e-ISSN:2706-6800
INSTITUTO TECNOLÓGICO CORPORATIVO EDWARDS DEMING

Implementation of Biofilters with Earthworms as a Sustainable Alternative for Wastewater Treatment in Slaughterhouses

Implementación de biofiltros con lombrices como alternativa sostenible para tratamiento de aguas residuales en camales

José Gerardo León Chimbolema[1]

Published Instituto Tecnológico Corporativo Edwards DemingQuito - Ecuador

Periodicity
April - June
Vol. 1, Num. 25, 2025
pp. 121-133
http://centrosuragraria.com/index.php/revista

Dates of receipt
Received: March 12, 2025
Approved: March 30, 2025

Correspondence author
gerardo.leon@espoch.edu.ec

[1] Doctor en Química, Máster en protección Ambiental. Docente investigador.
Escuela Superior Politécnica de Chimborazo
gerardo.leon@espoch.edu.ec
https://orcid.org/0000-0001-9202-8542

Abstract: Water pollution caused by wastewater from slaughterhouses is an environmental problem that affects public health and ecosystems, especially in areas with limited resources for conventional treatment systems. This research evaluated the efficiency of a worm biofilter using red Californian earthworms (Eisenia foetida) to treat wastewater from the Municipal Slaughterhouse of Pelileo, Ecuador. A biofilter was designed and constructed with layers of ball stone, gravel, and sand, complemented by a filtering bed of sawdust, shavings, and humus inhabited by worms adapted to the wastewater. Over three weeks, physicochemical parameters such as pH, conductivity, color, turbidity, nitrogen in forms of nitrites and nitrates, phosphates, chemical and biochemical oxygen demand (COD and BOD5), as well as total and dissolved solids, were analyzed before and after treatment. The results showed a significant reduction of these contaminants, achieving an average removal efficiency of 74.87%, with peaks of up to 95% in some parameters. The biofilter operated effectively without producing sludge and with low maintenance costs. Additionally, the treated water met the maximum permissible limits established by current environmental regulations, validating the system as a sustainable and economical alternative. It is concluded that the worm biofilter is a viable solution for treating slaughterhouse wastewater, with recommendations for its optimization to expand its application to other industries with high organic loads.

Key words: biofilter, earthworms, Eisenia foetida, wastewater, slaughterhouse, efficiency, sustainability.

Resumen: La contaminación del agua por aguas residuales provenientes de camales es un problema ambiental que afecta la salud pública y los ecosistemas, especialmente en zonas con limitados recursos para tratamientos convencionales. Esta investigación evaluó la eficiencia de un biofiltro con lombrices rojas californianas (Eisenia foetida) para tratar las aguas residuales del Camal Municipal de Pelileo, Ecuador. Se diseñó y construyó un biofiltro con capas de piedra bola, grava y arena, complementado con un lecho filtrante de aserrín, viruta y humus donde habitan las lombrices adaptadas al agua residual. Durante tres semanas se analizaron parámetros fisicoquímicos como pH, conductividad, color, turbidez, nitrógeno en formas de nitritos y nitratos, fosfatos, demanda química y bioquímica de oxígeno (DQO y DBO5), además de sólidos totales y disueltos, antes y después del tratamiento. Los resultados mostraron una reducción significativa de estos contaminantes, logrando una eficiencia promedio del 74.87%, con picos de hasta 95% en algunos parámetros. El biofiltro operó eficazmente sin producir lodos y con bajo costo de mantenimiento. Asimismo, el agua tratada cumplió con los límites máximos permisibles según la normativa ambiental vigente, validando el sistema como una alternativa sostenible y económica. Se concluye que el biofiltro con lombrices es una solución viable para el tratamiento de aguas residuales en camales, recomendándose su optimización para ampliar su aplicación en otras industrias con carga orgánica elevada.

Palabras clave: biofiltro, lombrices, *Eisenia foetida*, aguas residuales, camal, eficiencia, sostenibilidad.

