Ambiente & Água - An Interdisciplinary Journal of Applied Science
ISSN 1980-993X – doi:10.4136/1980-993X
www.ambi-agua.net
E-mail: ambi.agua@gmail.com

Evaluation of biological wastewater treatment in stabilization lagoons from Punta Carnero, Salinas – Ecuador

ARTICLES doi:10.4136/ambi-agua.2822

Received: 17 Dec. 2021; Accepted: 07 Mar. 2022

Juan José Humanante Cabrera[1*]; Lucrecia Cristina Moreno Alcivar[1,2]; Carlos Alberto Deza Navarrete[1]; Ana Mercedes Grijalva Endara[1,3]; Juan Humanante Moreno[4]; Joan Alberto Suárez Tomalá[2]

[1]Graduate School. National University of Tumbes, University Avenue, s/n, 24001, Pampa Grande, Tumbes, Peru. E-mail: lmoreno@upse.edu.ec, cdezan@untumbes.edu.pe, ana.grijalvae@ug.edu.ec
[2]Department Engineering Sciences Faculty. Santa Elena Peninsula State University, Santa Elena Principal Avenue, 240350, La Libertad, Santa Elena, Ecuador. E-mail: lmoreno@upse.edu.ec, joan.suareztomala@upse.edu.ec
[3]Department Chemical Sciences Faculty. Guayaquil University, Avenue 10 NO Guayaquil, 090514, Guayaquil, Guayas, Ecuador. E-mail: ana.grijalvae@ug.edu.ec
[4]Postgraduate master's degree. Guayaquil University, Avenue 10 NO Guayaquil, 090514, Guayaquil, Guayas, Ecuador. E-mail: juan.humanante@eppetroecuador.ec
[*]Corresponding author. E-mail: jhumanante@hotmail.com

ABSTRACT

This research evaluated the wastewater treatment system of the Punta Carnero sector, in relation to pollutant efficiency load removal, final effluent quality and impact on the ecosystem, and finally to determine if the final discharge can be reused for agricultural irrigation. The research was based on the affluent and effluent characterization of the system, carried out in three phases: i) Taking of simple samples, analyzed in an accredited water laboratory and analysis of the contaminant loads efficiency; ii) Review of results compared to the Table of "Discharge limits to a freshwater receiving body"; iii) Examination of results based on the "Water Quality Criteria for Agricultural Irrigation" Table of the Ecuadorian regulation TULSMA (2015). BOD (62.42%), COD (62.41%) and FC (53.58%) removal efficiencies did not comply with current Ecuadorian regulations. The quality of the effluent with respect to the parameters evaluated for discharges to a freshwater receiving body denoted a non-optimal quality of final discharge, negatively impacting the ecosystem. Finally, the evaluation determined parameters that exceed the water quality criteria for agricultural irrigation allowed: Oils-Fats (5.65 mg/l), FC (62,900 NMP/100ml), Hg (0.00141 mg/l), OD (8.86 mg/l). After evaluating the wastewater treatment system, it was determined that the pollutant load removal efficiency and effluent quality is not optimal for discharge into a receiving water body, so it's not suitable for reuse in agricultural irrigation.

Keywords: affluent, effluent, water quality.

Avaliação do tratamento biológico de águas residuais em lagoas de estabilização de Punta Carnero, Santa Elena – Equador

RESUMO

O objetivo da pesquisa foi avaliar o sistema de tratamento de águas residuais do setor de

Punta Carnero, em relação à sua eficiência na remoção de cargas poluentes, a qualidade do efluente final e seu impacto no ecossistema e, finalmente, determinar se o descarte final pode ser reutilizado para irrigação agrícola. A pesquisa consistiu na caracterização da influência e do efluente do sistema, desenvolvido em três fases: i) Retirada de amostras simples, testadas em um laboratório de água credenciado e análise da eficiência das cargas poluentes; ii) Revisão dos resultados comparados com a Tabela de "Limites de descarga para um corpo receptor de água doce", iii) Exame dos resultados de acordo com a Tabela de "Critérios de qualidade da água para irrigação agrícola" da regulamentação equatoriana TULSMA (2015). A eficiência de remoção da BDO (62,42%), COD (62,41%) e CF (53,58%) não estão em conformidade com os regulamentos atuais do Equador. A qualidade do efluente com respeito aos parâmetros avaliados para descargas em um corpo receptor de água doce, denotam uma qualidade não ideal de descarga final, afetando negativamente o ecossistema; finalmente, a avaliação determinou parâmetros que excedem os critérios de qualidade da água para irrigação agrícola: Óleos-Gorduras (5,65 mg/l), CF (62900 NMP/100ml), Hg (0,00141 mg/l), OD (8,86 mg/l). Após avaliação do sistema de tratamento de águas residuais, foi determinado que sua eficiência na remoção de cargas poluentes e sua qualidade de efluentes não é ótima para ser descarregada em um corpo de água receptor, portanto, não é adequada para reutilização na irrigação agrícola.

Palavras-chave: afluente, efluente, qualidade da água.

1. INTRODUCTION

In Latin America, the application of biological treatments to treat wastewater of domestic origin is more readily available (Vargas *et al.*, 2020). This treatment is known as “conventional” because it’s common and widely used, which usually involves low costs (Roy and Saha, 2021). The treatments are simple, efficient and cost-effective, and use microorganisms to degrade a large part of biodegradable waste from wastewater effluents (Al-Qodah *et al.*, 2020; Jung and Pauly, 2011). The main objectives of these treatments are the elimination of pathogenic microorganisms, suspended solids and the reduction of organic matter to an acceptable level (Grigorieva *et al.*, 2013; Leite *et al.*, 2005).

