ORIGINAL ARTICLE

Reusing of Urban Wastewater Treated for Irrigation Purposes of Stabilization Ponds

Reutilización de agua residual urbana depurada de una laguna de estabilización con fines de riego

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Gisel Guerra Hernández[I]*, Oscar Brown Manrique[I], Beatriz Melo Camaraza[I], Alexander Hernández Rodríguez[I], Marcos Edel Martínez Montero[I], Ernesto Donis Almeida[II]

[I]Universidad de Ciego de Ávila Máximo Gómez Báez (UNICA), Ciego de Ávila, Cuba.
[II]Dirección Provincial de Recursos Hidráulicos, Ciego de Ávila, Cuba.

ABSTRACT: The increase in competition for the use of water makes it an increasingly scarce resource for agricultural irrigation; it is necessary to search for alternative sources, such as the reuse of wastewater in agriculture that represents benefits for the soil and crops. The research was carried out with the objective of evaluating the quality of treated residual water in stabilization ponds for agricultural irrigation purposes, from the analysis of the physical, chemical and microbiological parameters of residual water. The main results indicate the presence of a facultative lagoon with efficiencies of 50%, 53%, 98% and 94% for the removal of biochemical oxygen demand, chemical oxygen demand, thermotolerant coliforms and total coliforms, respectively. That accounts for 74% of total operation efficiency of the lagoon with 2 $mg \cdot L^{-1}$ of dissolved oxygen in it. These values indicate that the effluent from the stabilization pond can be used for irrigation of cooked food crops according to the recommendations of the World Health Organization for Latin America and the Caribbean.

***Keywords*:** Alternative Source, Total Coliforms, Thermotolerant Coliforms, Efficiencies, Agriculture.

RESUMEN: El incremento de la competencia por el uso del agua hace que esta sea un recurso cada vez más escaso para el riego agrícola; siendo necesaria la búsqueda de fuentes alternas, como la reutilización de las aguas residuales en la agricultura que representan beneficios para el suelo y los cultivos. La investigación se realizó con el objetivo de evaluar la calidad del agua residual depurada en lagunas de estabilización del municipio de Morón en la provincia de Ciego de Ávila, Cuba, con fines de riego agrícola a partir del análisis de los parámetros físicos, químicos y microbiológicos del agua residual. Los principales resultados indican la presencia de una laguna facultativa, eficiencias de remoción de coliformes termotolerantes de 98%, eficiencias de remoción de coliformes totales de 94%, eficiencias de remoción de demanda química de oxígeno de 53%, eficiencias de remoción de demanda bioquímica de oxígeno de 50%, eficiencia total de funcionamiento de la laguna de 74% y oxígeno disuelto de 2 $mg \cdot L^{-1}$. Estos valores indican que el efluente de la laguna de estabilización puede ser utilizarse para la irrigación de cultivos alimenticios cocidos según las recomendaciones de la Organización Mundial de la Salud para América Latina y el Caribe**.**

***Palabras clave*:** Agua residual, coliformes totales, coliformes termotolerantes, eficiencias, reutilización.

INTRODUCTION

Wastewater has been used in agriculture for many years due to the benefit it represents for the soil and the crop (Pérez-Díaz *et al.*, 2019). In the current context of climate change and global water deficit, its use has increased due to alternative supplies of water and can be applied to food crops that are consumed raw and cooked; industrial and fodder (Polón-Pérez *et al.*, 2019).

Annually, 380 billion m^3 of wastewater are produced worldwide and this volume is expected to increase to 470 billion m^3 by the end of 2030 and reach 574 billion m^3 in 2050 (Mendoza-Retana *et al.*, 2021).

The use of urban effluents is a viable alternative to increase the local availability of water resources and nutrients for plants; however, its use in agriculture requires measures to avoid risks to human health and the environment (Sánchez-Gutiérrez & Gómez-Castro, 2021).

*Author for correspondence: Gisel Guerra-Hernández, e-mail: gisel@unica.cu

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Cuba has a sanitation infrastructure made up of more than 300 stabilization ponds, 5,442 kilometers of sewerage networks, 163 waste pumping stations and 12 treatment plants to achieve adequate final disposal of effluents (Gil, 2016).