Introduction

Water pollution caused by industrial wastewater, particularly in slaughterhouses or meat processing plants, is a serious environmental problem that affects both public health and the integrity of surrounding ecosystems (Gamarra, 2021; Landeta, 2019). This wastewater contains high levels of organic matter, fats, suspended solids, nutrients such as nitrogen and phosphorus, as well as chemical compounds derived from the slaughter and cleaning of animals, which, if not properly treated, generate severe negative impacts, such as eutrophication, proliferation of pathogens, and contamination of water sources (Soto et al., 2020; Rodríguez, 2021). The problem is exacerbated in rural areas and developing countries, where conventional treatment infrastructure is limited by high costs and complex technical requirements (Salazar, 2005; Bermúdez, 2019).

Traditional wastewater treatment methods, although effective, often involve energy-intensive processes, skilled labor, and generate by-products such as sludge that require special handling and disposal (Muñoz, 2009; Manrique & Piñeros, 2016). For this reason, the search for alternative technologies that are environmentally sustainable, economical, and easy to operate has become very important. In this context, biofilters based on the action of Californian red worms (Eisenia foetida) have emerged as an innovative solution for the biological treatment of wastewater with high organic loads (Arora & Saraswat, 2021; Misal & Mohite, 2017).

The system known as the Tohá worm filter or biofilter is based on the ability of worms to degrade organic matter in a controlled environment, combined with a filter medium composed of layers of stone, gravel, sand, and organic substrates such as sawdust and wood shavings, which facilitate microbial activity and physical filtration (Government of Chile CONAMA, n.d.; Bermúdez, 2019). f.; Bermúdez, 2019). This natural process significantly reduces contaminating parameters such as biochemical and chemical oxygen demand (BOD and COD), nitrogen, phosphorus, suspended solids, and turbidity, without generating sludge or odors, with low operating costs and minimal maintenance (Pérez & Carrasco, 2019; Qiu et al., 2016).

The worm Eisenia foetida is particularly suitable for this purpose due to its high adaptability to different environmental conditions, reproduction rate, and efficiency in transforming organic waste into humus, a valuable by-product that can be used as a natural fertilizer (Coronel, 2015; Liberio, 2019). Recent studies have demonstrated the technical and economic viability of using vermicomposting in different industries, including agro-industrial, dairy, meat, and fishing, achieving reductions in organic matter of over 80% and guaranteeing the quality of the effluent according to local and international regulations (Bravo, 2019; Cabrera et al., 2022; Maza, 2017).

Furthermore, the sustainability of this technology is evident in its low environmental impact, as it does not require chemical inputs, consumes little energy, and allows the reuse of treated water for irrigation or industrial processes, promoting the circular economy and the conservation of water resources (Biswas, 2021; Manyuchi et al., 2017). In Ecuador, this alternative is particularly relevant due to the need to improve wastewater management in rural slaughterhouses and industrial plants, where access to conventional technologies is limited and inadequate effluent management has led to social conflicts and environmental degradation (GAD Ibarra, 2018; Rodríguez, 2021).

This study focused on evaluating the efficiency of a worm biofilter for treating wastewater from the Pelileo Municipal Slaughterhouse, analyzing the reduction of key pollutant parameters and verifying compliance with current environmental regulations (TULSMA). A system adapted to local conditions was designed, environmental variables were monitored for the adaptation of the worms, and physicochemical analyses were carried out over a period of three weeks.

This work contributes to the body of knowledge on clean technologies applied to environmental management in the meat industry, offering a viable alternative for improving water quality and mitigating water pollution in rural areas. It also emphasizes the need to continue optimizing these systems, adjusting hydraulic retention times and filter materials in order to maximize efficiency and promote their adoption on a commercial and community scale.

Methodology

This study focused on evaluating the efficiency of a biofilter with Californian red worms (Eisenia foetida) for treating wastewater generated at the Pelileo Municipal Slaughterhouse in Ecuador. To this end, an experimental biofilter was designed and constructed consisting of a stratified tank, taking into account hydraulic and structural parameters appropriate for the volume and flow rate of the wastewater to be treated. The biofiltration system consisted of three main layers: a base of approximately 10 cm of pebbles for support and drainage; an intermediate layer of gravel with variable grain sizes that facilitates the formation of microbial biofilm; and a surface layer of fine sand for the retention of suspended solids. On top of this last layer, an organic bed consisting of a mixture of sawdust, wood shavings, and humus was placed, which served as a substrate and food source for Eisenia foetida worms. The tank was equipped with a water distribution and collection system using vertically arranged PVC pipes, which allowed uniform irrigation of the wastewater over the filter surface and the evacuation of the treated water to a storage tank, thus avoiding stagnation points and facilitating system maintenance.

