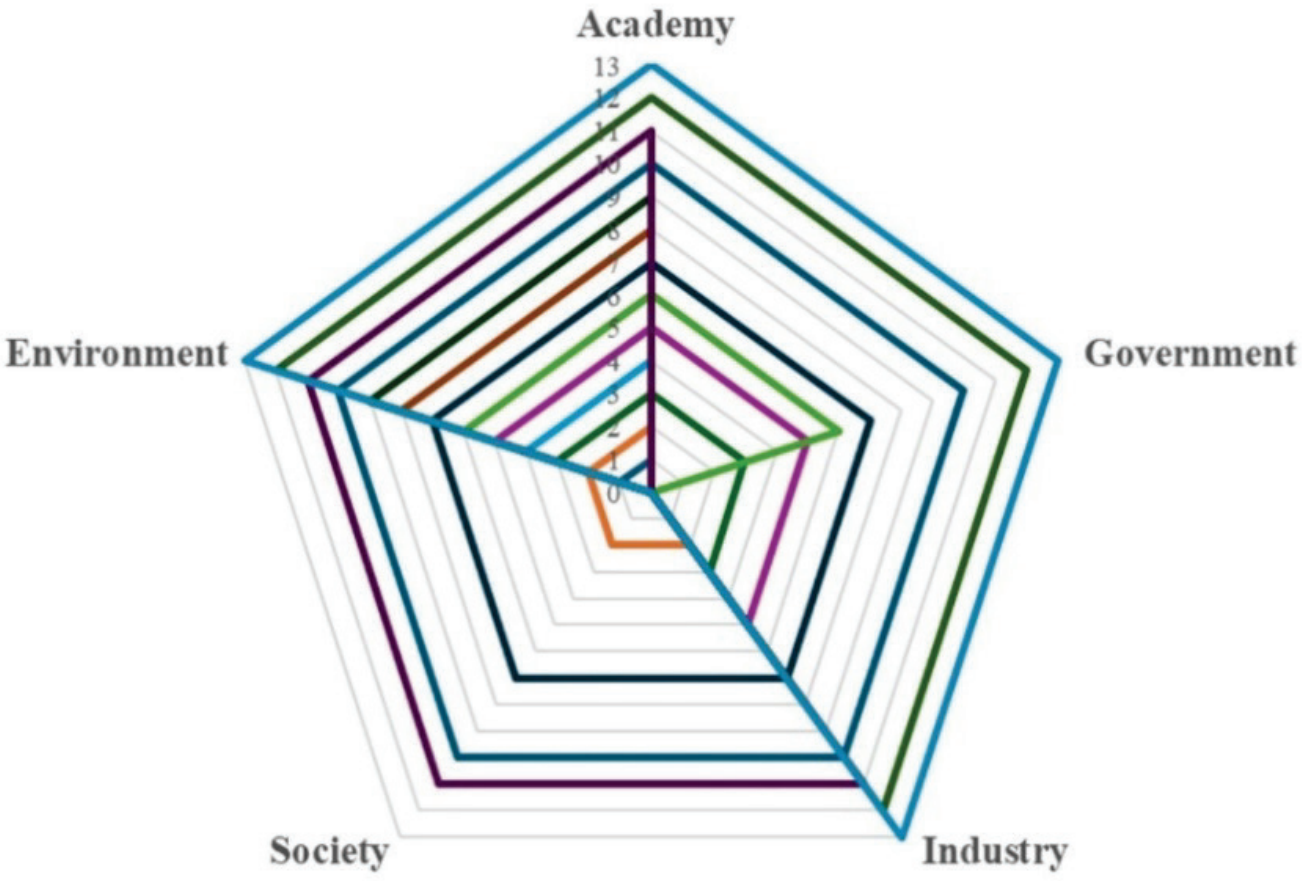


Figure 6. Interrelationship between the actors.

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From the scoping review, it was identified that 76.92 % of the studies are led by actors from the academy, 15.39 % by entities directly dependent on the government, and the rest are developed from the industrial sector —private—, as organizations that provide services to other interested actors (Figure 7).

