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Efficiency of a remediation filter (TEVAP) for the removal of pollutants in swine effluents

Eficiência de um filtro de remediação (TEVAP) na remoção de poluentes em efluentes suínos

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ABSTRACT

Introduction: Swine breeding is a fast growing activity of socioeconomic relevance and potential pollution, whose sustainable expansion depends on technological alternatives that minimize environmental impact, such as techniques and remediation operations in these areas. Remedial effluents must be properly managed prior to their application to soil to avoid potential environmental contamination and damage to human health. **Objective:** The objective was to evaluate the physical and chemical parameters of effluent samples, before and after the treatment through a system of evapotranspiration (TEVAP) for swine manure. **Method:** Physical-chemical aspects were investigated, evaluated before (control: raw effluent) and after treatment, 10 days (treated effluent) and 40 days (final effluent) were investigated. In addition, a microbiological evaluation was performed. **Results:** The hydrogenation potential (pH) did not change. There was a reduction of chemical substances (chemical *oxygen demand* (COD), ammoniacal nitrogen, chlorides), *total dissolved solids* (TDS), temperature, alkalinity, electrical conductivity, total hardness and thermotolerant coliforms, for treated and final effluents. There was an increase in dissolved oxygen (OD). The efficiency of the COD system for the treated effluent was 40%, and for the final effluent was 98%. **Conclusions:** Chemical and microbiological results indicate that the treated effluent, i.e. gray water, can be reused for cleaning pig facilities, although there is a need for additional treatment to achieve complete inactivation for use and direct contact with animals. The low cost of implementation of TEVAP, together with the efficiency of the organic load removal, and with the rural communities, allows the mitigation of negative impacts to the environment, propitiating prevention in the transmission of possible diseases.

KEYWORDS: Pig Breeding; System of Evapotranspiration (TEVAP); Removal Efficiency; Health

RESUMO

Introdução: A suinocultura é uma atividade de rápido crescimento, de relevância socioeconômica e potencial poluidor, cuja expansão sustentável depende de alternativas tecnológicas que minimizem o impacto ambiental, como técnicas e operações de remediação de áreas, a fim de evitar a contaminação ambiental potencial e danos à saúde humana. **Objetivo:** Avaliar os parâmetros físico-químicos de amostras de efluentes, através de um filtro de evapotranspiração (TEVAP) para dejetos suínos. Método: Foram investigados os aspectos físico-químicos e microbiológicos, antes (controle: efluente bruto) e após o tratamento, no 10º dia (efluente tratado) e no 40º dia (efluente final). **Resultados:** O potencial hidrogeniônico (pH) não exibiu alteração. Houve redução de substâncias químicas (demanda química de oxigênio (DQO), nitrogênio amoniacal, cloretos), sólidos dissolvidos totais, temperatura, alcalinidade, condutividade elétrica, dureza total e coliformes termotolerantes paras os efluentes tratado e final. Verificou-se aumento do oxigênio dissolvido (OD). A eficiência do sistema com relação à DQO, para o efluente tratado foi de 40% e, para o efluente final, foi de 98%. **Conclusões:** Os resultados químicos e microbiológicos indicam que o efluente tratado, pode ser reutilizado para limpeza de instalações de suínos. O baixo custo do TEVAP aliado à eficiência na remoção de carga orgânica podem possibilitar a mitigação de impactos negativos ao meio ambiente e à saúde.

PALAVRAS-CHAVE: Suinocultura; Filtro de evapotranspiração (TEVAP); Eficiência de Remoção; Saúde

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INTRODUCTION

Pig farming is a socially and economically important activity. The mitigation of the environmental impact caused by this activity is urgent and has great environmental relevance[1,2]. Because it produces large amounts of wastewater, pig farming poses threats to the environment. On the other hand, this activity also has the potential to generate soil fertilization[3,4]. Pig manure is a potential source of nutrients[5,6]. Therefore, the pursuit of new waste recycling alternatives that do not involve its direct use as fertilizer must be comprehensive and include all segments of the production chain, taking into account concepts of environmental sustainability[7].