Stabilization lagoons are passive systems built to treat wastewater by biological processes (Florentino *et al.*, 2019); they are used for the upgrading of liquid effluents from domestic, agricultural and industrial sources (Jimoh *et al.*, 2019; Nuñez and Fragoso, 2020). Due to the low implementation cost, ease of operation, minimal energy consumption and high efficiency in the reduction of pathogenic organisms, this is the type of wastewater treatment most used in underdeveloped countries (Araújo *et al.*, 2016; Li *et al.*, 2018; Romero and Castillo, 2018). There are generally three types of lagoon systems: anaerobic, facultative and maturation or aerobic, each with different design and treatment characteristics (Dos Santos and Van Haandel, 2021; Matsumoto and Sánchez, 2016). Anaerobic lagoons operate in the absence of oxygen and have depths of 3 to 5 meters (Perú, 2007; Cortés *et al.*, 2017); facultative lagoons decompose the Biochemical Oxygen Demand (BOD) or organic matter (Sánchez and Matsumoto, 2013), by aerobic, anaerobic and facultative bacteria, with depths ranging from 1.5 to 2.5 meters (Sánchez *et al.*, 2011; Treviño and Cortés, 2016). Maturation lagoons are used at the end of treatment, and their depths vary from 0.5 to 1.5 meters (Cárdenas *et al.*, 2005; Tilley, 2011). The efficiency of stabilization lagoons depends mainly on factors such as depth, hydraulic retention time, temperature, bacteria and algae (Bezerra *et al.*, 2020).

González and Chiroles (2011) argue that for every liter of wastewater, at least eight liters of freshwater are polluted, so it is important to consider that untreated or inadequately treated effluents are the main source of pollution to natural water bodies (Cedeño, 2020), changing their chemistry and seriously altering the ecosystems that depend on them (Lahera, 2010).

Wastewater treatment plants are built to reduce the impact of polluted effluents (Morera *et al.*, 2017); however, many facilities leave aside the external effects that may occur in the operation and maintenance phase in each of these production units (Hernández *et al.*, 2017), so that the implementation of environmental regulations and standards are presented in order to define water quality criteria for discharge and ensure the non-contamination of water resources (Marçal and Silva, 2017). In Ecuador, problems have arisen due to the absence of sufficient treatment and physical infrastructure (Montero *et al.*, 2020), and it's estimated that only 10% of wastewater is discharged into bodies of water with some type of effluent treatment (Sato *et al.*, 2013; Velasco *et al.*, 2019). Ecuadoran public institutions charged with regulating wastewater discharge include the Environmental Management Departments of Provincial Prefectures and Mayor's Offices to the highest environmental authority in the country, which is the Ministry of the Environment (Peña *et al.*, 2018). The reuse of wastewater for agricultural irrigation has advantages associated with the improvement of the fertility of agricultural soils by providing organic matter (Silva *et al.*, 2018), but the effluent discharged must be evaluated from the agronomic and bacteriological point of view (Cisneros and Saucedo, 2016). Therefore, TULSMA (2015) states that the use of wastewater for irrigation is prohibited, except for that which has been previously treated and complies with the water quality levels for agricultural irrigation.

The scientific relevance of this research is characterized by exposing the high degree of contamination of the treated wastewater and potential risk to human contamination and environmental degradation through the analysis of Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Nitrogen and Fecal Coliforms that can be harmful to the habitants, flora, and fauna of the study area. The wastewater treatment system using stabilization lagoons is located on Punta Carnero Road in Salinas Canton, Province of Santa Elena – Ecuador. It currently has a system of seven lagoons: three anaerobic, two facultative and two aerobic or maturation, which discharges its previously treated effluent into the Achayan River, which finally drains to Punta Carnero Beach towards the Pacific Ocean (Humanante, 2016). This system is part of the eight lagoon systems in the Santa Elena Province under the responsibility of the company AGUAPEN-EP, which has been providing services to the province since 1998 (Suárez and Panchana, 2021). This research evaluated the affluent and effluent of the wastewater treatment efficiency, the possible effects on the ecosystem produced by the quality of the final effluent, and finally determined if the final discharge is optimal for agricultural irrigation. The investigation was based on water quality analyses performed in an accredited water laboratory, through simple samples of wastewater taken at the inlet and outlet of the lagoon system on April 15, April 28 and July 6, 2021. The results of water quality tests were compared with the Unified Text of Secondary Environmental Legislation of Ecuador in relation to the General Standards Table for effluent discharge into freshwater bodies, which regulates the following parameters: Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Nitrogen (N) and Phosphorus (P). Finally, the results were also compared with water quality criteria for agricultural or irrigation water table, which regulates the following parameters: Oils-Fats, Aluminum, Arsenic, Beryllium, Boron, Cadmium, Zinc, Cobalt, Copper, Fecal Coliforms, Chromium, Fluoride, Iron, Parasite Eggs, Lithium, Floating Material, Mercury, Manganese, Molybdenum, Nickel, Nitrites, Dissolved Oxygen, pH, Lead, Selenium, Sulfates and Vanadium.

2. MATERIAL AND METHODS

To carry out the investigation, the characteristics of the raw wastewater must first be known (Table 1). The research was developed in the wastewater treatment system of the Punta Carnero Sector in Salinas Canton, Santa Elena Province (Ecuador), located at UTM coordinates 509066 E, 9750151 N. Wastewater arriving to the system comes from the cantons of La

Libertad and Salinas, which in turn is collected and transported through sanitary sewer networks to the wastewater treatment system. At present, the Stabilization lagoon system is composed of three anaerobic lagoons, two facultative and two aeration or maturation lagoons, which are inadequate for the current population. Biological treatment processes are carried out in the lagoons: anaerobic treatment in anaerobic lagoons and aerobic treatment in facultative and maturation lagoons, which are connected to each other by means of 400 mm diameter PVC pipes through distribution chambers; finally, the treated water passes through a chlorination labyrinth and its final effluent is discharged into a natural waterway (Humanante, 2016). The research was carried out in three phases.

Table 1. Characteristics of the raw wastewater.

Characteristics of wastewater	Description
Physical	Turbidity Color Odor Total solids Temperature
Chemical	Chemical Oxygen Demand (COD) Total Organic Carbon (TOC) Nitrogen Phosphorus Chlorides Sulfates Alkalinity pH Heavy Metals Trace Elements Priority Pollutants Chemical Oxygen Demand (COD) Total Organic Carbon (TOC) Biochemical Oxygen Demand (BOD) Oxygen required for nitrification
Biological	Microbial population

Source: Wijaya and Soedjono (2018).