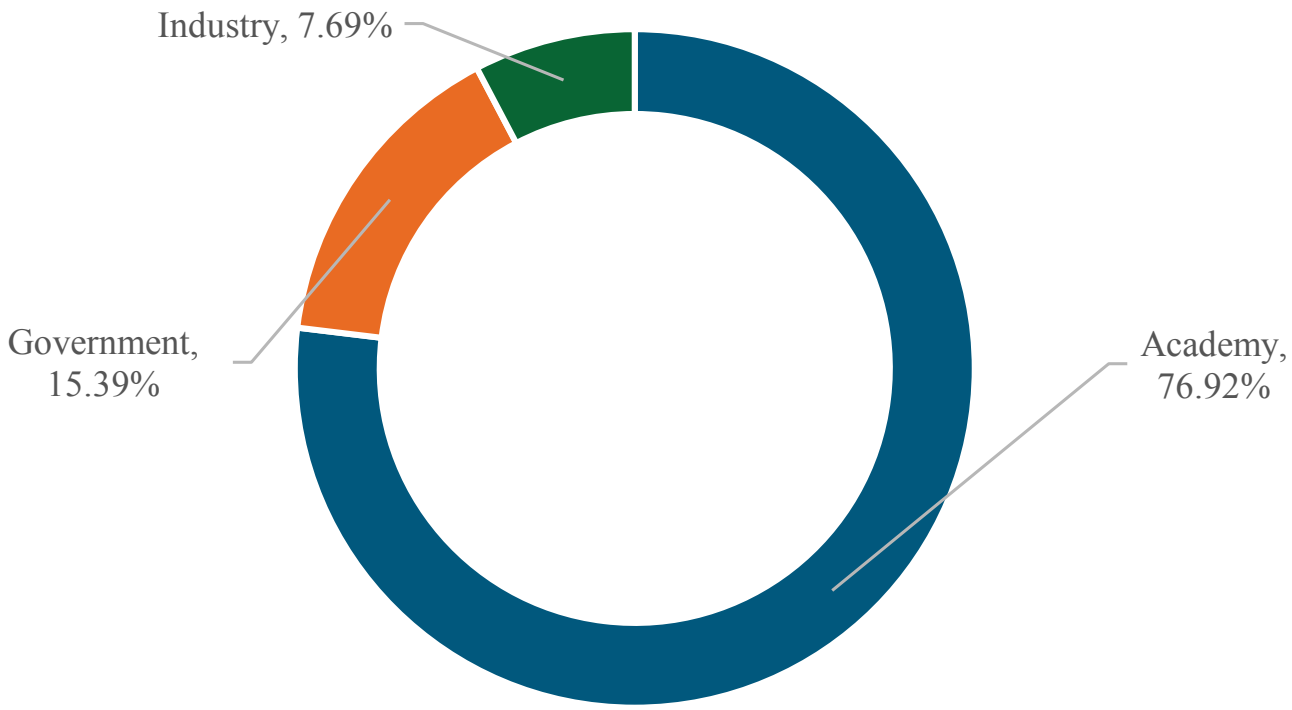


Figure 7. Actors of the PENTApropeller, who lead the development of strategies of the reviewed studies.

A concurrence analysis of the retrieved studies was carried out with the intention of identifying the relationship of the most relevant terms of the studies; VOSviewer version 1.6.20, released on October 31, 2023, was used for this analysis (Jan van Eck *et al*., 2023). Titles and

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abstractions were analyzed, omitting the structure of abstracts and copyright statements.

The complete count method was used. With a minimum threshold of occurrence of 2; while, to select the most relevant terms, a relevance score was calculated. In total, 125 terms were selected and analyzed, the main ones being "Treatment", "System", "Watewater", "Removal", "COD", "FOG", "Removal efficiency", "Slaughterhouses" with an occurrence of 22, 17, 14, 13 and 10 (Figure 8).

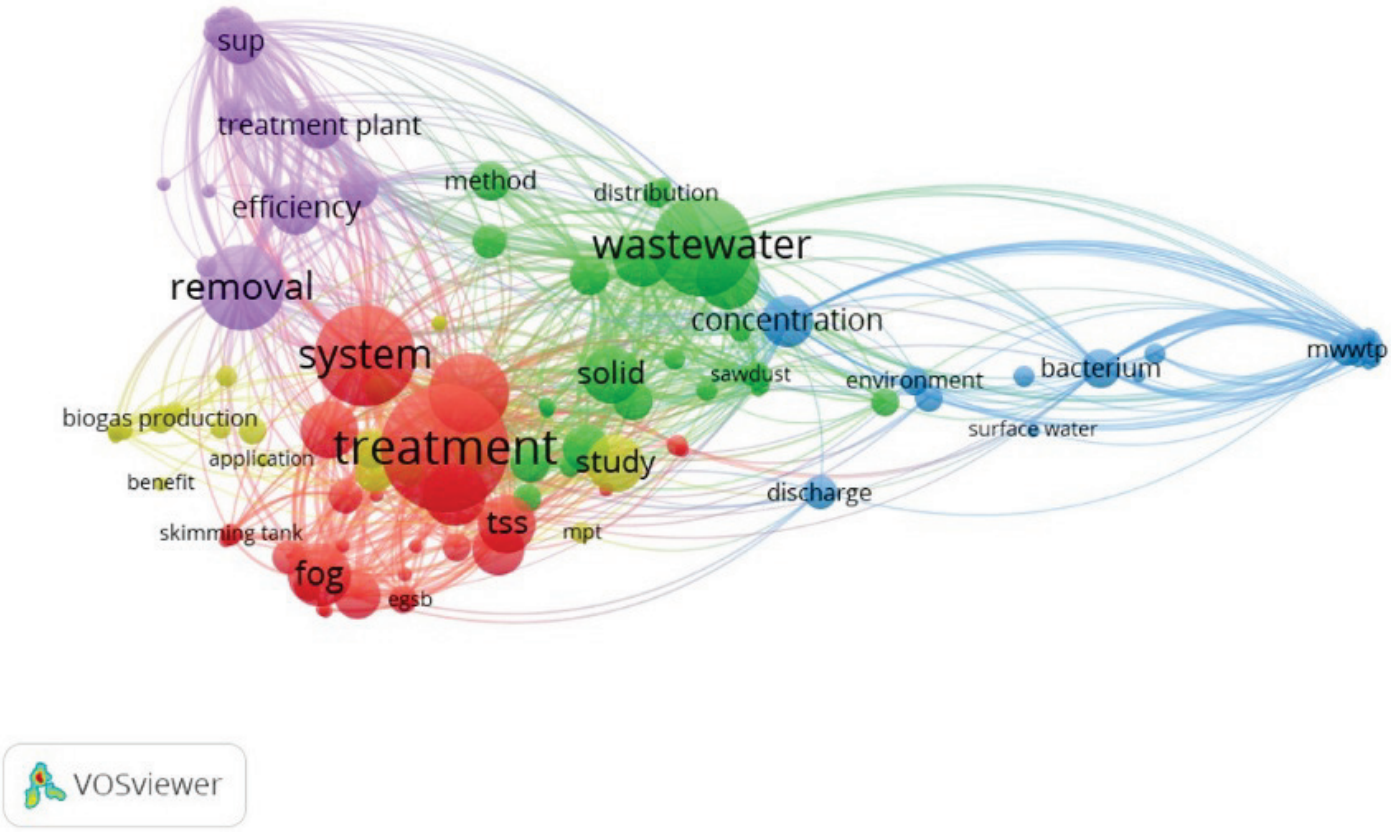


Figure 8. Map of co-occurrences of study terms.