Ciego de Ávila Province has an urban wastewater treatment system made up of ten facultative lagoons with removal efficiencies of chemical oxygen demand and biochemical oxygen demand that range between 35-55%, which is why they cause negative impacts on surface water sources

The objective of the work was to evaluate the functioning of the stabilization lagoon for agricultural irrigation purposes in Morón Municipality, Cuba by evaluating the physical, chemical and microbiological parameters as essential aspects for increasing the efficiency of organic load removal to improve wastewater quality.

MATERIALS AND METHODS

The research was carried out in the stabilization lagoon of Morón Municipality, in Ciego de Ávila Province, Cuba; located between the planar coordinates Cuba Norte X = 744367 m and Y = 257166 m (Figure 1).

Analysis of Physical, Chemical and Microbiological Parameters

The analysis of the physical, chemical and microbiological parameters of the influent and effluent were carried out by the personnel of the laboratory of the National Company of Technical Services of Ciego de Ávila Province. The following indicators were measured.

Water temperature (*T*) was measured using the laboratory method with a calibrated thermometer for a range below 50 °C (Luna-Imbacuán *et al.*, 2016). Electrical conductivity (*EC*) was measured through the electrometric method for a range lower than 4 000 µS cm $^{-1}$ (Castillo-Sánchez *et al.*, 2020). Dissolved oxygen (*DO*) was determined using the Winkler method for a range of 2 to 7 mg L^{-1} (Recalde-Mortola & Vielma-Puente, 2022). Hydrogen potential (*pH*) was determined by the electrometric method for a range from 6 to 9 pH units (Pérez-Díaz *et al.*, 2019). Settleable solids *(SS)* were determined using the Inhoff Cone for a range of less than 10 mL L^{-1} (Dunán-Ávila *et al.*, 2020). Total coliforms (*TC*) and thermotolerant coliforms (*CTT*) were determined using the multiple tube technique for a range below 1 000 mg L^{-1} (Baird *et al.*, 2017). Total phosphorus (*PT*) was determined by the stannous chloride colorimetric method for a range lower than 10 mg L^{-1} (Perojo-Bellido de Luna *et al.*, 2022). Chemical oxygen demand (COD): using the accelerated autoclave digestion method to dichromate for a range below 120 mg L^{-1} (Mayta & Mayta, 2017). Biochemical oxygen demand (BOD_5) was determined using the incubation method for 5 days at 20°C and determination by Winkler for a range below 60 mg L^{-1} (Limache-Quispe & Tirado-Rebaza, 2022).

The removal efficiency of the organic load was estimated based on the concentration of total coliforms, thermotolerant coliforms and on chemical and biochemical oxygen demands in inlet tributaries and outlet effluents. The total removal efficiency was also determined according to Romero-López & Castillo-Torres (2018) through the following equations:

$$\eta_{rem} = \frac{(C_E - C_S)}{C_E} . 100 \quad (1)$$

$$\eta_{func} = \frac{\Sigma\left(\eta_{CT} + \eta_{CTT} + \eta_{DQO} + \eta_{DBO_5}\right)}{4} \quad (2)$$

Where η_{rem} is the organic load removal efficiency (%), C_E the concentration of tributaries (mg L^{-1}), *CS the* effluent concentration (mg L^{-1}), η_{func} is the total removal efficiency (%), η_{CT} the removal efficiency of *total* coliforms (%), η_{CTT} the removal efficiency of thermotolerant coliforms (%), η_{DQO} the chemical oxygen demand efficiency (%) and η_{BOD5} biochemical oxygen demand efficiency (%).

FIGURE 1. Satellite map of the lagoon's location.