2.1. Pollutant load removal efficiency

The first phase involves determining the value of the pollutant load removal efficiency of the wastewater treatment system. First, two simple samples were taken in the lagoon system (Figure 1), simple samples representing the composition of the water for that specific time and location (Romero, 2004). The first simple sample was taken in the affluent of the system, water distribution chamber with outlet to anaerobic lagoons at UTM Coordinates 509203 E 9750365 N; the second simple sample was taken in the effluent of the water outlet system of the Parshall Flume with discharge to the Achayan River at UTM Coordinates 509042 E 9749661 N. Next, the samples taken in glass and plastic bottles of one liter capacity were refrigerated at a temperature of 4.3ºC, and one milliliter of sulfuric acid was added to the glass bottle. The samples were then transported to an accredited water testing laboratory, where they were analyzed and finally the test results were received approximately fifteen days after the samples were taken and left. Third, once the test results were obtained, the results were processed using the equation (Romero, 2004) to determine the pollutant load removal efficiency of the wastewater treatment system (Equation 1).

$$E(\%) = \frac{(S_0 - S)}{S_0} \times 100 \quad (1)$$

The equation shows: E (%) is the pollutant load removal efficiency in percent; S_0 is the affluent pollutant load in milligrams per liter (mg/l) and S is the effluent pollutant load in milligrams per liter (mg/l).

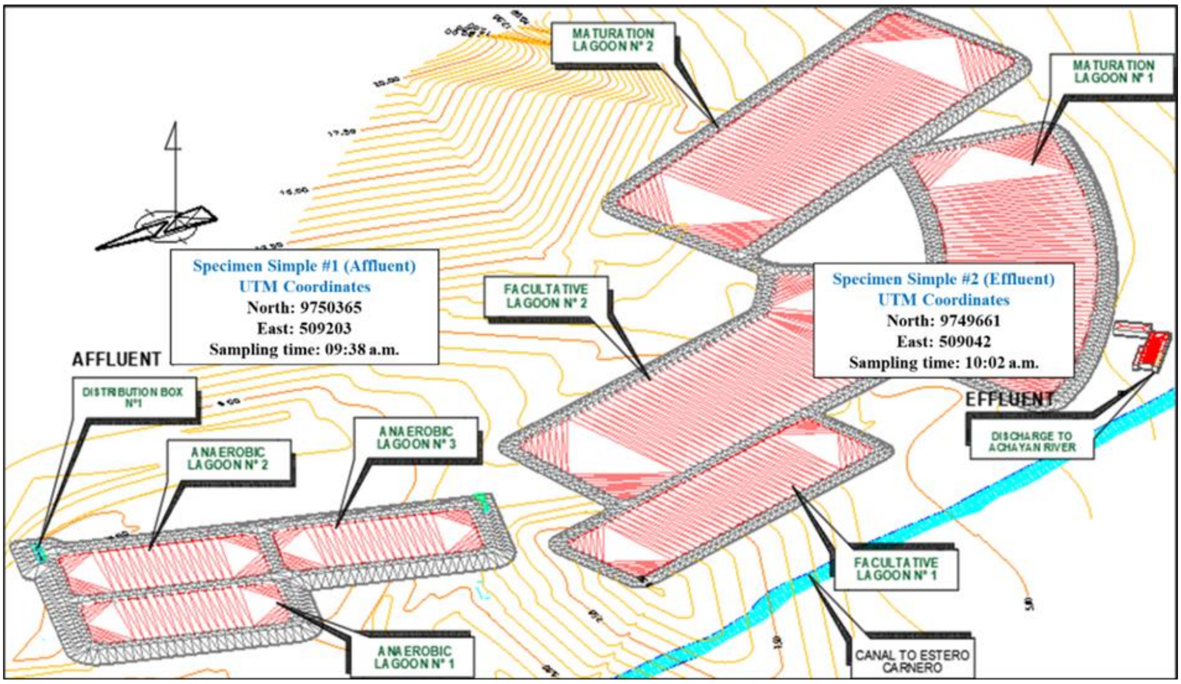

Figure 1. Wastewater treatment system of the Punta Carnero sector, Salinas - Ecuador (Humanante, 2016), simple sampling location.

2.2. Effluent water quality for discharge to a freshwater body

To determine the quality of effluent from the wastewater treatment system, in this second phase, simple samples were taken from the final effluent (discharge to the Achayan River) on three dates:

S1: Simple sample taken directly from the discharge, packaged in two plastic bottles and one glass bottle, both with a capacity of one liter (April 15, 2021).

S2: Simple sample taken directly from the discharge, packaged in two plastic bottles and one glass bottle, both with a capacity of one liter (April 28, 2021).

S3: Simple sample taken directly from the discharge, packaged in two plastic bottles and one glass bottle, both with a capacity of one liter (July 6, 2021).

After the results of the tests of the simple samples taken at the accredited laboratory, "Grupo Quimico Marcos" were obtained; these data were processed in the MINITAB statistical software to determine the mean and standard deviation of the system final effluent. Once these indicators were obtained and represented graphically S1, S2 and S3, the quality of the water discharged into the Achayan River was determined. Once the quality of the discharged water was known, the general standard for effluent discharge to freshwater bodies was presented in relation to the parameters evaluated in the laboratory: Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Nitrogen (N) and Total Phosphorus (P), and the possible effects caused by poor wastewater treatment and its impact on the environment (Table 2).

Table 2. General standard for effluent discharge to freshwater bodies and possible effects of exceeding the maximum permissible limits in the discharge of treated wastewater to the Achayan River (freshwater body).

Parameters	Expressed as	Unity	M.A.L.*	Possible effects
Biochemical Oxygen Demand	BDO	mgO_2/l	100	Damage to flora and fauna (Raffo and Ruiz, 2014).
Chemical Oxygen Demand	COD	mgO_2/l	200	Absence of oxygen in aquatic organisms (Mayta and Mayta, 2017).
Total Nitrogen	N	mg/l	10	Affects plant and animal life (Espinosa *et al.*, 2013).
Total Phosphorus	P	mg/l	50	Algae growth and absence of oxygen (Reyes *et al.*, 2017).

*Maximum Allowable Limit of discharge to a freshwater body.
Source: Section 5.2.4. from TULSMA (2015).

2.3. Effluent water quality for agricultural irrigation water reuse

The third phase of the research was to determine if the water that had been treated and then discharged to the Achayan River (freshwater body) can be destined for water reuse for agricultural irrigation. For this purpose the guidelines established in the Unified Text of Secondary Environmental Legislation of Ecuador 2015 must be followed, where TULSMA (2015) states that water for agricultural use is understood as that used for crop irrigation and other related or complementary activities established by the competent bodies.