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Discussion

It is a reality that there are strategies developed and used in slaughterhouses that have responded to previous contexts; however, the new demands for the care, conservation and regeneration of the environment and the development of humanity free of the risk of acquiring diseases due to exposure to co-generated pollutants from production processes, make it necessary to develop schemes that are capable of optimal remeasurement; *i.e.*, strategies must be able to maximize efficiency in the removal of toxic pollutants, and have the capacity to minimize the risk of generating damage to the environment and society; this with a vision of recovery and reuse as an input in the same or another value chain and thus reduce -in the best of cases- eliminate the negative impact on the ecosystem. So, it is necessary that these strategies be developed in a holistic way, by the main stakeholders; as proposed by the PENTApropeller model -academy, government, industry, society and environment-.

In this study, it has been clearly identified that the actors in the PENTApropeller -academy, government, industry, society, and environment- are interested in addressing the problems arising from inadequate wastewater management practices, either explicitly or implicitly. This finding is noteworthy in this study because, when evaluating the implications of the actors in the treatment of wastewater generated from the animal slaughter process, most of the scientific contributions come from academy (76.92 %), followed by government (15.39 %) and, finally, industry (7.69 %).

Of the five actors, 60.00 % have an explicit interest, while the other actors -society and the environment- have an implicit contribution.

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The PENTApropeller from its actors, contributes from the (a) academy, with the generation of knowledge, solves complex problems with science and technology, as mentioned Abulibdeh *et al*. (2024), Ellemers (2021), Scholz (2020); the (b) industry, by allowing processes to be applied and changed, improves the efficiency of its production systems by minimizing the risk of causing collateral problems through the development and use of technology (Paschek *et al*., 2022; Raihan *et al*., 2024; Villar & Khan, 2021); the (c) government, which promotes the development of technologies through financing, and which through the development of regulatory schemes has the capacity to improve the quality of life of societies (Budi *et al*., 2020; Udeagha & Ngepah, 2023; Wirba, 2024); the (d) society, which as an entity of the ecosystem has the capacity to evaluate whether strategies are in harmony with the development of humanity's activities, without affecting it (Upreti, 2023; Zhanbayev *et al*., 2023; Zorpas, 2024); and, the (e) environment, which, being the space in which the life of society takes place, requires its conservation (Anthony, 2024; Luna-Nemecio *et al*., 2020; Mishra *et al*., 2021). However, with regard to slaughterhouses, the use of water as a resource is significant; therefore, proper management is an alarming need. In this sense, it coincides with Madeira *et al*. (2023), that within the global agenda, the circularity of the by-products generated by wastewater treatment is found. This is a strategy, which is becoming increasingly emphasized, to reuse co-generated waste from value chains and revalue it as raw material or inputs in the same chain or another value chain, so that the benefits of the components of the waste are reused, at the same time, in which the damage that can be caused to the environment is minimized, by an indiscriminate disposition. Therefore, wastewater from slaughterhouses must be disposed of through the use of

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adequate, efficient, and economically viable treatments, coinciding with Kothari *et al*. (2024). In addition to this, the treated water can be revalued and used by the same or another value chain, which benefits from the components of said effluent.

Finally, it is considered that the development of strategies from a holistic perspective of the PENTApropeller actors can contribute to improving the quality of the environment and humanity, by providing wastewater treated in an environmentally friendly way in an efficient and easily adaptable and scalable way, to sectors interested in adopting the developed technology.

The academic community generates, applies, and disseminates the knowledge developed in universities, as cited Aguinis *et al*. (2021); De Jong and Del Junco (2024); Hargreaves (1999); Hutchinson and Huberman (1994), and McGrail *et al*. (2006) as part of academic processes inspired by the professional responsibility to share the results derived from the development of research projects. This situation is decisive in its leadership in the publication of studies. So, it is a reality that it is the members of the academy themselves who seek and generate links with industry to highlight the potential of the knowledge developed by professors and students. In this sense, industry is the strategic ally of academy, as it provides resources for this achievement, as mentioned by Goldfarb (2008).

The contributions between academy and industry are highly enriching because there is solidity in the generation and application of knowledge, since applications are validated at the implementation site and not at the pilot or laboratory level; academics have the opportunity to test hypotheses and assumptions derived from concepts and ideas. The

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close relationship between academics and corporate society enriches the contribution.

We agree with Evans (2010a) that academy has the experience to share research findings and exploit them to the fullest, while industry manages its resources and ideas with a long-term approach; this cooperative work, while limiting the number of academic products, increases the reception of manuscripts in the initial phase. However, the number of academic products is limited because industry is more interested in appropriating and commercializing research results, as mentioned by Tijssen (2004).

The government plays an important role in academy by funding scientific activity, as noted by Evans (2010b). Unfortunately, this cooperation between industry and government is almost non-existent. Government agencies focus on enforcing the law, in the case of the regulatory industry. Therefore, we agree with Meerts (2020) and Meerts (2018) that the inclusion of the public sector in the private sector implies a violation of corporate security, as it is monitored and supervised by the state, a situation that directly affects the operational autonomy of the private sector.

Government publications focus on disseminating the context of public policies, in line with Vilkins and Grant (2017), and on government transparency, as cited by Zuccolotto *et al*. (2014).

Furthermore, it coincides with Yang *et al*. (2023) in that corporate publications alone receive fewer views and citations, whereas when there is collaboration between corporate entities and universities, views and citations are higher.