The sustainable expansion of pig farming in Brazil depends on technological alternatives that minimize the negative environmental impact caused by the wastewater generated by this activity[8]. Pig farming practices and the lack of proper recovery of affected areas create contaminated spots with severe impact on the ecosystems and risks to human health[2]. The source of contamination is often associated with pig slurry deposits, since these are sources of drainage from these livestock farming activities[2,8]. These areas are devoid of vegetation due to harsh soil conditions that prevent the rooting of plant species. Immediate remediation of these areas is necessary to suppress the generation and build-up of contaminants and their negative effects on ecosystems[9,10].

Pig breeding is a fast-growing branch of the food industry[11]. As a result, it increases pig manure generation as well as pig-related water consumption. Swine effluent contains pig urine, feces, water spills, undigested food remains, antimicrobial drug residues and microorganisms. Given these characteristics, it is recommended that this material be properly managed prior to its application on the ground to avoid potential environmental contamination[12,13]. Pig manure is characterized by a high content of suspended solids, organic matter and a high content of phosphorus and nitrogen[14]. In addition, high levels of microbial populations can be found, including total coliform bacteria, *Escherichia coli* and *Salmonella* sp[14].

The literature reports treatment strategies for pig manure, which include biological processes designed for the effective removal of compound substances and inactivation of bacteria[15,16]. In contrast to pig production, environmental legislation regarding safety parameters is recent[17,18]. In Brazil, National Environmental Council Resolution (Conama) n. 430, of May 13, 2011[19] is used to guide effluent management in bodies of water.

Pig farming is also recognized as an activity of high pollution potential, since it mostly generates liquid effluents with a high content of organic matter, nutrients and heavy metals (e.g. Cu and Zn). The practice commonly adopted by Brazilian pig farming has been the storage of these residues in ponds or tanks and their subsequent application as plant fertilizer and soil conditioner. In regions where effluent generation exceeds soil carrying capacity and/or environmental regulatory agency recommendations, nutrient treatment or export alternatives must be adopted[13,20].

However, nothing has been established about the safety parameters for the reuse of livestock-farming water neither for the control and measurement of the water used in this process. Perhaps the lack of awareness of functional aspects of swine effluent management systems is a gap to be filled. Little is known about the optimization of pollutant removal technologies.

In this context, the objective of this study was to evaluate the physicochemical parameters of swine effluent samples, as well as the removal efficiency of an evapotranspiration system (TEVAP), which consists of a remediation filter, in addition to the water consumption of the system.

METHOD

Treatment system (TEVAP)

The experiment used a remediation filter, whose system can remedy contamination situations and the damage caused to the environment as a result of pig farming. It was set up at the Federal Institute of Education, Science and Technology of Ceará (IFCE), in its campus in Crato, Brazil. The sustainable-use tool was a TEVAP so that it could be developed and disseminated by permaculturists of various nationalities. It is a waterproofed tank filled with different layers of substrate and planted with fast-growing plant species with high demand for water. It is a closed system with no infiltration into the soil. It receives effluents that go through natural processes of microbial degradation of organic matter, mineralization and absorption of nutrients and water by roots, and then evapotranspiration by plants (Figure 1). In order to meet the proposed objectives, the study was conducted in three different phases, as per Figure 1.

Collection, storage of samples and physicochemical analysis

The samples were collected in two areas: the settling box and the TEVAP, at IFCE, Crato campus, on three separate days, at the following intervals: 1st day (first sample); 10th day (second sample) and 40th day (third sample), with three repetitions for each collection.

After the setup of the settling box and the TEVAP that make up the effluent treatment system, it was possible to store the product of the washing of 22 stalls and 10 calving cells of a pig pen with 100 animals. Samples were obtained in the following sequence: site 1 - settling box containing raw effluent, then site 2 - TEVAP containing treated effluent and final effluent. After treatment with the remediation filter, solid-liquid separation and treated wastewater were obtained.