In this phase, the results obtained from the accredited water laboratory are compared with the water quality criteria for agricultural irrigation (Table 3); this table also mentions the environmental impacts caused by poor quality water reused for agricultural irrigation (Perú, 2006).

Table 3. Water quality criteria for agricultural irrigation

Parameters	Expressed as	Unity	Quality Criterion	Environmental Impacts*
Aluminum	Al	mg/l	5.0	Plant growth impacts
Arsenic	As	mg/l	0.1	Harvest yield impacts
Beryllium	Be	mg/l	0.1	Plant growth impacts
Boron	B	mg/l	0.75	Harvest yield impacts
Cadmium	Cd	mg/l	0.05	Plant disorders
Chromium	Cr	mg/l	0.1	Unacceptable harvests
Cobalt	Co	mg/l	0.01	Plant disorders
Copper	Cu	mg/l	0.2	Plant growth impacts
Dissolved Oxygen	OD	mg/l	3	Decreased oxygen
Fecal Coliforms	CF	NMP/100ml	1000	Diseases to the population
Floating Matter	-	-	Absence	Harvest yield impacts
Fluorine	F	mg/l	1.0	Plant growth impacts
Iron	Fe	mg/l	5.0	Plant growth impacts
Lead	Pb	mg/l	5.0	Plant growth impacts
Lithium	Li	mg/l	2.5	Harvest yield impacts
Manganese	Mn	mg/l	0.2	Plant disorders
Mercury	Hg	mg/l	0.001	Food chain problems

Continue...

Continued...

Molybdenum	Mo	mg/l	0.01	Plant growth impacts
Nickel	Ni	mg/l	0.2	Plant disorders
Nitrites	NO_2	mg/l	0.5	Eutrophication
Oils and Fats	Visible	mg/l	Absence	Plant growth impacts
Parasite Eggs	-	-	Absence	Diseases to the population
pH	pH	-	6-9	Plant growth impacts
Selenium	Se	mg/l	0.02	Harvest yield impacts
Sulfates	SO_4^2	mg/l	250	Plant leaf burns
Vanadium	V	mg/l	0.1	Plant growth impacts
Zinc	Zn	mg/l	2	Plant growth impacts

***Environmental Impacts (Perú, 2006).**
Source: Section 5.1.3. from TULSMA (2015).

3. RESULTS AND DISCUSSION

The research shows the following results based on the evaluation carried out in three phases:

3.1. Pollutant load removal efficiency results

The pollutant load removal efficiency (Table 4) was determined based on the affluent, which is the incoming pollutant load (S_0), and the effluent, which is the outgoing pollutant load (S) of the wastewater treatment system evaluated. A total of 28 parameters were evaluated, each of which was analyzed in the laboratory and the results obtained from the tests were processed in Excel software (Table 3), A graph of individual values is also shown, classifying the parameters that denoted an efficiency greater than 50%, less than 50%, no efficiency (0%) and negative values that indicate that the system is greater than that entering it (Figure 2).

Table 4. Pollutant load removal efficiency.

Parameters	Unity	Affluent S_0	Effluent S	Removal Efficiency (%)
Aluminum	mg/l	1.084	0.002	99.82
Arsenic	mg/l	0.00215	0.00215	0.00
Beryllium	mg/l	0.001	0.002	-100.00
Boron	mg/l	0.391	0.373	4.60
Cadmium	mg/l	0.001	0.001	0.00
Chromium	mg/l	0.003	0.001	66.67
Cobalt	mg/l	0.00041	0.00041	0.00
Copper	mg/l	0.035	0.00116	96.69
BDO	mgO_2/l	379.2	142.5	62.42
Dissolved Oxygen	mg/l	5.15	8.86	-72.04
COD	mgO_2/l	632.63	237.8	62.41
Fecal Coliforms	NMP/100ml	135500	62900.0	53.58
Fluorine	mg/l	1.01	0.57	43.56
Iron	mg/l	0.984	0.034	96.54
Lead	mg/l	0.005	0.003	40.00
Lithium	mg/l	0.01	0.009	10.00
Manganese	mg/l	0.088	0.066	25.00
Mercury	mg/l	0.00141	0.00141	0.00

Continue...

Continued...

Molybdenum	mg/l	0.001	0.001	0.00
Nickel	mg/l	0.004	0.00123	69.25
Nitrites	mg/l	0.115	0.115	0.00
Oils and Fats	mg/l	9.76	5.65	42.11
Selenium	mg/l	0.00306	0.00306	0.00
Sulfates	mg/l	165	94	43.03
Total Phosphorus	mg/l	6.3	5.9	6.35
Total Nitrogen	mg/l	53	56	-5.66
Vanadium	mg/l	0.003	0.002	33.33
Zinc	mg/l	0.156	0.023	85.26

Ecuadorian regulations only regulate three parameters for pollutant load removal efficiency. The removal of BOD and COD was 62.42% and 62.41%, respectively, which indicates that the efficiency of these parameters doesn't reach the values established in current Ecuadorian regulations (INEN, 2012), where it's established that there must be a 70-85% removal rate in order for the treatment in the lagoon system to be considered good. On the other hand, in the microbiological parameter of Fecal Coliforms, the removal efficiency was 53.58%, which doesn't meet the requirements of the Environmental Secondary Legislation Text of 2015, where it provides for a removal of 99.9% of this pollutant, which relates that the treatment is not adequate.

The removal efficiency of COD and BOD of about 60% is relatively insufficient especially if the initial COD values in the raw water is high. This usually suggests the use of a pretreatment step before the biological step (Al-Qodah *et al*, 2019).

Heavy metal removal efficiencies were obtained in the treatment system (Figure 2), in which: Al (99.82%), Cu (96.69%), Fe (96.54%), Zn (85.26%), Ni (69.25%), Cr (66.67%), BOD (62.42%), COD (62.41%) and CF (53.58%), had a pollutant load removal greater than 50%; F (43.56%), SO_4 (43.03%), Oils and Fats (42.11%), Pb (40.00%), V (33.33%), Mn (25.00%), Li (10.00%) and B (4.60%), its pollutant load removal was below 50%; As, Cd, Co, Hg, Mo, NO_2 and Se, no removal of pollutant load; finally, N (-5.66%), OD (-72.04) and Be (-100.00), presented an inefficient removal in their treatment since the final load increased in relation to their initial load.

