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Optimization and redesign of the Santo Domingo leachate treatment plant: an approach to environmental efficiency and sustainable development

Optimización y rediseño de la planta de tratamiento de lixiviados en Santo Domingo: un enfoque hacia la eficiencia ambiental y el desarrollo sostenible

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Abstract: The research stems from a growing concern about the negative impact of leachates, which are highly contaminated and complex liquids, on public health and the environment. Through detailed analysis and technical data collection, including on-site evaluation of the plant, deficiencies in the current treatment were identified. The study included estimation of the leachate flow rate using the volumetric method based on height differentiation. A detailed leachate characterization was performed to determine the efficiency of the existing treatment, focusing on the removal of Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD) and Turbidity. In addition, a treatability test was conducted using a specific flocculation and agitation process. The results revealed a deficient operation of the plant, with a daily production of 26 m3 of leachate that was not adequately treated. Therefore, the design of a vertical subsurface artificial wetland was proposed, meticulously calculating its surface area, retention time, dimensions and the amount of filter media required. It is concluded that there is an imperative need to redesign and optimize all the treatment phases of the plant.

Keywords: redesign, leachate, treatment, sustainability, environmental efficiency.

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Resumen: La investigación parte de una preocupación creciente por el impacto negativo de los lixiviados que son líquidos altamente contaminados y complejos, sobre la salud pública y el medio ambiente. Mediante un análisis detallado y la recopilación de datos técnicos, incluyendo la evaluación in situ de la planta, se identificaron deficiencias en el tratamiento actual. El estudio incluyó la estimación del caudal de lixiviados utilizando el método volumétrico basado en la diferenciación de alturas. Se realizó una caracterización detallada de los lixiviados para determinar la eficiencia del tratamiento existente, enfocándose en la remoción de la Demanda Bioquímica de Oxígeno (DBO5), Demanda Química de Oxígeno (DQO) y Turbiedad. Además, se llevó a cabo una prueba de tratabilidad empleando un proceso de floculación y agitación específicos. Los resultados revelaron una operación deficiente de la planta, con una producción diaria de 26 m3 de lixiviados no tratados adecuadamente. Por ello, se propuso el diseño de un humedal artificial vertical subsuperficial, calculando meticulosamente su área superficial, tiempo de retención, dimensiones y la cantidad de medio filtrante necesario. Se concluye que es una necesidad imperante de rediseñar y optimizar todas las fases de tratamiento de la planta.

Palabras clave: rediseño, lixiviados, tratamiento, sostenibilidad, eficiencia ambiental.

Introduction

Canton Santo Domingo, located in the province of Santo Domingo de los Tsáchilas, Ecuador, faces a crucial challenge in solid waste management, exacerbated by accelerated demographic and economic growth. With a population exceeding 450,000 inhabitants, the region is experiencing a proportional increase in solid waste generation, estimating a production of approximately 300 tons per day (Ministry of Environment, 2018)This increase has direct implications on the production of leachates, highly polluting liquid byproducts, derived from the decomposition of garbage in landfills.

The leachate treatment plant at the Santo Domingo Environmental Complex has shown inadequacies in its capacity to handle these increasing volumes and their complex composition. Leachate, which contains dissolved organic matter, heavy metals, inorganic salts and xenobiotics, represents a significant risk to public health and the environment if not properly managed (Toufexi et al., 2013)..

Faced with this problem, this study advocates a redesign and optimization of the leachate treatment plant, based on an exhaustive review of current technologies and processes. The need for this intervention arises from the deficient operation of the plant and its non-compliance with national environmental standards.

The proposed redesign is based on a detailed characterization of the leachate and a critical evaluation of the deficiencies in the current treatment stages. This proposal includes the revitalization and optimization of the anaerobic and aeration lagoons, as well as the implementation of more efficient physicochemical processes, such as improved coagulation and flocculation. These improvements ensure more effective pollutant removal throughout the different stages of the treatment process.

In addition, the study considers the incorporation of environmentally sustainable technologies, such as artificial wetlands, for the secondary treatment of leachate. These systems, in addition to their efficacy in pollutant removal, provide additional benefits in terms of landscape conservation and biodiversity (Luna-Pabello & Aburto-Castañeda, 2014).

In the context of Santo Domingo, the redesign of the plant not only seeks to comply with environmental regulations but also to improve the quality of life of its inhabitants. A gradual implementation of the improvements is recommended, accompanied by a maintenance and continuous monitoring plan. Community awareness and environmental education are also key to ensuring the long-term sustainability of the project.

Leachate Treatment

Leachate treatment is essential in municipal solid waste management, especially in landfills. Leachate, resulting from the percolation of liquids through accumulated waste, contains a complex mixture of contaminants such as organic and inorganic compounds and heavy metals. This composition, which varies according to the nature of the waste and environmental conditions, represents a significant risk to public health and the environment due to its potential to contaminate soils and aquifers(Chaouki et al., 2021).

Conventional methods for treating leachate include physical, chemical and biological techniques. Physical processes, such as filtration, focus on removing solid particles, while chemical treatments use agents such

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as coagulants to address dissolved contaminants. Biological approaches rely on microorganisms to break down organic matter. However, technological evolution has introduced advanced methods such as reverse osmosis and anaerobic digestion, which offer greater efficiency in removing impurities and reducing environmental impacts(Czatzkowska et al., 2023).

Effective leachate treatment goes beyond environmental compliance; it is a vital component of sustainable waste management. By minimizing ecological risks, biodiversity is protected, and water quality is maintained (Abdel-Shafy et al., 2024; Lei et al., 2023).