RESULTS AND DISCUSSION

Analysis of Physical Characteristics

The analysis of the physical characteristics allowed knowing that the lagoon presented a good functioning due to the presence of green algae of the genus *Chlorella, Scenedesmus and Chalamydonomas* They are great producers of oxygen. The photosynthetic activity of these algae and surface reaeration favor the production of oxygen necessary for the purification process (Vanegas-Benavides & Reyes-Rodríguez, 2017)**.** The average monthly minimum air temperature was 25.8 °C, which favored the development of degradation processes (Luna-Imbacuán *et al.*, 2016).

Analysis of Chemical Characteristics

The analysis of the chemical parameters shows that the hydrogen potential of the influent and the effluent was 7.7 and 8.1 units, respectively. These values are within the permissible range according to Pérez-Díaz *et al.* (2019). The consumption of CO_2 by the algae causes the pH to increase in the lagoon, which can reach values higher than 9.0. However, pH values lower than 6.2 units, affect methane production activity; therefore, organic acids and other compounds with unpleasant odors are released, which indicate deficient functioning of the lagoon (Guzmán-Pérez *et al.*, 2021).

The average values of electrical conductivity (*EC*) in the influents and effluents were 1058.0 µS cm^{-1} and 952.0 µS cm^{-1}, respectively, which are lower than the permissible values of effluent discharge to receiving bodies (< 4 000 µS cm^{-1}) according to Castillo-Sánchez *et al.*(2020).

The settleable solids (*SS*) were practically null on the surface of the lagoon and increased with depth up to average values of 2 mL L^{-1}; therefore, the condition established for this parameter is met (<10 mL L^{-1}) according Dunán-Ávila *et al.* (2020).

The contributions of total phosphorus in the influent and the effluent were 6 mg L^{-1} and 0.90 mg L^{-1}, respectively. This decrease was related to the presence of the *Chlorella sp.* microalgae, which reduces the nitrogen and phosphorus load (Tafur-Alvarez & Estrada, 2019). This important nutrient can be incorporated into the soil through irrigation for the development of crops such as bananas, sweet potatoes, beans, corn and rice in areas surrounding the lagoon (Sánchez-Gutiérrez & Gómez-Castro, 2021).

Dissolved oxygen concentrations were 0 mg L^{-1} and 2 mg L^{-1} in the influent and effluent, respectively. The result was lower in relation to the range of 2 to 7 mg L^{-1} suggested by Recalde-Mortola & Vielma-Puente (2022). These values are low due to the low penetration of sunlight; as well as the abundance and activity of specific groups of microorganisms (Huinil, 2020).

The biochemical oxygen demand values in the influent and effluent were 176 mg L^{-1} and 112 mg L^{-1}, respectively, for an efficiency of 50%, behavior associated with the low availability of dissolved oxygen (Mayta & Mayta, 2017; Echeverría *et al.*, 2021).

The results of the chemical oxygen demand were 60 mg L^{-1} and 40 mg L^{-1} in the influent and effluent, respectively for an efficiency of 53%, behavior associated with low availability of dissolved oxygen consumed in the chemical oxidation of oxidizable matter, whether biodegradable or not (Limache-Quispe & Tirado-Rebaza, 2022).

Analysis of Microbiological Characteristics

The results of the values of thermotolerant coliforms were 92,000 mg L^{-1} and 1,200 mg L^{-1} in the influent and effluent, respectively, for an efficiency of 98%. The value of the effluent is lower than the limit established of 2 000 mg L^{-1} in various Latin American countries for irrigation with wastewater (Baird *et al.*, 2017)**.**

Total coliform values were 1,60,000 mg L^{-1} and 1,200 mg L^{-1} in the influent and effluent, respectively, for an efficiency of 93%. The effluent value is slightly higher than 1 000 mg L^{-1}, the limit value recommended by the World Health Organization for crop irrigation (Baird *et al.*, 2017)**.** In this way, the effluent obtained is not suitable for irrigation of food crops that are consumed raw; but it is suitable for cooked food crops.

The use of wastewater in agriculture benefits third world countries by controlling pollution and increasing agricultural production in the face of lack of water resources. However, the presence of pathogenic microorganisms in these waters can cause diseases, so it is important to remove effectively coliforms in the treatment process. Responsible use is crucial to ensure health safety (Cortés-Martínez *et al.*, 2017).