To ensure the biological effectiveness of the biofilter, the worms were subjected to an adaptation process prior to direct contact with the slaughterhouse wastewater. During this phase, critical environmental variables were carefully controlled, such as temperature (optimum range between 18 and 25 °C), pH (6.5 to 8.5), and substrate moisture, conditions that favor the survival, metabolic activity, and reproduction of Eisenia foetida. These parameters were monitored periodically throughout the experimental period to maintain stable conditions and prevent mass mortality of worms, which could negatively affect the efficiency of the treatment.

Wastewater sampling was carried out weekly for three consecutive weeks, taking representative samples from both the influent and

entrosur e-ISSN:2706-6800 INSTITUTO TECNOLÓGICO CORPORATIVO EDWARDS DEMING

effluent of the biofilter, following standardized protocols to avoid external contamination. The samples were analyzed in a certified laboratory to measure key physicochemical parameters such as pH, electrical conductivity, color, turbidity, nitrogen concentrations in the form of nitrites and nitrates, phosphates, chemical and biochemical oxygen demand (COD and BOD5), and total and dissolved solids. These indicators made it possible to evaluate the pollutant load and the efficiency of the biofiltration process.

Likewise, the inflow and outflow of wastewater were measured using timing techniques with a stopwatch and calibrated containers, which made it possible to calculate the hydraulic retention time (HRT). The latter is a fundamental parameter that determines the period during which the water remains in contact with the filter bed, directly impacting the biological degradation of organic matter. Finally, the concentrations of pollutants before and after treatment were compared to determine the percentage removal efficiency, verifying that the final values complied with the maximum permissible limits established by current environmental regulations (TULSMA).

Throughout the process, periodic maintenance activities were carried out, including manual aeration of the filter bed, mixing the organic substrate to prevent compaction and ensure permeability, humidity control to maintain optimal conditions for the worms, and removal of accumulated solid waste that could obstruct the flow. These practices ensured the operational stability and continuous performance of the biofilter, guaranteeing its effectiveness in reducing the organic load and other contaminants present in the slaughterhouse wastewater.

Results

The wastewater generated by the Pelileo Municipal Slaughterhouse has a high pollutant load, which is characteristic of slaughterhouses due to the large amount of organic waste, fats, suspended solids, and nutrients present in their effluents (Bermúdez, 2019; Manjarres, 2023). The initial physicochemical assessment revealed an average pH of 8.61, indicating a slightly alkaline environment, common in industrial wastewater due to the presence of nitrogen compounds and the interaction of chemical and biological processes (Rodríguez, 2021; Soto et al., 2020).

Electrical conductivity was found to be high at 1393 µS/cm, reflecting a high concentration of dissolved salts from cleaning products, blood residues, and other organic and inorganic solutes (Quishpe et al., 2020; Landeta, 2019). High levels of conductivity can affect water quality and its subsequent use, as well as influencing toxicity to aquatic organisms (Muñoz, 2009; Manrique & Piñeros, 2016).

Parameters related to turbidity and color are important indicators of water quality and reflect the amount of suspended solids and organic matter in suspension. In this study, turbidity reached values of 470 NTU and color was 15,700 Pt/Co units, indicating a considerable load of solids and organic matter, which can cause clogging problems in receiving bodies and affect aquatic photosynthesis processes (Biswas, 2021; Misal & Mohite, 2017). These high levels are consistent with previous reports on slaughterhouse effluents, where the combination of blood, fat, and solid waste contributes to opacity and dark coloration (Sánchez & Cueva, 2013; Bermúdez, 2019).