The physicochemical parameters analyzed were: pH, temperature, chemical oxygen demand (COD), dissolved oxygen (DO),

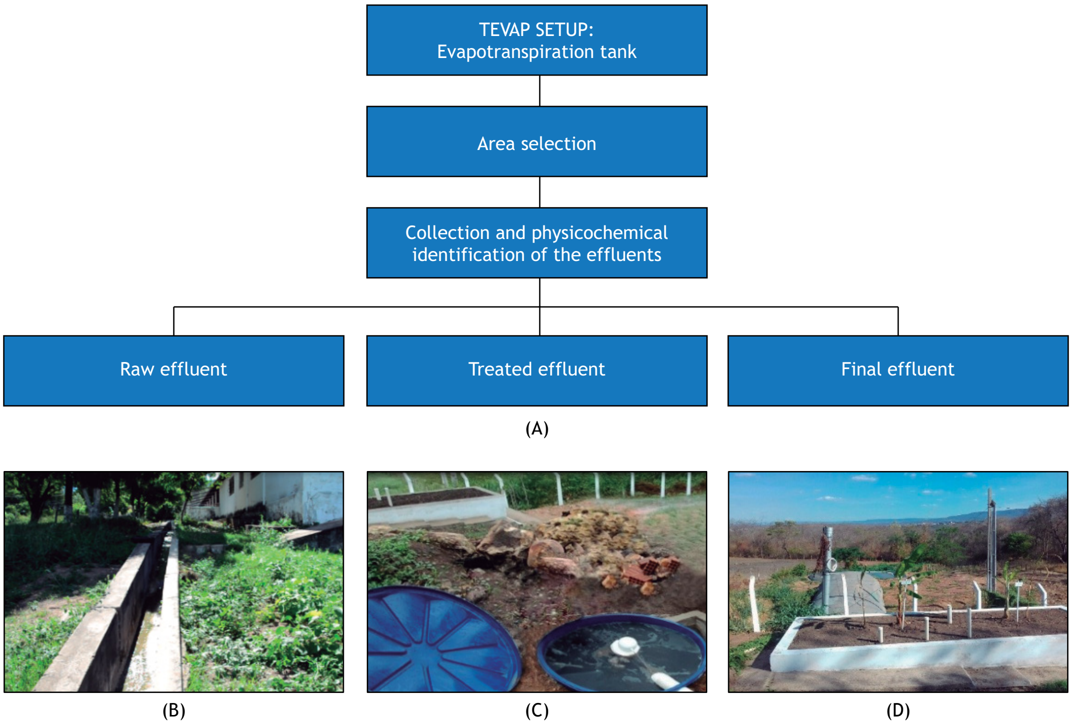


Figure 1. Study development flowchart. Sampling locations are indicated: (A) TEVAP setup flowchart and its respective collection phases for analysis; (B) channel through which the effluent flows after pig pen wash; (C) settling box that temporarily receives pig manure before being stored in the TEVAP; and (D) TEVAP - overlapping culture septic basin, germinated after evapotranspiration.

potential of hydrogen, sedimentable solids, total suspended solids, total dissolved solids (TDS), electrical conductivity, ammoniacal nitrogen (AN) and nitrate, total iron, hardness and chlorides, alkalinity. Analytical procedures were done in accordance with the Standard Methods for the Examination of Water and Wastewater[21] and the Manual of Supply and Wastewater Physicochemical Analyses[22].

Water consumption monitoring: hydrometer setup

In order to evaluate water use, a hydrometer was set up inside the pig farming facilities, in the washing of the pig breeding sector and in the waste drainage by a channel.

It is a technological, modern and efficient device that is present in both urban and rural communities. Its main objective is to control and record the amount of water for consumption in general.

The effluents were directed for final reception in the basin or remediation filter, i.e. the TEVAP.