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The development of efficient strategies has great benefits. In the first instance, on (a) society, since the proper management of the polluting wastewater emanating from the slaughterhouse will contribute to minimizing the diseases that are attributed to wastewater contamination -*e.g.*, cholera, dysentery, typhoid fever, poliomyelitis-. In the second instance, it benefits the (b) environment, since the system of removal of pollutants from wastewater and the reuse of treated water within the value chain of the slaughterhouse or another sector with a reverse logistics approach supported by the practice of Circular Economy, will allow the discharges of treated water to have the least possible negative impact on flora and fauna. In addition, (c) slaughterhouses benefit, because this will allow them to make the use-reuse of the water system within the value chain more efficient, while at the same time allowing them to contribute to reducing the water footprint due to the discharge of polluting water, finally contributing to an improvement of processes from the Circular Economy approach. In fourth place is the (d) academy, which benefits from the generation and application of knowledge emanating from the professors and students of the Universities, who develop innovative technologies to provide solutions to real problems. While, ultimately, the (e) government benefits from the development of its own technology generated by its citizens, so that these are for the use of the country without the need to pay for a technology transfer from abroad. All this from the methodological proposal that seeks to optimize and revalue the waste generated in the slaughterhouse and its potential for use in the same or another value chain of interest, in this case, the agricultural sector and its performance will be analyzed.

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Conclusions

This study addressed a scoping review to identify and analyze the interests and implications of the actors of the PENTApropeller -academy, government, industry, society, and environment-. The review identified that academy is the main actor directing research projects, which address the development of strategies that pursue the efficient management of wastewater cogenerated by slaughterhouses. It is necessary to review other productive sectors to identify if there is any scheme of interaction between actors interested in the development of strategies that improve the quality of life of society and the environment. This review highlights that (a) the adequate management of the water supply -*i.e.*, where it is used, when needed, and uncontaminated- as well as; and (b) the efficiency of systems for removing pollutants from the ecosystem; they are important for the good development of public health and the environment, as a strategy that contributes to the achievement of sustainability.

Just because society and the environment do not frame the dissemination of explicit contributions does not mean that they are not interested in the use, treatment, and reuse of water in slaughterhouses. This study has identified that explicit actors consider implicit actors in their studies. So, it is necessary to strengthen and increase the participation of society and the environment in studies.

Academy develops strategies in the interest of generating and applying knowledge and considers the environment and society to be in its interest; but it is sometimes limited by government support. In addition, the scaling up of technological developments is complex due to

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the lack of links with the private sector, as the industry is secretive in its operations due to certain information confidentiality policies.

The government develops strategies to improve the quality of life of its citizens by offering quality services and considers the environment and society to be in its interest; however, it is sometimes limited by the knowledge available to its members and by resistance to change from some industries that lack a vision of continuous improvement and investment to update production processes.

Industry develops strategies with a view to improving its production processes, reducing costs, and increasing its competitive margin, and considers the environment and the government to be in its interest due to regulatory compliance. However, it is sometimes limited by a lack of knowledge of the needs of society and the environment and ultimately lacks the perspective of knowledge developed by academy.

To strengthen this framework, it is desirable for industry to allow academy to apply the knowledge it generates, through government funding support, by issuing calls for proposals for the development of high-impact research projects.

The explicit actors must encourage society to participate substantially in the development of solution strategies; the context and tacit knowledge that society experiences are of utmost importance in enriching contributions. Similarly, industry must strengthen the link between the public and private sectors, allowing both academy and government to strengthen productive operations.

So, in each of these areas, the environment must be taken into account by the PENTApropelle stakeholders so that the development and

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implementation of solution strategies are efficient and effective under a sustainability approach.

The lack of a holistic perspective among PENTApropelle stakeholders can lead to fragmented solutions. Therefore, for a wastewater treatment strategy in slaughterhouses to be efficient, it must not only rely on the available treatment technology, but also on the integration of individual and shared interests in the design and adoption of strategies by the stakeholders involved.

This literature review lays the foundation for the development of studies interested in strengthening wastewater treatment systems holistically, considering water use, treatment, and reuse in slaughterhouses, thereby assisting the decision-making process.

Finally, this study lays the foundations for the development of schemes that allow the integration of a framework for the actors of the PENTApropeller in a multidisciplinary and transdisciplinary way in common harmony between the actors, which promotes the development of robust transversal strategies with social and environmental impact. Due to the current context of the development of society, it is necessary to develop alternative strategies that allow remedying and reducing the negative impacts of waste under a sustainability approach.

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Conflicts of interest

The authors declare no conflicts of interest.

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Use of Artificial Intelligence

Artificial Intelligence was not used during the research, writing, or editing of this article.

References

Abulibdeh, A., Zaidan, E., & Abulibdeh, R. (2024). Navigating the confluence of artificial intelligence and education for sustainable development in the era of industry 4.0: Challenges, opportunities, and ethical dimensions. *Journal of Cleaner Production*, *437*, 140527. https://doi.org/10.1016/j.jclepro.2023.140527

Adou, K. E., Kouakou, A. R., Ehouman, A. D., Tyagi, R. D., Drogui, P., & Adouby, K. (2022). Coupling anaerobic digestion process and electrocoagulation using iron and aluminium electrodes for slaughterhouse wastewater treatment. *Scientific African*, *16*, e01238. https://doi.org/10.1016/j.sciaf.2022.e01238

Aguinis, H., Yu, L., & Tosun, C. (2021). How to enhance scholarly impact: recommendations for university administrators, researchers and educators. *International Journal of Contemporary Hospitality Management*, *33*(8), 2485-2499. https://doi.org/10.1108/ijchm-10-2020-1189

Alfonso-Muniozguren, P., Gomes, A. I., Saroj, D., Vilar, V. J. P., & Lee, J. (2021). The role of ozone combined with UVC/H2O2 process for the tertiary treatment of a real slaughterhouse wastewater. *Journal of Environmental Management*, *289*, 112480. https://doi.org/10.1016/j.jenvman.2021.112480

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Anthony, B. (2024). The role of community engagement in urban innovation towards the co-creation of smart sustainable cities. *Journal of the Knowledge Economy*, *15*(1), 1592-1624. https://doi.org/10.1007/s13132-023-01176-1

Azam, R., Kothari, R., Singh, H. M., Ahmad, S., Ashokkumar, V., & Tyagi, V. V. (2020). Production of algal biomass for its biochemical profile using slaughterhouse wastewater for treatment under axenic conditions. *Bioresource Technology*, *306*, 123116. https://doi.org/10.1016/j.biortech.2020.123116