Total Removal Efficiency Analysis

The removal efficiencies of the parameters that intervene in the operation of the lagoon influence total removal of the lagoon of 74% which is lower than the established minimum limit of 85% to achieve a good operation (Vargas *et al.*, 2020). This value is fundamentally associated with the low values found in the BOD_5 and COD removal efficiencies, which is why it is considered that the operation of the lagoon is regular.

These BOD_5 and COD efficiency values are low due to the low penetration of sunlight; as well as the abundance and activity of specific groups of anaerobic microorganisms, which is why it is considered that the functioning of the lagoon is regular; however, the purified water can be used to irrigate cooked food crops (Figure 2).

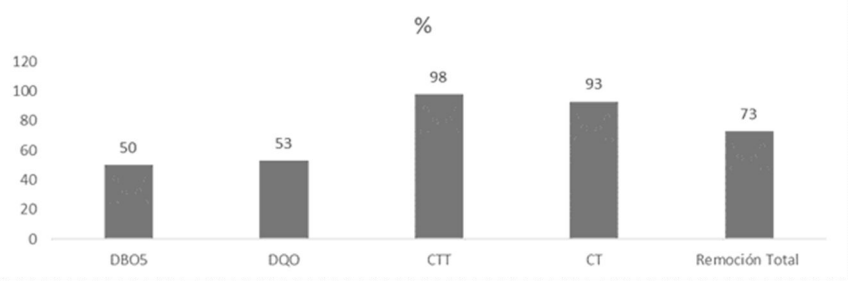

FIGURE 2. Representation of the purification efficiencies and operation of the lagoon.

The result of this parameter suggests the need to implement practices for the reuse of treated wastewater in stabilization ponds for agricultural irrigation of crops that are not directly consumed; being necessary the application of actions to avoid damage to the soil, the crop and human health.

CONCLUSIONS

- Efficiencies of 50%, 53%, 98% and 94% were obtained for the removal of biochemical oxygen demand, chemical oxygen demand, thermotolerant coliforms and total coliforms, respectively. The above reveals a low total removal efficiency of 74% (less than 85%).
- Dissolved oxygen concentrations were 0 mg L^{-1} and 2 mg L^{-1} in the influent and effluent, respectively.
- These values are low due to the low penetration of sunlight; as well as the abundance and activity of specific groups of microorganisms, which is why it is considered that the functioning of the lagoon is regular; however, the purified water can be used to irrigate cooked food crops.

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Gisel Guerra-Hernández. MSc., Prof. Auxiliar, Universidad de Ciego de Ávila Máximo Gómez Báez (UNICA), Centro de Estudios Hidrotécnicos (CEH), Ciego de Ávila, Cuba, e-mail: gisel@unica.cu.
Oscar Brown-Manrique. Dr.C., Prof. Titular, Universidad de Ciego de Ávila Máximo Gómez Báez (UNICA), Centro de Estudios Hidrotécnicos (CEH), Ciego de Ávila, Cuba, e-mail: obrown@unica.cu.
Beatriz Melo-Camaraza. Ing. Hidráulica, Universidad de Ciego de Ávila Máximo Gómez Báez (UNICA), Departamento de Ingeniería Hidráulica, Ciego de Ávila, Cuba, e-mail: beatrizmc@unica.cu.
Alexander Hernández-Rodríguez. Ing. Hidráulico, Universidad de Ciego de Ávila Máximo Gómez Báez (UNICA), Centro de Estudios Hidrotécnicos (CEH), Ciego de Ávila, Cuba, e-mail: alexanderh@unica.cu.
Marcos Edel Martínez-Montero. Dr.C., Prof. Titular, Universidad de Ciego de Ávila Máximo Gómez Báez (UNICA), Facultad de Ciencias Agropecuaria, Ciego de Ávila, Cuba, e-mail: cubaplantas@gmail.com.
Ernesto Donis-Almeida. Ing. Hidráulico, Dirección Provincial de Recursos Hidráulicos, Ciego de Ávila, Cuba, e-mail: donisalmeida18@gmail.com.

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