Statistical analysis

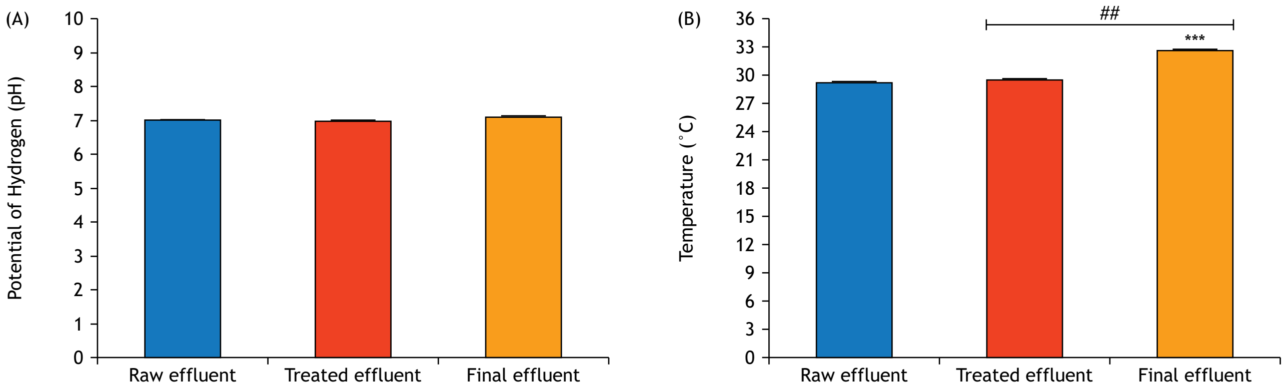
Parametric data were analyzed by one-way analysis of variance (ANOVA), with subsequent Tukey's test. The minimum significance level (α) adopted was 0.05. Three independent experiments were performed. The system efficiency was also evaluated based on the equation[17] of Efficiency = $(X_0 - X) / X_0 \cdot 100e$, where X_0 = baseline concentration and X = final concentration.

RESULTS AND DISCUSSION

Swine effluents should be handled properly to avoid negative environmental impact[17]. TEVAP, which consists of a remediation filter, was evaluated as an alternative treatment for pig manure to minimize health risks. The physicochemical parameters evaluated before treatment (control: raw effluent), 10th day (treated effluent) and 40th day (final effluent) after treatment were investigated. Microbiological evaluation was also done. The chemical profile of the TEVAP system in this study was similar to that observed by other authors in other pig farming systems[13,17].

No statistically significant change in the potential of hydrogen (pH) was observed between the raw effluent and the treated and final effluents (Figure 2A). The pH is one of the most important factors that drive the efficiency of the system, whose normal condition is found near neutrality. When there is some imbalance, i.e. when the pH is below 6.5 and needs to be corrected to avoid a decrease in biological activity, an option is to start an inactivation process, like increasing the pH above 10 by applying lime[23]. In terms of temperature, the final effluent has shown a significant increase when compared to the control and treated effluent (Figure 2B).

In biological systems, temperature plays an important role, since the rates of biochemical reactions are directly affected by it[24,25]. Faust[26] suggested that water temperature is one of the most important factors in predicting the survival of fecal



*** Differences from control; ### Differences between groups (p <0.001).

Figure 2. Determination of the potential of hydrogen (A) and temperature (B) of pig farming effluent samples before and after treatment with TEVAP. The results are the mean of independent experiments (n = 3) performed in triplicate.

coliforms as a quality parameter of effluents discharged into water ecosystems. Generally, only thermophilic processes are suitable for pathogen inactivation because bacteria are inactivated at temperatures above 60° C[25], with a population decrease of 64% after 12 days[27].

Aerobic and anaerobic biological processes are capable of inactivating microorganisms. The efficiency of pathogen inactivation is related to several factors, like antibiosis, redox potential, antagonism, nutritional deficiencies and exothermic metabolism[17]. Treatment of this waste is essential to maximize integration between environment and production[28].

Comparing parameters analyzed individually, different removal profiles were observed throughout the treatment. In this study, the COD parameter, which expresses the amount of oxygen needed to chemically oxidize organic matter[24.29], has shown a progressive drop throughout the TEVAP system.

The COD has had significant reduction between final and raw effluent (control). When compared to the control, the treated effluent was significantly reduced (Figure 3A). Between the tested times, the final effluent was significantly reduced in relation to the treated effluent. The efficiency of the system was 40% for the treated effluent and 98% for the final effluent. A similar result was found by Rodrigues et al.[29], whose total COD and BOD removal means were 96.7% and 98.4%, respectively. In general, the attributes related to physical removal were efficiently reduced, probably due to interstitial sedimentation, retention by flow restriction (filtration) and adhesion to the granules of the system materials.

The DO levels have shown significant variation when compared to the raw effluent (control). In the treated effluent there was an increase to 2 mg/L, while in the final effluent there was an increase of DO to 3.7 mg/L, statistically significant when compared to the control and treated effluent[30].