Aziz, A., Basheer, F., Sengar, A., Irfanullah, Khan, S. U., & Farooqi, I. H. (2019). Biological wastewater treatment (anaerobic-aerobic) technologies for safe discharge of treated slaughterhouse and meat processing wastewater. *Science of the Total Environment*, *686*, 681-708. https://doi.org/10.1016/j.scitotenv.2019.05.295

Bazrafshan, E., Zakeri, H. R., Vieira, M. G. A., Derakhshan, Z., Mohammadi, L., Mohammadpour, A., & Mousavi Khaneghah, A. (2022). Slaughterhouse wastewater treatment by integrated chemical coagulation and electro-Fenton processes. *Sustainability*, *14*(18). https://doi.org/10.3390/su141811407

Bingo, M. N., Njoya, M., Basitere, M., Ntwampe, S. K. O., & Kaskote, E. (2021). Performance evaluation of an integrated multi-stage poultry slaughterhouse wastewater treatment system. *Journal of Water Process Engineering*, *43*, 102309. https://doi.org/10.1016/j.jwpe.2021.102309

2026, Instituto Mexicano de Tecnología del Agua. Open Access bajo la licencia CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Budi, N. F. A., Fitriani, W. R., Hidayanto, A. N., Kurnia, S., & Inan, D. I. (2020). A study of government 2.0 implementation in Indonesia. *Socio-Economic Planning Sciences*, *72*, 100920. https://doi.org/10.1016/j.seps.2020.100920

Clarivate. (2024, December 23). *Web of Science*. https://www.webofscience.com/

COFEPRIS, Comisión Federal para la Protección contra Riesgos Sanitarios. (2006). *Evaluación de riesgos de los rastros y mataderos municipales*. https://www.gob.mx/cofepris/documentos/evaluacion-de-riesgos-de-los-rastros-y-mataderos-municipales

Crainic, R., & Fechete, R. (2024). Slaughterhouse wastewater properties assessment by modern and classic methods. *Water*, *16*(17), 2382. https://doi.org/10.3390/w16172382

De Jong, S., & Del Junco, C. (2024). How do professional staff influence academic knowledge development? A literature review and research agenda. *Studies in Higher Education*, *49*(6), 1042-1065. https://doi.org/10.1080/03075079.2023.2258155

De Nardi, I. R., Fuzi, T. P., & Del Nery, V. (2008). Performance evaluation and operating strategies of dissolved-air flotation system treating poultry slaughterhouse wastewater. *Resources, Conservation and Recycling*, *52*(3), 533-544. https://doi.org/10.1016/j.resconrec.2007.06.005

2026, Instituto Mexicano de Tecnología del Agua. Open Access bajo la licencia CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Derakhshan, A., Rezaei-Kalantari, R., Farzadkia, M., Tiyuri, A., & Esrafili, A. (2023). The effect of biological treatment methods on the concentration of carbonaceous pollutants in the slaughterhouse wastewater: A systematic review. *Case Studies in Chemical and Environmental Engineering*, *8*, 100451. https://doi.org/10.1016/j.cscee.2023.100451

Dos Santos-Pereira, A. K., Teixeira, K. C., Pereira, D. H., & Cavallini, G. S. (2024). A critical review on slaughterhouse wastewater: Treatment methods and reuse possibilities. *Journal of Water Process Engineering*, *58*, 104819. https://doi.org/10.1016/j.jwpe.2024.104819

Dosta, J., Rovira, J., Galí, A., Macé, S., & Mata-Álvarez, J. (2008). Integration of a coagulation/flocculation step in a biological sequencing batch reactor for COD and nitrogen removal of supernatant of anaerobically digested piggery wastewater. *Bioresource Technology*, *99*(13), 5722-5730. https://doi.org/10.1016/j.biortech.2007.10.021

Dyosile, P. A., Mdladla, C., Njoya, M., Basitere, M., Ntwampe, S. K. O., & Kaskote, E. (2021). Assessment of an integrated and sustainable multistage system for the treatment of poultry slaughterhouse wastewater. *Membranes*, *11*(8), 582. https://doi.org/10.3390/membranes11080582

Elkady, M., Yosri, Ahmed, M., Fathy, S. M., & Abbas, M. H. A. (2024). Slaughterhouse wastewater remediation using carbonized sawdust followed by textile filtration. *Applied Water Science*, *14*(12), 246. https://doi.org/10.1007/s13201-024-02312-1

2026, Instituto Mexicano de Tecnología del Agua.
Open Access bajo la licencia CC BY-NC-SA 4.0
(https://creativecommons.org/licenses/by-nc-sa/4.0/)

Ellemers, N. (2021). Science as collaborative knowledge generation. *British Journal of Social Psychology*, *60*(1), 1-28. https://doi.org/10.1111/bjso.12430

Elsevier Ltd. (2024). *Mendeley Cite* (v1.67.0). Elsevier Ltd. https://www.mendeley.com/reference-management/mendeley-cite

Elsevier. (2024a, December 23). *ScienceDirect*. https://www.sciencedirect.com/

Elsevier. (2024b, December 23). *Scopus*. https://www.scopus.com/

Evans, J. A. (2010a). Industry collaboration, scientific sharing, and the dissemination of knowledge. *Social Studies of Science*, *40*(5), 757-791. https://doi.org/10.1177/0306312710379931

Evans, J. A. (2010b). Industry induces academic science to know less about more. *American Journal of Sociology*, *116*(2), 389-452. https://doi.org/10.1086/653834

Fedorov, K., Rayaroth, M. P., Shah, N. S., & Boczkaj, G. (2023). Activated sodium percarbonate-ozone (SPC/O_3) hybrid hydrodynamic cavitation system for advanced oxidation processes (AOPs) of 1,4-dioxane in water. *Chemical Engineering Journal*, *456*, 141027. https://doi.org/10.1016/j.cej.2022.141027