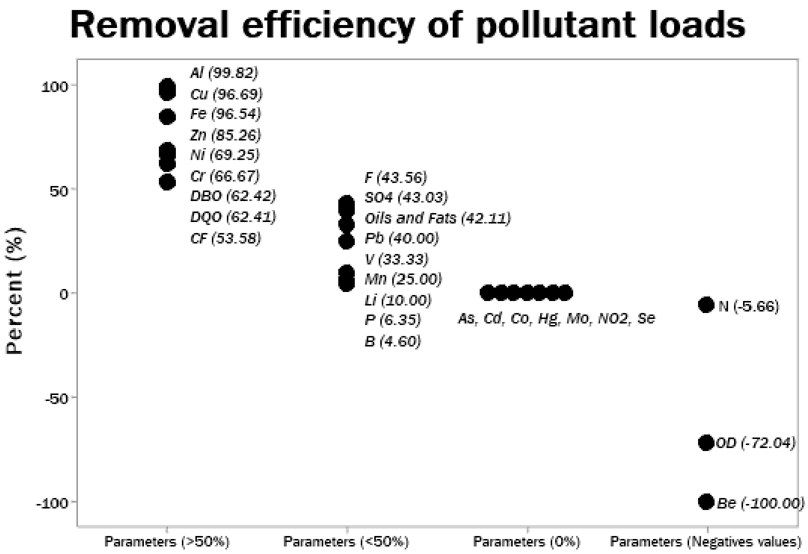

Figure 2. Removal Efficiency of pollutant loads.

3.2. Final effluent discharge quality results

It was determined that the effluent quality is not optimal for discharge with respect to BOD, COD and Total Nitrogen, while Total Phosphorus complies with present regulations.

The effluent quality of BOD (Figure 3), shows that it doesn't comply with the maximum permissible limit of 100 milligrams of oxygen per liter, which means that exceeding the established limit would cause negative effects to the flora and fauna of the sector where the water is discharged. On the other hand, the effluent quality of COD (Figure 4), like BOD, doesn't comply with the 200 milligrams of oxygen per liter established in the mentioned regulation, which denotes possible negative effects such as the absence of oxygen in aquatic microorganisms in the sector; Similarly, Total Nitrogen levels exceed the maximum permissible limit of 50 milligrams per liter (Figure 5), which indicates possible effects such as the vulnerability of plants and animals to high levels of N. However, the effluent quality of Total Phosphorus (Figure 6) complies with the maximum permissible limit of 10 milligrams per liter, which indicates that there are no problems in its discharge.

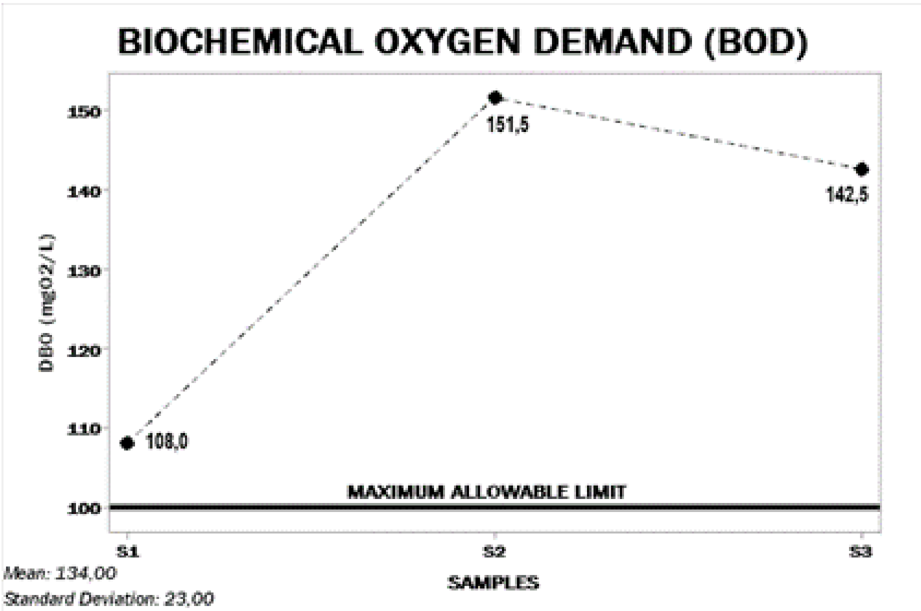

Figure 3. BOD Effluent Quality.

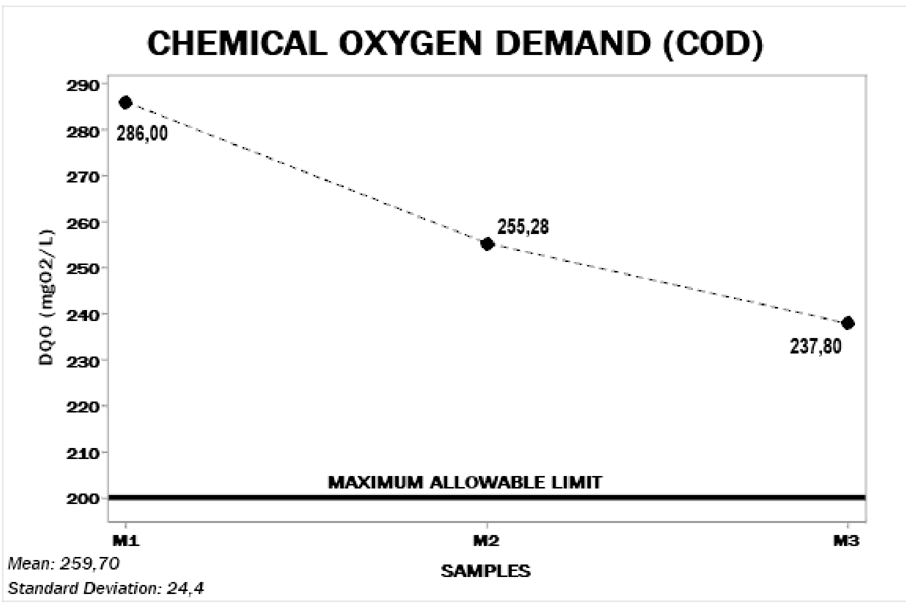

Figure 4. COD Effluent Quality.