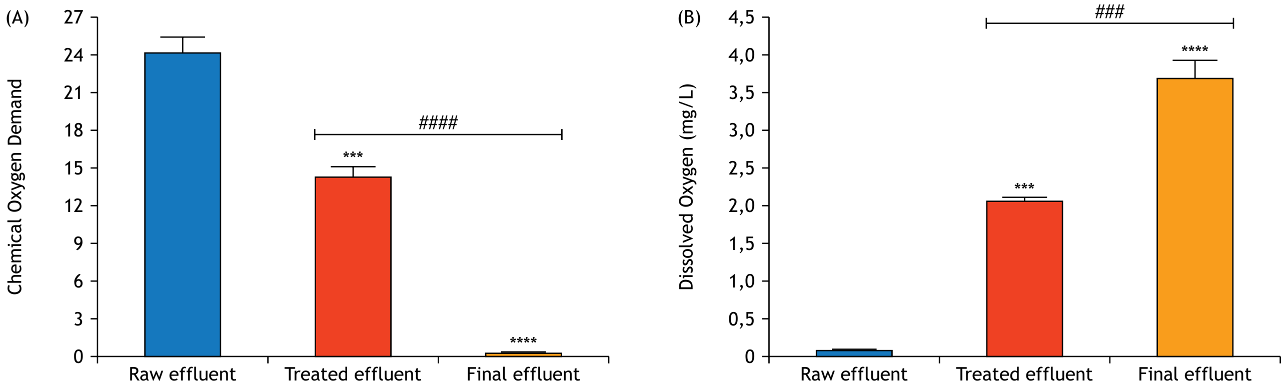
The AN levels of the final effluent have shown significant variation when compared to the raw effluent (control). Significant changes occurred among the tested times. The final effluent has shown a statistically significant reduction when compared to the treated effluent (Figure 4A). Regarding nitrate levels, no changes occurred.

There were no significant changes in suspended solids (SS) and total suspended solids (TSS) when compared to control and between treatments, treated effluent and final effluent. Among the treatments, there was a reduction in TDS, while for the TSS there was an increase in the final effluent (Figure 4A). The removal efficiency of the TEVAP system for SS, TSS and TDS was 73%, 60% and 48% for treated effluent and 98%, 42% and 42% for final effluent, respectively. Therefore, the efficiency obtained in this study for SS (73% and 98%) can be considered satisfactory, considering that the pig farming wastewater under treatment had heavy organic load. Another report has shown that one system had pollutant removal efficiency for TSS and TS of 91% and 62%, respectively[31,29]. The effluent from this activity has a high content of suspended solids and organic matter, as well as a high concentration of nutrients, especially phosphorus and nitrogen[32].

The electrical conductivity (Figure 5A), alkalinity (Figure 5B), total iron, total hardness, chlorides (Figure 5C) and coliforms (Figure 5D) parameters have shown statistical differences in relation to control and among all treatments tested (treated effluent and raw effluent). There is a linear relationship for conductivity as a function of total and mostly dissolved solids in all wastewater, pig farming, dairy and industrial waters[32].

Probably a longer time of filter operation would enable greater removal efficiency due to greater formation and stability of the biofilm.

The bacterial profile has shown a significant reduction in total coliforms, decreasing from 150 in the raw effluent to 11 x 10^{-3} fecal coliforms/100 mL in the final effluent. Therefore, the system under study proved effective in reducing the number of coliforms during treatment. This total reduction of coliforms was expected, since the reduction of the level of organic material during treatment was substantial. Viancelli et al.[17] suggested



*** Differences from control; ### Differences between groups (p <0.001).

Figure 3. Determination of chemical oxygen demand (A) and dissolved oxygen (B) of pig farming effluent samples before and after TEVAP treatment. The results are the mean of independent experiments (n = 3) performed in triplicate.