Feng, H., Hu, L., Mahmood, Q., Fang, C., Qiu, C., & Shen, D. (2009). Effects of temperature and feed strength on a carrier anaerobic baffled reactor treating dilute wastewater. *Desalination*, *239*(1-3), 111-121. https://doi.org/10.1016/j.desal.2008.03.011

2026, Instituto Mexicano de Tecnología del Agua. Open Access bajo la licencia CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Goldfarb, B. (2008). The effect of government contracting on academic research: Does the source of funding affect scientific output? *Research Policy*, *37*(1), 41-58. https://doi.org/10.1016/j.respol.2007.07.011

Gómez, W. (2023). Assessing PrEP messaging and communication: A review of the qualitative literature. *Current Opinion in Psychology*, *51*, 101586. https://doi.org/10.1016/j.copsyc.2023.101586

Google. (2024, December 23). *Google Scholar*. https://scholar.google.com/

Hargreaves, D. H. (1999). The knowledge-creating school. *British Journal of Educational Studies*, *47*(2), 122-144. https://doi.org/10.1111/1467-8527.00107

Hellal, M. S., El-Kamah, H. M., & Doma, H. S. (2024). High-performance internal circulation anaerobic granular sludge reactor for cattle slaughterhouse wastewater treatment and simultaneous biogas production. *BMC Biotechnology*, *24*(1), 29. https://doi.org/10.1186/s12896-024-00849-2

Hutchinson, J. R., & Huberman, M. (1994). Knowledge dissemination and use in science and mathematics education: A literature review. *Journal of Science Education and Technology*, *3*(1), 27-47. https://doi.org/10.1007/BF01575814

INAP, Instituto Nacional de Administración Pública. (2019). *Guía técnica 21. La administración de rastros municipales*. Instituto Nacional de Administración Pública. https://biblio.juridicas.unam.mx/bjv/id/1717

2026, Instituto Mexicano de Tecnología del Agua. Open Access bajo la licencia CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Iqbal, J., Shah, N. S., Sayed, M., Khan, J. A., Imran, M., Khan, Z. U. H., Niazi, N. K., Al-Taani, A. A., Howari, F., & Nazzal, Y. (2021). Exploring the potential of nano-zerovalent copper modified biochar for the removal of ciprofloxacin from water. *Environmental Nanotechnology, Monitoring & Management*, *16*, 100604. https://doi.org/10.1016/j.enmm.2021.100604

Jan van Eck, N., Waltman, L., & Leiden University's Centre for Science and Technology Studies (CWTS). (2023). *VOSviewer (1.6.20)*. Centre for Science and Technology Studies. https://www.vosviewer.com/

Kanafin, Y. N., Makhatova, A., Meiramkulova, K., & Poulopoulos, S. G. (2022). Treatment of a poultry slaughterhouse wastewater using advanced oxidation processes. *Journal of Water Process Engineering*, *47*, 102694. https://doi.org/10.1016/j.jwpe.2022.102694

Kothari, R., Azam, R., Bharti, A., Goria, K., Allen, T., Ashokkumar, V., Pathania, D., Singh, R. P., & Tyagi, V. V. (2024). Biobased treatment and resource recovery from slaughterhouse wastewater via reutilization and recycling for sustainable waste approach. *Journal of Water Process Engineering*, *58*, 104712. https://doi.org/10.1016/j.jwpe.2023.104712

Luna-Nemecio, J., Tobón, S., & Juárez-Hernández, L. G. (2020). Sustainability-based on socioformation and complex thought or sustainable social development. *Resources, Environment and Sustainability*, *2*, 100007. https://doi.org/10.1016/j.resenv.2020.100007

2026, Instituto Mexicano de Tecnología del Agua. Open Access bajo la licencia CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Madeira, L., Ribau-Teixeira, M., Almeida, A., Santos, T., & Carvalho, F. (2023). Reuse of lime sludge from immediate one-step lime precipitation process as a coagulant (aid) in slaughterhouse wastewater treatment. *Journal of Environmental Management*, *342*, 118278. https://doi.org/10.1016/j.jenvman.2023.118278

Mak, S., & Thomas, A. (2022). Steps for conducting a scoping review. *Journal of Graduate Medical Education*, *14*(5), 565-567. https://doi.org/10.4300/jgme-d-22-00621.1

Marín-Peña, O., Alvarado-Lassman, A., Alvarado-Vallejo, A., Sandoval-Herazo, M., Hernández-Castelán, D. A., Zamora-Castro, S. A., & Sandoval-Herazo, L. C. (2024). Evaluation of a pilot-scale anaerobic biofilm reactor for the treatment of slaughterhouse effluents in rural areas. *Water Practice and Technology*, *19*(9), 3706-3720. https://doi.org/10.2166/wpt.2024.234

McGowan, J., Sampson, M., Salzwedel, D. M., Cogo, E., Foerster, V., & Lefebvre, C. (2016). Press Peer Review of Electronic Search Strategies: 2015 Guideline Statement. *Journal of Clinical Epidemiology*, *75*, 40-46. https://doi.org/10.1016/J.JCLINEPI.2016.01.021

McGrail, M. R., Rickard, C. M., & Jones, R. (2006). Publish or perish: A systematic review of interventions to increase academic publication rates. *Higher Education Research & Development*, *25*(1), 19-35. https://doi.org/10.1080/07294360500453053

Meerts, C. (2020). Corporate investigations: Beyond notions of public–private relations. *Journal of Contemporary Criminal Justice*, *36*(1), 86-100. https://doi.org/10.1177/1043986219890202

2026, Instituto Mexicano de Tecnología del Agua.
Open Access bajo la licencia CC BY-NC-SA 4.0
(https://creativecommons.org/licenses/by-nc-sa/4.0/)

Meerts, C. A. (2018). The organisation as the cure for its own ailments: Corporate investigators in The Netherlands. *Administrative Sciences*, *8*(3), 25. https://doi.org/10.3390/admsci8030025

Meiramkulova, K., Temirbekova, A., Saspugayeva, G., Kydyrbekova, A., Devrishov, D., Tulegenova, Z., Aubakirova, K., Kovalchuk, N., Meirbekov, A., & Mkilima, T. (2021). Performance of a combined treatment approach on the elimination of microbes from poultry slaughterhouse wastewater. *Sustainability*, *13*(6). https://doi.org/10.3390/su13063467

Microsoft Corp. (2024). *Microsoft Excel for Microsoft 365 (2411 build 16.0.18227.20082) (sotware)*. Microsoft Corp.