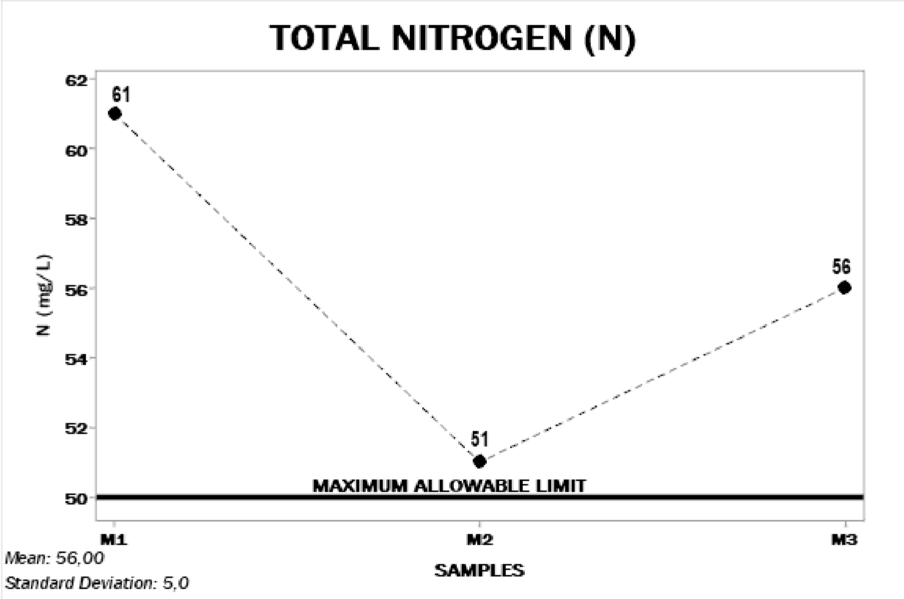

Figure 5. N Effluent Quality.

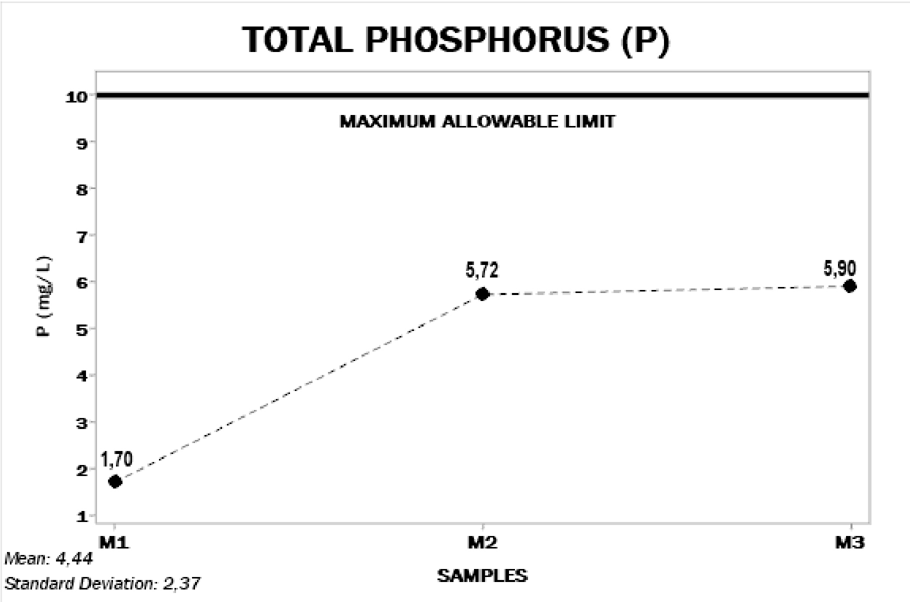

Figure 6. P Effluent Quality.

3.3. Results comparison obtained in the laboratory

Of the 27 parameters evaluated with the agricultural irrigation water quality criteria of the Unified Text of Secondary Environmental Legislation, the following comply with the requirements of the regulations Al (0.002 < 5.0), As (0.00215 < 0.1), Be (0.002 < 0.1), B (0.373 < 0.75), Cd (0.001 < 0.05), Cr (0.001 < 0.1), Co (0.00041 < 0.01), Cu (0.00116 < 0.2), Floating Matter (Absence), F (0.57 < 1), Fe (0.034 < 5), Pb (0.003 < 5), Li (0.009 < 2.5), Mn (0.066 < 0.2), , Mo (0.001 < 0.01), Ni (0.00123 < 0.2), NO_2 (0.115 < 0.5), Parasite eggs (Absence), pH (7.88 < 6-9), Se (0.00306 < 0.02), Sulfates (94 < 250), V (0.002 < 0.1) and Zn (0.023 < 2), while OD (8.86 > 3), Fecal Coliforms (62900 > 1000), Hg (0.00141 > 0.001), and Oils and Fats (5.65 > Absence) exceed agricultural irrgiation water quality criteria.

4. CONCLUSIONS

The removal efficiency of the wastewater treatment system doesn't meet the efficiencies established in existing regulations, so it is determined that the biological treatment is not optimal. It is proposed as an improvement to achieve these efficiencies that there should be more frequent control of the stabilization lagoons, as well as more frequent removal of the silt that is present in these lagoons, which doesn't allow the water entering the system to be treated in an efficient manner.

According to the results of the study, the quality of the water discharged into the receiving body (Achayan River) is poor, which could have serious consequences in the future, since high concentrations of BOD, COD and N directly affect plants and animals in the sector, and indirectly affect people who bathe in the sea.

The treated wastewater is not suitable for reuse for agricultural irrigation because it doesn't fully comply with the criteria established in Table 2 of the Ecuadorian Environmental Regulations.