In terms of nutrients, significant concentrations of nitrogen were detected in the form of nitrites (2.9 mg/L) and nitrates (79 mg/L), as well as phosphates at 49 mg/L. These concentrations exceed the recommended limits for effluent discharge, implying a high risk of eutrophication in natural water bodies, promoting algal proliferation and affecting biodiversity (Qiu et al., 2016; Manyuchi et al., 2017). Nitrogen and phosphorus are essential nutrients, but in excess they contribute to environmental degradation, a recurring problem in areas with intensive industrial and agricultural activity (Rodríguez, 2021; Cabrera et al., 2022).

Chemical oxygen demand (COD) and five-day biochemical oxygen demand (BOD5) reached values of 4980 mg/L and 2900 mg/L, respectively, indicating a very high organic load. These demands reflect the amount of biodegradable and non-biodegradable organic matter present in the effluent, key parameters for assessing pollution and designing appropriate treatments (Pérez & Carrasco, 2019; Maza, 2017). High BOD and COD values are typical in wastewater from the meat industry and slaughterhouses, as a result of blood, fat, tissue, and animal remains (Bravo, 2019; Manjarres, 2023).

Total solids (4524 mg/L) and dissolved solids (847.7 mg/L) are also high, confirming the need for treatment to effectively reduce suspended particles and soluble materials to avoid negative impacts on receiving water bodies (Rodríguez, 2021; Manrique & Piñeros, 2016). The presence of solids contributes to increased turbidity and can affect aquatic fauna, as well as hindering subsequent treatment processes (Soto et al., 2020; Sánchez & Cueva, 2013).

e-ISSN:2706-6800

Various studies have shown that slaughterhouses are a major source of water pollution in Ecuador and other regions due to the lack of adequate treatment systems and improper waste management (Quishpe et al., 2020; GAD Ibarra, 2018). For example, Landeta (2019) and Rodríguez (2021) highlight that the direct or insufficiently treated discharge of wastewater into rivers and streams produces negative environmental effects such as eutrophication, fish mortality, and deterioration of drinking water quality. In addition, these effluents may contain pathogenic microorganisms that pose a risk to public health (Soto et al., 2020).

The problem is exacerbated in rural and semi-urban areas, where technical and economic constraints hinder the implementation of conventional treatment plants (Muñoz, 2009; Biswas, 2021). Therefore, the search for accessible, sustainable, and low-cost technologies is a priority to mitigate the environmental impacts associated with slaughterhouses (Misal & Mohite, 2017; Cabrera et al., 2022).

In conclusion, the physicochemical characterization carried out confirms the high pollutant load of the wastewater from the Pelileo Municipal Slaughterhouse, coinciding with the scientific literature and highlighting the urgent need to implement efficient treatment systems, such as worm biofilters, which have proven effective in reducing these critical parameters (Manjarres, 2023; Arora & Saraswat, 2021).

Efficiency of the worm biofilter in removing contaminants

After the implementation of the biofilter with Eisenia foetida worms, significant reductions were observed in all parameters analyzed. The pH of the treated water decreased to 7.64, within the optimal range for most aquatic organisms and in accordance with the limits established by Ecuadorian environmental regulations (Manjarres, 2023). Electrical conductivity was reduced to 887.2 µSiemens/cm, indicating a decrease in the concentration of dissolved salts, possibly due to retention and microbial metabolism favored by the biofilter (Biswas, 2021).

Color and turbidity showed substantial improvement, with final values of 965 Pt/Co units and 32 UTN, respectively, indicating effective treatment of organic matter and suspended solids. This clarification is essential to avoid negative impacts on receiving bodies and facilitate water reuse (Misal & Mohite, 2017).

With regard to nutrients, nitrites decreased to 0.15 mg/L, nitrates to 45 mg/L, and phosphates to 9.5 mg/L, representing a removal of 94.83%, 43.04%, and 80.61%, respectively. This reduction helps mitigate eutrophication and problems associated with excess nutrients in aquatic systems (Qiu et al., 2016; Manyuchi et al., 2017).

Chemical and biochemical oxygen demand showed very significant decreases, reaching values of 350 mg/L for COD and 178 mg/L for BOD5, equivalent to reductions of 92.98% and 93.86%. This confirms the high capacity of the biofilter to degrade biodegradable organic matter, comparing favorably with other biological technologies (Bravo, 2019; Cabrera et al., 2022).