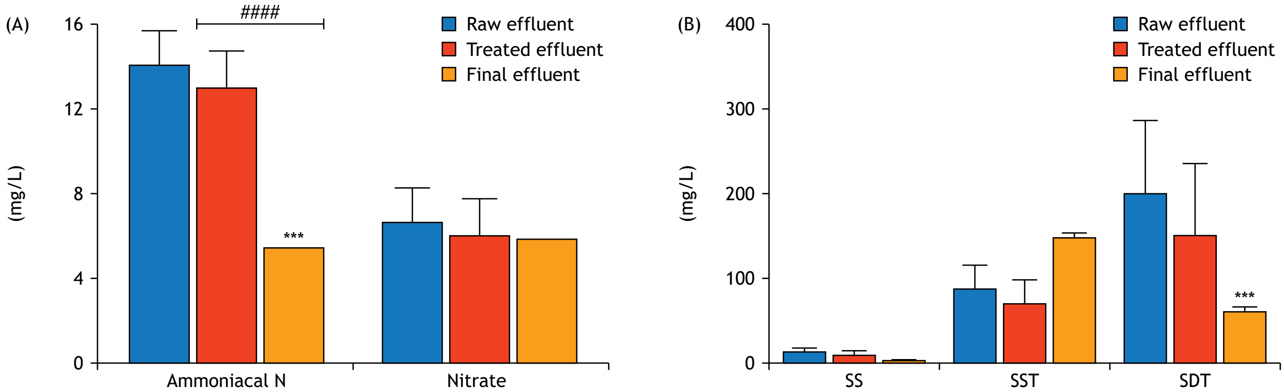


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Figure 4. (A) Ammoniacal nitrogen and nitrate concentration and (B) determination of sedimentary solids (SS), total suspended solids (TSS) and total dissolved solids (TDS) in pig farming effluent samples before and after TEVAP treatment. The results are the mean of independent experiments (n = 3) performed in triplicate.

that an anaerobic process decreased fecal indicators due to an increase in microbiological competition for substrate.

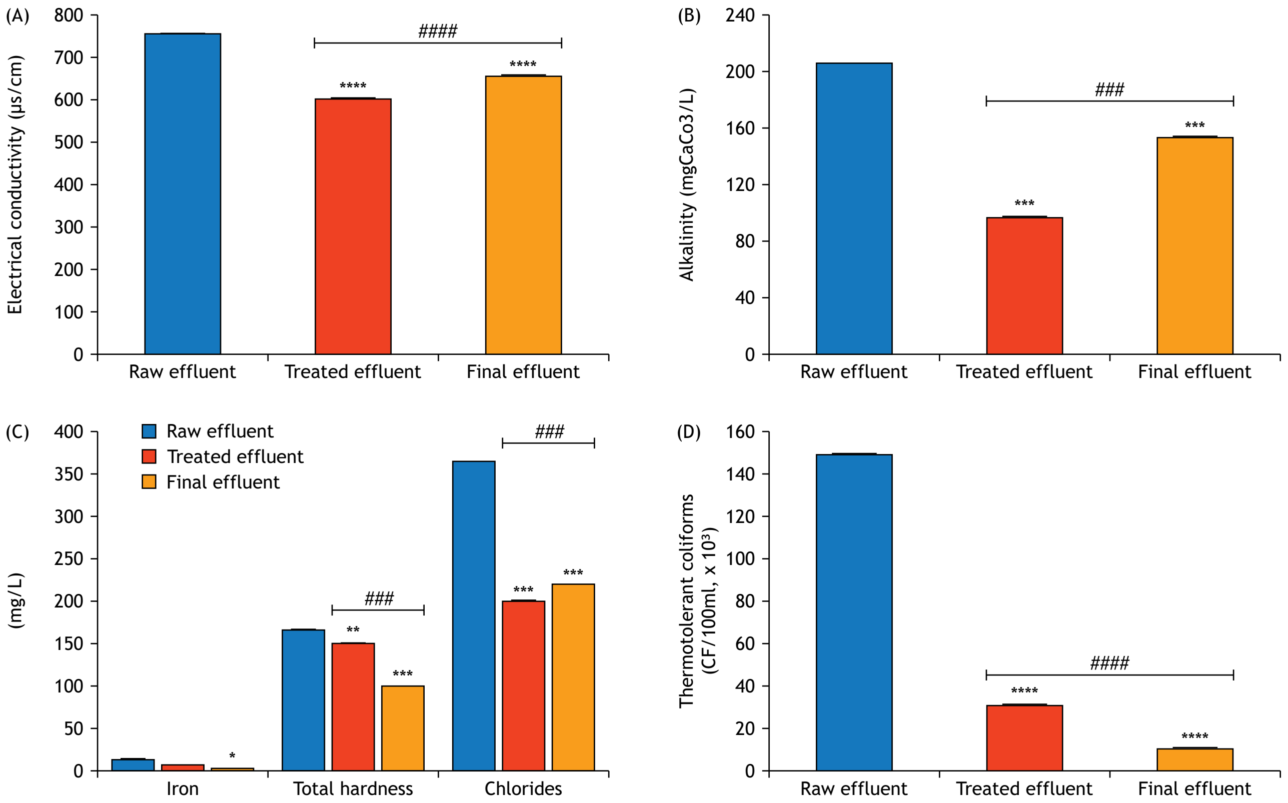
Pig farming is directly dependent on natural resources. It demands large amounts of water and generates much waste, which must be properly treated. Therefore, greater knowledge of the impact of such activity on water resources and the environment is required[33,34].