5. REFERENCES

AL-QODAH, Z.; AL-QUDAH, Y.; ASSIREY, E. Combined biological wastewater treatment with electrocoagulation as a post-polishing process: A review. **Separation Science and Technology**, v. 55, n. 13, p. 2334-2352, 2020. https://doi.org/10.1080/01496395.2019.1626891

AL-QODAH, Z.; AL-QUDAH, Y.; OMAR, W. On the performance of electrocoagulation-assisted biological treatment processes: a review on the state of the art. **Environmental Science and Pollution Research,** v. 26, n. 28, p. 28689-28713, 2019. https://doi.org/10.1007/s11356-019-06053-6

ARAÚJO, G.; LIMA, I.; ARAÚJO, A.; SILVA, M. Avaliação experimental e modelagem matemática de filtros anaeróbios como alternativa de baixo custo para remoção de algas de efluentes de lagoas de estabilização. **Engenharia Sanitária e Ambiental**, v. 21, n. 4, p. 687-696, 2016. https://doi.org/10.1590/S1413-41522016134641

BEZERRA, E.; DE SOUZA, I.; SAAVEDRA, N. Variability in phytoplankton community structure and influence on stabilization pond functioning. **Revista Ambiente & Água**, v. 15, n. 2, p. 1-13, 2020. https://doi.org/10.4136/ambi-agua.2507

CÁRDENAS, C.; JAEGER, C.; VILLASMIL, H.; PERRUOLO, T.; YABROUDI, S.; LÓPEZ, F.; HERRERA, L.; CASTEJÓN, O. Evaluation of the units that conform the wastewater treatment plant south Maracaibo. **Journal of the Engineering Technical Faculty of the Zulia's University**, v. 28, n. 2, p. 97-109, 2005.

CEDEÑO, H. Analysis of the water quality parameters of the dead river effluent for possible reuse of Manta. **Knowledge Pole: Scientific-Professional Journal**, v. 5, n. 2, p. 579-604, 2020. http://dx.doi.org/10.23857/pc.v5i2.1299

CISNEROS, O.; SAUCEDO, H. Wastewater reuse in agriculture. **Water Technology Institute Mexican**, 2016. 170 p.

CORTÉS, F.; TREVIÑO, A.; ESPINOZA, A.; SÁENZ, A.; ALCORTA, M.; GONZÁLEZ, J. *et al.* Optimization in the design of a wastewater treatment system integrated by three stabilization lagoon. **Water Technology and Sciences**, v. 8, n. 4, p. 139-155, 2017. https://doi.org/10.24850/j-tyca-2017-04-09

DOS SANTOS, S. L.; VAN HAANDEL, A. Transformation of Waste Stabilization Ponds: Reengineering of an Obsolete Sewage Treatment System. **Water 2021**, v. 13, n. 9, p. 1193, 2021. https://doi.org/10.3390/w13091193

ESPINOSA, M.; LEÓN, Y.; RODRIGUEZ, X. Problem of the determination of nitrogen species (total nitrogen and ammonia) in wastewater. **CENIC Journal. Chemical Sciences**, v. 44, p. 1-12, 2013.

FLORENTINO, A.; COSTA, M.; NASCIMENTO, J.; FARES ABDALA, E.; MOTA, C.; DOS SANTOS, A. Identification of microalgae from waste stabilization ponds and evaluation of electroflotation by alternate current for simultaneous biomass separation and cell disruption. **Engenharia Sanitaria e Ambiental**, v. 24, n. 1, p. 177-186, 2019. https://doi.org/10.1590/S1413-41522019193972

GONZÁLEZ, M.; CHIROLES, S. Safe use and microbiological risks of wastewater for agriculture. **Cuban Journal of Public Health**, v. 37, n. 1, p. 61-73, 2011.

GRIGORIEVA, E. V.; BONDARENKO, N. V.; KHAILOV, E. N.; KOROBEINIKO, A. Analysis of optimal control problems for the process of wastewater biological treatment. **Math Journal: Theory and Applications**, v. 20, n. 2, p. 103-118, 2013.

HERNÁNDEZ, A.; QUIMIS, A.; MOLINA, G.; MORENO, L. The treatment of wastewater in Portoviejo Canton and its potential environmental impact. **UNESUM-Sciences: Multidisciplinary Scientific Journal**, v. 1, n. 2, p. 47-58, 2017. https://doi.org/10.47230/unesum-ciencias.v1.n2.2017.17

HUMANANTE, J. **Reduction of coliforms in effluent stabilization lagoon of Salinas - Libertad applying bacteria**. 2016. Thesis (Master's Degree in Sanitary Engineering) - Guayaquil University, Guayaquil, 2016.

INEN. **Normas para estudio y diseño de sistemas de Agua potable y disposición de aguas residuals PPara poblaciones mayores a 1000 habitantes**. Quito, 2012. p. 420.

JIMOH, T. A.; KESHINRO, M. O.; COWAN, K. A. Microalgal–Bacterial Flocs and Extracellular Polymeric Substances: Two Essential and Valuable Products of Integrated Algal Pond Systems. **Water, Air, & Soil Pollution**, v. 230, n. 4, p. 95, 2019. https://doi.org/10.1007/s11270-019-4148-3

JUNG, H.; PAULY, D. 4.19 - Water in the Pulp and Paper Industry. *In:* WILDERER, P. (ed.). **Treatise on Water Science**. Oxford: Elsevier, 2011. p. 667-683.

LAHERA, V. Sustainable Infrastructure: Wastewater Treatment Plants. **Journal of Territorial Studies**, v. 12, n. 2, p. 58-69, 2010.

LEITE, V.; ATHAYDE, G.; SOUSA, J.; LOPES, W.; PRASAD, S.; SILVA, S. Tratamento de águas residuárias em lagoas de estabilização para aplicação na fertirrigação. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 9, n. 1, p. 71-75, 2005. https://doi.org/10.1590/1807-1929/agriambi.v9nsupp71-75

LI, M.; ZHANG, H.; LEMCKERT, C.; ROIKO, A.; STRATTON, H. On the hydrodynamics and treatment efficiency of waste stabilisation ponds: From a literature review to a strategic evaluation framework. **Journal of Cleaner Production**, v. 183, p. 495-514, 2018. https://doi.org/10.1016/j.jclepro.2018.01.199

MARÇAL, D.; SILVA, C. Avaliação do impacto do efluente da estação de tratamento de esgoto ETE-Pirajá sobre o Rio Parnaíba, Teresina (PI). **Engenharia Sanitária e Ambiental**, v. 22, n. 4, p. 761-772, 2017. https://doi.org/10.1590/S1413-41522017148242

MATSUMOTO, T.; SÁNCHEZ, I. Performance of the Sewage Treatment Plant of São João de Iracema (Brazil). **Ingeniería**, v. 21, n. 2, p. 176-186, 2016. https://doi.org/10.14483/udistrital.jour.reving.2016.2.a04

MAYTA, R.; MAYTA, J. Removal of Chromium and Chemical Oxygen Demand of Tannery Wastewater by Electrocoagulation. **Journal of the Peruvian Chemical Society**, v. 83, n. 3, p. 331-340, 2017.