Total and dissolved solids, indicators of particulate pollution, were reduced to 6.25 mg/L and 560 mg/L, respectively, demonstrating the system's ability to retain solid particles and prevent the generation of polluting sludge (Maza, 2017; Pérez & Carrasco, 2019).

These results are consistent with international studies that value vermifiltration as an ecological, economical, and efficient solution. For example, Arora and Saraswat (2021) documented similar reductions in BOD and COD, while Cabrera et al. (2022) showed 86.9% efficiency for BOD5 in the treatment of wastewater from the meat industry, demonstrating the versatility of the technology.

Operational aspects, maintenance, and applicability

Hydraulic retention time (HRT) is one of the most important parameters for the design and operation of worm biofilters, as it directly influences the effectiveness of the biological process. In this study, the estimated HRT was approximately 24 hours, which is considered adequate for Eisenia foetida worms to perform their metabolic functions and for the associated microbial community to degrade the organic matter present in the wastewater (Biswas, 2021; Bravo, 2019). The literature indicates that too short an HRT can limit the necessary contact between the water and the filter medium, reducing the removal of contaminants, while excessive HRT can cause bed saturation and generate anaerobic conditions, compromising the stability and efficiency of the system (Misal & Mohite, 2017; Pérez & Carrasco, 2019).

During biofilter operation, a periodic maintenance regime was implemented to ensure the proper functioning of the system. This maintenance included manual aeration and mixing of the filter bed, activities aimed at preventing substrate compaction and maintaining the permeability necessary for adequate wastewater flow (Bermúdez, 2019; Liberio, 2019). These actions also allow for a sufficient supply of oxygen, a critical factor in preventing the generation of unpleasant

entrosur e-ISSN:2706-6800
INSTITUTO TECNOLÓGICO CORPORATIVO EDWARDS DEMING

odors and the proliferation of anaerobic microorganisms that can negatively affect effluent quality (Soto et al., 2020; Manyuchi et al., 2017).

Constant monitoring of environmental parameters, such as substrate moisture and temperature, was key to the survival and optimal activity of the worms. Eisenia foetida worms are sensitive to sudden changes in these conditions, so maintaining a stable environment ensures the biological stability of the biofilter and maximizes its performance (Manjarres, 2023; Liberio, 2019). The adaptability of these worms to different environments has been widely documented, and their role as a bioremediation agent positions them as a fundamental component of sustainable treatment systems (Arora & Saraswat, 2021; Cabrera et al., 2022).

A notable advantage of the biofilter was the absence of unpleasant odors and undesirable solid waste during operation, which facilitates its application in urban and rural contexts without the negative impacts typically associated with conventional technologies, such as anaerobic systems or lagooning (Manjarres, 2023; Bermúdez, 2019). In addition, the process generates high-quality humus as a by-product, an organic fertilizer that can be used in agricultural activities, thus promoting a sustainable cycle and contributing to the local circular economy (Coronel, 2015; Landeta, 2019).

In terms of the quality of the treated water, analyses confirmed that it complied with the maximum permissible limits defined in Ecuadorian environmental regulations (TULSMA), demonstrating the technical and environmental viability of the biofilter for wastewater treatment in slaughterhouses, especially in locations where investment in conventional systems is limited or non-existent (GAD Ibarra, 2018; Rodríguez, 2021). This regulatory compliance is essential to ensure the protection of receiving water bodies and public health.

This study contributes to the growing body of scientific evidence supporting the use of vermicompost filters as an economical, ecological, and efficient alternative for the treatment of industrial and municipal wastewater. The ease of operation and low maintenance costs represent significant advantages over conventional systems that require high energy consumption and complex sludge management (Pérez & Carrasco, 2019; Manyuchi et al., 2017). In addition, the biofilter's adaptability to different organic loads and types of water makes it applicable in multiple industries, including agribusiness, fishing, and dairy (Maza, 2017; Bravo, 2019).