Mishra, B. K., Kumar, P., Saraswat, C., Chakraborty, S., & Gautam, A. (2021). Water security in a changing environment: Concept, challenges and solutions. *Water*, *13*(4), 490. https://doi.org/10.3390/w13040490

Mkilima, T., Saspugayeva, G., Dakieva, K., Tussupova, Z., Zhaken, A., Kumarbekuly, S., Daribay, A., & Khussainov, M. (2024). Enhancing slaughterhouse wastewater treatment through the integration of microbial fuel cell and electro-Fenton systems: A comprehensive comparative analysis. *Journal of Water Process Engineering*, *57*, 104743. https://doi.org/10.1016/j.jwpe.2023.104743

Montiel-Rosales, A., Montalvo-Romero, N., Fernández-Echeverría, E., & Ruiz-Hernández, O. (2024). *Holistic perspective of slaughterhouse wastewater from the context of the PENTApropeller: A scoping review*. Open Science Framework. https://osf.io/eu63v/

2026, Instituto Mexicano de Tecnología del Agua. Open Access bajo la licencia CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Paschek, D., Luminosu, C.-T., & Ocakci, E. (2022). Industry 5.0 challenges and perspectives for manufacturing systems in the society 5.0. In: Draghici, A., & Ivascu, L. (eds.). *Sustainability and innovation in manufacturing enterprises: Indicators, models and assessment for industry 5.0* (pp. 17-63). Springer Singapore. https://doi.org/10.1007/978-981-16-7365-8_2

Prill, R., Karlsson, J., Ayeni, O. R., & Becker, R. (2021). Author guidelines for conducting systematic reviews and meta-analyses. *Knee Surgery, Sports Traumatology, Arthroscopy*, *29*(9), 2739-2744. https://doi.org/10.1007/s00167-021-06631-7

PROFEPA, Procuraduría Federal de Protección al Ambiente. (2015). *LEY GENERAL PARA LA PREVENCIÓN Y GESTIÓN INTEGRAL DE LOS RESIDUOS*. https://www.gob.mx/profepa/documentos/ley-general-para-la-prevencion-y-gestion-integral-de-los-residuos-62914

Quiroga, G., García-de-Siles, J. L., & Food and Agriculture Organization of the United Nations. (1994). *Manual para la instalación del pequeño matadero modular de la FAO* (núm. 120). Estudio FAO: Producción y Sanidad Animal.

Raihan, A., Ridwan, M., & Rahman, M. S. (2024). An exploration of the latest developments, obstacles, and potential future pathways for climate-smart agriculture. *Climate Smart Agriculture*, *1*(2), 100020. https://doi.org/10.1016/j.csag.2024.100020

2026, Instituto Mexicano de Tecnología del Agua. Open Access bajo la licencia CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Rajpal, A., Ali, M., Choudhury, M., Almohana, A. I., Alali, A. F., Munshi, F. M. A., Khursheed, A., & Kazmi, A. A. (2022). Abattoir wastewater treatment plants in India: Understanding and performance evaluation. *Frontiers in Environmental Science*, *10*. https://doi.org/10.3389/fenvs.2022.881623

Ramadan, L., Deeb, R., Sawaya, C., El Khoury, C., Wazne, M., & Harb, M. (2023). Anaerobic membrane bioreactor-based treatment of poultry slaughterhouse wastewater: Microbial community adaptation and antibiotic resistance gene profiles. *Biochemical Engineering Journal*, *192*, 108847. https://doi.org/10.1016/j.bej.2023.108847

Ramírez-Montoya, L. A., Valenzuela, E. I., De Velasco-Maldonado, P. S., Hernández-Montoya, V., Menéndez, J. A., Montes-Morán, M. A., & Cervantes, F. J. (2023). Carbon-based materials boost the anaerobic treatment of slaughterhouse wastewater. *Journal of Water Process Engineering*, *56*, 104553. https://doi.org/10.1016/j.jwpe.2023.104553

Sandoval, M. A., & Salazar, R. (2021). Electrochemical treatment of slaughterhouse and dairy wastewater: Toward making a sustainable process. *Current Opinion in Electrochemistry*, *26*, 100662. https://doi.org/10.1016/j.coelec.2020.100662

Sandoval, M. A., Coreño, O., García, V., & Salazar-González, R. (2024). Enhancing industrial swine slaughterhouse wastewater treatment: Optimization of electrocoagulation technique and operating mode. *Journal of Environmental Management*, *349*, 119556. https://doi.org/10.1016/j.jenvman.2023.119556

2026, Instituto Mexicano de Tecnología del Agua.
Open Access bajo la licencia CC BY-NC-SA 4.0
(https://creativecommons.org/licenses/by-nc-sa/4.0/)

Savin, M., Bierbaum, G., Hammerl, J. A., Heinemann, C., Parcina, M., Sib, E., Voigt, A., & Kreyenschmidt, J. (2020). Antibiotic-resistant bacteria and antimicrobial residues in wastewater and process water from German pig slaughterhouses and their receiving municipal wastewater treatment plants. *Science of the Total Environment*, *727*, 138788. https://doi.org/10.1016/j.scitotenv.2020.138788