Sousa et al.[135] observed that cotton cultivars fertilized with pig effluent had better performance of dry matter, absorption and nutrient accumulation when compared to crops that had not been irrigated with this biofertilizer. Souza et al.[35] found that sweet pepper production was not contaminated by thermotolerant coliforms and *Salmonella* ssp. when using pig farming wastewater after pretreatment.

As for the water demand in pig management, to wash the pig breeding stalls (breeding, gestation, maternity, nursery and the channel that collects all the waste from the washed places), based on the measurement and records from the hydrometer setup inside the pen, a consumption of 1,250 L/41 min of water was observed. This result can subsidize and ensure the control and proper use of this important resource.

The relevance of monitoring the experiment with the hydrometer[36] stands out. The literature reports that the inability to monitor water use through hydrometers hindered the accuracy of the measurements on pig breeding and slaughtering. Thus, the mean estimate of water consumption for the supply of five stalls for approximately 10 hours a day through volumetric method was 551 L[37].

The significant reduction of almost all parameters analyzed after treatment with the TEVAP suggests that this may be a good alternative for the treatment of pig farming effluents. A similar reduction was reported by Pereira et al.[27] when evaluating the removal of pig farming effluents. They highlighted that government agencies have been paying special attention to intensive pig farming due to its potential pollution and problems related to epidemiology.



*** Differences from control; ### Differences between groups (p <0.001).

Figure 5. (A) Determination of hydraulic conductivity, (B) alkalinity, (C) iron, total hardness and chlorides and (D) thermotolerant coliforms from pig farming effluent samples before and after treatment with TEVAP. The results are the mean of independent experiments (n = 3) performed in triplicate.

Pig farming requires manure management and treatment, in addition to the use of the effluents, which are intrinsic to the production process. The TEVAP is an option of low-cost setup and operation. It reduces the need for complementary treatment processes, since the stabilization of the waste starts in the system itself. This study adds knowledge about some physical, chemical and microbiological aspects that are vital for the proper functioning of this system. The cultural aspect is also relevant and needs to be addressed, considering that some farmers may be reluctant to adopt these alternatives.

The setup of a TEVAP can be advantageous and environmentally friendly, since the attempt to maximize pig production may be harmful to forests, water, soil, native fauna and flora, microorganisms etc. If poorly planned, this type of production will have an impact on environmental conservation. Care for the environment must be an integral practice of any production process.

On the other hand, there are still major challenges to be overcome in mitigating the environmental impact of these remediation systems (TEVAP), like more effective control of gas emissions and the development and adoption of more efficient technologies for removing heavy metals, antibiotics and pathogens.

CONCLUSIONS

The adopted solution, composed of an anaerobic system (TEVAP), has shown full-scale high efficiency in the removal of organic and solid matter, with values above 98% for COD, and significant reduction of other parameters, thus confirming its feasibility in the treatment of pig farming wastewater. It is an option of low-cost setup and operation that takes into account the impact on the environment. This study brings more information about physical, chemical and microbiological aspects that can be helpful for the users of the system. The physicochemical and microbiological results indicate that the treated effluent can be reused in crops and to wash pig breeding facilities. However, the results show the need for additional treatment to achieve complete inactivation in cases where direct contact with animals is required.

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Conflict of Interest

Authors have no potential conflict of interest to declare, related to this study's political or financial peers and institutions.