We recommend expanding the use of this technology in other rural and industrial areas, as well as conducting complementary studies to optimize operating parameters, such as irrigation rate, substrate composition, and hydraulic retention time, in order to maximize process efficiency and facilitate the reuse of treated water for irrigation or production processes, thereby contributing comprehensively to environmental and economic sustainability (Biswas, 2021; Arora & Saraswat, 2021).

Conclusions

This study has demonstrated that the implementation of a biofilter with Californian red worms (Eisenia foetida) represents an effective, sustainable, and viable alternative for the treatment of wastewater from the Pelileo Municipal Slaughterhouse. The high removal capacity of critical pollutants, including organic matter, nutrients, and suspended solids, confirms that this biological system is capable of significantly reducing the pollutant load present in these highly polluting effluents, achieving efficiencies greater than 90% in parameters such as biochemical oxygen demand (BOD5) and chemical oxygen demand (COD). This positions the biofilter as a technology comparable to, and in some cases superior to, conventional treatment systems, but with considerable advantages in terms of low operating costs, ease of maintenance, and lower environmental impact.

Initial characterization of the wastewater showed severe contamination with high levels of nutrients such as nitrates, nitrites, and phosphates, as well as high concentrations of total and dissolved solids, which affect water quality and pose a risk to public health and aquatic ecosystems. The effective reduction of these parameters after passing through the biofilter confirms the system's ability to mitigate the negative effects of these contaminants, preventing eutrophication and other problems associated with the discharge of untreated effluents. The operational stability of the system, evidenced by the maintenance of favorable environmental conditions for the survival and activity of the worms, was fundamental to ensuring the continuous efficiency of the process.

In addition, the biofilter stood out for its low energy requirements and the absence of sludge or solid waste generation, which facilitates its operation in rural or semi-urban areas where infrastructure and technical resources are limited. This feature represents added value by reducing costs and risks associated with sludge disposal, one of the

e-ISSN:2706-6800

main challenges in conventional systems. The absence of unpleasant odors and the simultaneous production of high-quality humus as a by-product add an additional dimension of sustainability, allowing the organic waste generated to be used in agriculture and promoting the local circular economy.

The hydraulic retention time of approximately 24 hours was a determining factor in the efficient degradation of organic matter, as it allowed adequate contact between the wastewater and the active biological medium. Regular maintenance, including manual aeration and prevention of filter bed compaction, was essential to maintain the permeability of the system and the health of the vermicomposting biomass. These aspects highlight the importance of careful management and constant monitoring to maximize efficiency and avoid adverse conditions, such as the emergence of anaerobic environments or mass worm mortality.

Compliance of the treated water parameters with Ecuadorian environmental regulations (TULSMA) supports the applicability of the biofilter for discharge or reuse in productive activities, which is essential for environmental protection and water resource sustainability. The versatility of the system suggests its possible extension to other industries that generate high organic loads, such as agribusiness, the dairy industry, or fishing, increasing the positive impact of this technology on integrated wastewater management.

The Eisenia foetida worm biofilter combines technical efficiency, environmental sustainability, and economic viability, making it an appropriate solution for highly complex environmental problems in contexts with limited resources. Future studies should focus on optimizing operating parameters such as irrigation rate, substrate composition, and retention times to further enhance efficiency and explore integration with complementary treatment systems or water reuse in closed production cycles.

This research contributes to scientific knowledge on clean technologies applied to industrial wastewater treatment, especially in the Latin American context, promoting the adoption of innovative solutions that respond to real sustainable environmental management needs. The widespread implementation of vermicomposting biofilters could represent a significant shift towards more responsible production and environmental management models, with tangible benefits for human health, the environment, and the local economy.

References

Arora, A., & Saraswat, S. K. (2021). Vermifiltration technology for wastewater treatment: A review. *Environmental Technology & Innovation, 21*, 101275. https://doi.org/10.1016/j.eti.2020.101275

Bermúdez, R. (2019). *Estudio del sistema lombrifiltro para tratamiento de aguas residuales en la industria láctea*. Quito: Universidad Central del Ecuador.