Scholz, R. W. (2020). Transdisciplinarity: Science for and with society in light of the university's roles and functions. *Sustainability Science*, *15*(4), 1033-1049. https://doi.org/10.1007/s11625-020-00794-x

Secretaría de Agricultura y Desarrollo Rural. (2023). *Capacidad instalada para el sacrificio de especies pecuarias*. https://www.gob.mx/agricultura/dgsiap/documentos/capacidad-de-sacrificio-de-especies-pecuarias

Secretaría de Salud. (2004). Productos y Servicios. Especificaciones sanitarias en los establecimientos dedicados al sacrificio y faenado de animales para abasto, almacenamiento, transporte y expendio. Especificaciones sanitarias de productos (NOM-194-SSA1-2004). https://www.dof.gob.mx/nota_detalle.php?codigo=661587&fecha=18/09/2004#gsc.tab=0

Shende, A. D., Dhenkula, S., Rao, N. N., & Pophali, G. R. (2022). An improved primary wastewater treatment system for a slaughterhouse industry: A full-scale experience. *Water Science and Technology*, *85*(5), 1688-1700. https://doi.org/10.2166/wst.2022.041

2026, Instituto Mexicano de Tecnología del Agua. Open Access bajo la licencia CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Shi, Z., Tan, X., Li, Y., Sheng, Y., Zhang, Q., Xu, J., & Yang, Y. (2023). A novel fungal-algal coupling system for slaughterhouse wastewater treatment and lipid production. *Bioresource Technology*, *387*, 129585. https://doi.org/10.1016/j.biortech.2023.129585

SpringerNature. (2024, December 23). *SpringerLink*. https://rd.springer.com/

Teo, C. J., Karkou, E., Vlad, O., Vyrkou, A., Savvakis, N., Arampatzis, G., & Angelis-Dimakis, A. (2023). Life cycle environmental impact assessment of slaughterhouse wastewater treatment. *Chemical Engineering Research and Design*, *200*, 550-565. https://doi.org/10.1016/j.cherd.2023.11.016

Terán-Hilares, R., Garcia-Bustos, K. A., Sanchez-Vera, F. P., Colina-Andrade, G. J., & Pacheco-Tanaka, D. A. (2021). Acid precipitation followed by microalgae (*Chlorella vulgaris*) cultivation as a new approach for poultry slaughterhouse wastewater treatment. *Bioresource Technology*, *335*, 125284. https://doi.org/10.1016/j.biortech.2021.125284

Tijssen, R. J. W. (2004). Is the commercialisation of scientific research affecting the production of public knowledge? *Research Policy*, *33*(5), 709-733. https://doi.org/10.1016/j.respol.2003.11.002

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., Moher, D., Peters, M. D. J., Horsley, T., Weeks, L., Hempel, S., Akl, E. A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft, A., Wilson, M. G., Garritty, C.,… & Straus, S. E. (2018). PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Annals of Internal Medicine*, *169*(7), 467-473. https://doi.org/10.7326/M18-0850

2026, Instituto Mexicano de Tecnología del Agua. Open Access bajo la licencia CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Udeagha, M. C., & Ngepah, N. (2023). The drivers of environmental sustainability in BRICS economies: Do green finance and fintech matter? *World Development Sustainability*, *3*, 100096. https://doi.org/10.1016/j.wds.2023.100096

Upreti, G. (2023). Ecosociocentrism: The Earth first paradigm for sustainable living. In: *Ecosociocentrism: The Earth first paradigm for sustainable living* (pp. 307-367). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-41754-2_13

Vilkins, S., & Grant, W. J. (2017). Types of evidence cited in Australian Government publications. *Scientometrics*, *113*(3), 1681-1695. https://doi.org/10.1007/s11192-017-2544-2

Villar, A. S., & Khan, N. (2021). Robotic process automation in banking industry: A case study on Deutsche Bank. *Journal of Banking and Financial Technology*, *5*(1), 71-86. https://doi.org/10.1007/s42786-021-00030-9

Wirba, A. V. (2024). Corporate Social Responsibility (CSR): The role of government in promoting CSR. *Journal of the Knowledge Economy*, *15*(2), 7428-7454. https://doi.org/10.1007/s13132-023-01185-0

Yang, R., Wu, Q., & Xie, Y. (2023). Are scientific articles involving corporations associated with higher citations and views? An analysis of the top journals in business research. *Scientometrics*, *128*(10), 5659-5685. https://doi.org/10.1007/s11192-023-04808-0

2026, Instituto Mexicano de Tecnología del Agua.
Open Access bajo la licencia CC BY-NC-SA 4.0
(https://creativecommons.org/licenses/by-nc-sa/4.0/)

Zahedi, S., Gros, M., Balcazar, J. L., Petrovic, M., & Pijuan, M. (2021). Assessing the occurrence of pharmaceuticals and antibiotic resistance genes during the anaerobic treatment of slaughterhouse wastewater at different temperatures. *Science of the Total Environment*, *789*, 147910. https://doi.org/10.1016/j.scitotenv.2021.147910

Zhanbayev, R. A., Irfan, M., Shutaleva, A. V, Maksimov, D. G., Abdykadyrkyzy, R., & Filiz, Ş. (2023). Demoethical model of sustainable development of society: A roadmap towards digital transformation. *Sustainability*, *15*(16). https://doi.org/10.3390/su151612478

Zorpas, A. A. (2024). The hidden concept and the beauty of multiple "R" in the framework of waste strategies development reflecting to circular economy principles. *Science of the Total Environment*, *952*, 175508. https://doi.org/10.1016/j.scitotenv.2024.175508

Zuccolotto, R., Riccio, E. L., & Sakata, M. C. G. (2014). Characteristics of scientific production on governmental transparency. *International Journal of Auditing Technology*, *2*(2), 134. https://doi.org/10.1504/ijaudit.2014.066234

2026, Instituto Mexicano de Tecnología del Agua. Open Access bajo la licencia CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)