MONTERO, F.; MOLINA, C.; PILLCO, B.; SARDUY, L.; DIÉGUEZ, K. Evaluation of the Environmental Impact of the Wastewater Treatment Plant Construction. Case Pindo Chico River, Puyo, Pastaza, Ecuador. **Science, Environment and Climate**, v. 3, n. 1, p. 23-39, 2020. https://doi.org/10.22206/cac.2020.v3i1.pp23-39

MORERA, S.; COROMINAS, L.; RIGOLA, M.; POCH, M., COMAS, J. Using a detailed inventory of a large wastewater treatment plant to estimate the relative importance of construction to the overall environmental impacts. **Water Research**, v. 122, p. 614-623, 2017. https://doi.org/10.1016/j.watres.2017.05.069

NUÑEZ, J.; FRAGOSO, P. Use of aquatic macroinvertebrates as an evaluation system for stabilizing El Salguero lagoon (Colombia). **Technological Information**, v. 31, n. 3, p. 277-284, 2020. http://dx.doi.org/10.4067/S0718-07642020000300277

PEÑA, S.; MAYORGA, J.; MONTOYA, R. Proposal for the treatment of wastewater from the city of Yaguachi (Ecuador). **Science and Engineering**, v. 39, n. 2, p. 161-167, 2018.

PERÚ. Comisión Nacional del Agua. **Manual de Agua Potable, Alcantarillado y Saneamiento**. Lima, 2007. 234p.

PERÚ. Ministerio de Salud. Dirección General de Salud Ambiental e Inocuidad Alimentaria. **Riego de Vegetales y Bebederos de Animales**. Lima, 2006. 134p.

RAFFO, E.; RUIZ, E. Characterisation of waste water and biochemical oxygen demand. **Industrial Data**, v. 17, n. 1, p. 71-80, 2014.

REYES, M.; ZÁRATE, A.; CARRILLO, S.; DURÁN, C. Removal of Phosphorus in a Laboratory Scale System of Artificial Wetlands. **Central Chemistry**, v. 2, n. 1, p. 25-32, 2017. https://doi.org/10.29166/quimica.v2i1.546

ROMERO, J. Tratamiento de aguas residuals. *In:* Romero Rojas, J. A. **Tratamiento de aguas residuales; teoria y principios de diseño**. Bogotá: Escuela Colombiana de Ingenieria, 2004. p. 1248.

ROMERO, T.; CASTILLO, Y. Updating of status of Mayabeque city stabilization lagoons. **Hydraulic and Environmental Engineering**, v. 39, n. 2, p. 72-85, 2018.

ROY, M.; SAHA, R. 6 - Dyes and their removal technologies from wastewater: A critical review. *In*: BHATTACHARYYA, S.; MONDAL, N. K.; PLATOS, J.; SNÁŠEL, V.; KRÖMER, P. (eds). **Intelligent Environmental Data Monitoring for Pollution Management.** Elsevier, 2021. p. 127-160.

SÁNCHEZ, I.; MATSUMOTO, T. Bathymetric survey and performance of waste stabilization ponds system. **Journal of Agricultural Science**, v. 30, n. 1, p. 65-78, 2013.

SÁNCHEZ, R.; ROSA, E.; MORENO, M. Analysis of the reliability of operation of optional lagoons primaries in Villa Clara-Cuba. **Chemical Technology**, v. 31, n. 1, p. 23-38, 2011.

SATO, T.; QADIR, M.; YAMAMOTO, S.; ENDO, T.; ZAHOOR, A. Global, regional, and country level need for data on wastewater generation, treatment, and use. **Agricultural Water Management**, v. 130, p. 1-13, 2013. https://doi.org/10.1016/j.agwat.2013.08.007

SILVA, J.; TORRES, P.; MADERA, C. Domestic wastewater reuse in agriculture. A review. **Colombian Agronomy**, v. 26, n. 2, p. 347-359, 2018.

SUÁREZ, J.; PANCHANA, R. **Statistical evaluation of physical, chemical and bacteriological analysis parameters of the effluents of the wastewater treatment system located on the side of Punta Carnero road in Salinas Canton.** 2021. Thesis (Civil Engineering) – Santa Elena Peninsula State University, La Libertad, 2021.

TILLEY, E. *et al.* **Compendium of sanitation systems and technologies**. 2nd ed. Dübendorf: EAWAG, 2011. p. 161.

TREVIÑO, A.; CORTÉS, F. Reduced design method for stabilization lagoon. **Mexican Journal of Agricultural Sciences**, v. 7, n. 4, p. 729-742, 2016.

TULSMA. **Libro VI de la calidad ambiental**. Quito: Environment Ministry of Ecuador, 2015. p. 184.

VARGAS, A.; CALDERÓN, J.; VELÁSQUEZ, D.; CASTRO, M., NÚÑEZ, D. Biological system analysis for domestic wastewater treatment in Colombia. **Ingeniare: Chilean Journal of Engineering**, v. 28, p. 315-322, 2020. https://dx.doi.org/10.4067/S0718-33052020000200315

VELASCO, G.; MONCAYO, J.; CHUQUER, D. Diagnosis of wastewater treatment system of Manta, **Infoanalytic Journal**, v. 7, n. 1, p. 27-39, 2019. https://doi.org/10.26807/ia.v7i1.93

WIJAYA, I.; SOEDJONO, E. Physicochemical characteristic of municipal wastewater in tropical area: Case study of Surabaya City, Indonesia. **IOP Conf. Series: Earth and Environmental Science,** v. 135, p. 1-6, 2018. https://doi.org/10.1088/1755-1315/1/012018