Biswas, S. (2021). Efficiency of vermifiltration in municipal wastewater treatment and nutrient recovery. *Journal of Environmental Management, 280*, 111754. https://doi.org/10.1016/j.jenvman.2020.111754

Bravo, J. (2019). Economic feasibility of vermifiltration in food industry wastewater treatment. *Water Science and Technology, 79*(2), 234-242. https://doi.org/10.2166/wst.2018.456

Cabrera, M., Sánchez, L., & Torres, J. (2022). Application of vermifiltration in the treatment of wastewater from the meat processing industry. *Journal of Cleaner Production, 338*, 130574. https://doi.org/10.1016/j.jclepro.2022.130574

Coronel, J. (2015). Caracterización biológica de *Eisenia foetida* para sistemas de vermifiltración. *Revista Ecuatoriana de Ciencias Ambientales, 12*(1), 1-12.

GAD Ibarra. (2018). Diagnóstico ambiental de los centros de faenamiento en la provincia de Imbabura.

Landeta, M. (2019). *Tratamiento de aguas residuales en centros de faenamiento: alternativas ecológicas*. Riobamba: ESPOCH.

Liberio, J. (2019). Adaptación y alimentación de *Eisenia foetida* en biofiltros. *Revista Latinoamericana de Biotecnología Ambiental, 14*(3), 30-41.

Manjarres, D. A. (2023). *Evaluación de un biofiltro de lombrices para la disminución de la carga orgánica en las aguas residuales del Camal Municipal de Pelileo* (Tesis de licenciatura). Escuela Superior Politécnica de Chimborazo.

Manrique, A., & Piñeros, R. (2016). Evaluación comparativa de sistemas naturales para tratamiento de aguas residuales. *Ingeniería y Ambiente, 9*(1), 15-25.

Maza, A. (2017). Remoción de contaminantes en aguas residuales pesqueras mediante lombrifiltro. *Journal of Water Process*

entrosur e-ISSN:2706-6800

INSTITUTO TECNOLÓGICO CORPORATIVO EDWARDS DEMING

Engineering, 20, 50-57. https://doi.org/10.1016/j.jwpe.2017.05.004
Misal, S., & Mohite, S. (2017). Vermifiltration: an effective biological wastewater treatment technology. *Environmental Technology, 38*(3), 365-374. https://doi.org/10.1080/09593330.2016.1205507
Muñoz, M. (2009). Tecnologías alternativas para el tratamiento de aguas residuales. *Revista Iberoamericana de Tecnología Ambiental, 14*(1), 20-30.
Manyuchi, C., Chimbari, M. J., & Mukaratirwa, S. (2017). Vermifiltration for wastewater treatment and reuse in irrigation. *Environmental Science and Pollution Research, 24*(5), 537-546. https://doi.org/10.1007/s11356-016-8120-4
Pérez, C., & Carrasco, L. (2019). Tratamiento de aguas residuales lácteas mediante sistemas lombrifiltro. *Revista de Ingeniería Química, 28*(2), 40-45.
Qiu, H., Yu, J., Yang, L., & Liu, Y. (2016). Enhancing constructed wetland performance by Eisenia foetida earthworms. *Ecological Engineering, 91*, 410-416. https://doi.org/10.1016/j.ecoleng.2016.02.027
Quishpe, G., Valdivieso, A., & Aguilar, L. (2020). Evaluación del impacto ambiental en centros de faenamiento en Ecuador. *Revista Latinoamericana de Ciencias Ambientales, 25*(2), 45-53.
Rodríguez, L. (2021). Impacto ambiental de las aguas residuales en camales de Ecuador. *Revista Científica de Ingeniería Ambiental, 17*(1), 18-25.
Sánchez, P., & Cueva, J. (2013). Aplicación de humedales artificiales para el tratamiento de aguas residuales. *Ingeniería Ambiental, 7*(1), 8-15.
Salazar, J. (2005). Alternativas económicas para el tratamiento de aguas residuales en zonas rurales. *Revista Iberoamericana de Tecnología Ambiental, 10*(1), 1-10.
Soto, F., Paredes, M., & Ramírez, M. (2020). Contaminación orgánica en centros de faenamiento: diagnóstico y tratamiento. *Revista de Ingeniería Sanitaria, 35*(1), 20-30.