Thus, environmental efficiency in leachate treatment is vital to mitigate the negative impacts associated with landfills (Clemente et al., 2023; Toufexi et al., 2013).(Clemente et al., 2023; Toufexi et al., 2013). This approach focuses on reducing water and soil pollution, as well as minimizing emissions of harmful gases Achieving high efficiency in leachate treatment is crucial to preserve ecosystems and ensure the sustainability of natural resources.

Efficient leachate treatment involves the implementation of advanced technologies and management practices that are adapted to the dynamic and complex nature of these wastes. This includes not only the effective removal of contaminants, but also the optimization of energy and resource consumption in the treatment process (Alexis et al., 2015; Grabska et al., 2015; Tamayo Orbegozoa et al., 2012).Environmental efficiency goes beyond mere regulatory compliance; it seeks to continuously improve processes to reduce the ecological footprint of waste treatment.

In the context of leachate treatment, environmental efficiency also implies the consideration of the useful life of facilities and equipment The adoption of durable technologies and the implementation of adequate maintenance practices are fundamental to ensure the long-term operability of treatment plants, thus reducing the need for frequent replacements and reducing the waste generated by obsolete equipment(Andrade Avalos et al., 2020).

In addition, environmental efficiency in leachate treatment must address adaptability to changing environmental regulations and increasing societal demands for more sustainable practices. This includes the ability of treatment plants to integrate into broader waste management systems, contributing to the creation of cleaner and healthier cities(De et al., 2022; Diaz et al., 2022; Karatas et al., 2022).

Therefore, in contexts such as Santo Domingo, the optimization and redesign of leachate treatment plants are essential to achieve efficient and sustainable waste management, contributing significantly to environmental and social well-being.

Materials and methods

The research was oriented towards a technical approach based on an analytical review of the literature, complemented by the collection of technical data obtained directly on site. Qualitative and quantitative methods were used for data collection. The detailed analysis of the plant operation was carried out through a qualitative approach, while the analysis of the data obtained was carried out through a quantitative approach. In addition, the Delphi Method was used to structure and analyze the information collected, and interviews were conducted to obtain data on actual plant conditions.

The technical diagnosis included on-site verification of both the design and operation of the plant. The dimensions, geometry and capacity of each of the systems comprising the plant were examined with the help of measurement tools and plant operations personnel. The actual condition of the plant was also observed during field visits.

Leachate generation was estimated using the volumetric method, based on height differentiation, recording the increase in leachate over time. This methodology included recording the initial height of the leachate and its proportional increase during a given period.

Regarding the treatability of the plant, a characterization of the leachate was carried out. A single sample was taken at each treatment stage, both at the inlet and outlet, following INEN 2169:2013. Each sample was labeled with relevant details such as name, place, time and date of collection, and volume. Gloves, masks, thermometer, sterile plastic containers, among other materials, were used for sampling.

The analysis parameters included BOD5, COD, pH, conductivity and temperature, and the analyses were performed at the Technical Analysis Laboratory. In addition, the data obtained were compared with the

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discharge limits stipulated in current regulations to evaluate the efficiency of the treatments implemented at the plant.

The identification and evaluation of the environmental impact were an essential part of the study, focusing on the impacts generated by the plant and their relevance for their prevention and assessment.

Finally, based on the data collected and the evaluations performed, a plant redesign proposal was issued. This proposal included treatability tests to determine the optimum doses of coagulants and flocculants and the design of a vertical flow sub-surface artificial wetland. Sizing was based on recognized standards and guidelines, and corresponding drawings were prepared using specialized software.

3. Result

Table 1 *Geometry of primary treatment*

Lagoon of Sedimentation Primary	**It has an isosceles trapezoid geometry with angles of 45^0 , whose height variation is one meter from the end of the smaller base to the end of the larger base, with two sludge evacuation sites of 5m wide, which are removed by a sludge pump and the sludge generated must be evacuated every 15 days.**
Lagoon Anaerobic	This is where the degradation process is initiated by anaerobic bacteria. It has an isosceles trapezoid geometry with angles of 45^0 , with a height variation of one meter from the end of the lower base to the end of the higher base.
Lagoon of Aeration	This is where the oxidation process of organic matter is initiated by feeding air using fine bubble diffusers from the blowers. It has a trapezoid geometry with angles of 45^0 , with a height variation of half a meter from the smaller base end to the larger one.
	Larger base end. It has 4 blowers of 10hp each, by means of 4 modules with 52 fine bubble diffusers.
Lagoon of Sedimentation Secondary	This is where the settling of sedimentable sludge begins. It has an isosceles trapezoid geometry with angles of 45^0 , with a height variation of one meter from the smaller base end to the larger base end, with a sludge evacuation site of 2m wide, which are removed by a sludge pump. The leachate is taken from this plant and fed to the physical-chemical plant by means of a 10hp pump.

The leachate treatment plant described in Table 1 uses a sequence of isosceles trapezoidal geometry lagoons with 45° angles, each designed for a specific purpose in leachate treatment. The Primary Sedimentation Lagoon focuses on the sedimentation of heavy solids, with regular sludge removal. The Anaerobic Lagoon initiates the biological decomposition process without oxygen, while the Aeration Lagoon, equipped with fine bubble diffusers, facilitates aerobic oxidation of organic matter. Finally, the Secondary Sedimentation Lagoon is used for additional sludge settling. This integrated design ensures an efficient reduction of contaminants in the leachate, preparing it for further treatment in the physicochemical plant, and underlines the importance of regular maintenance to optimize the operation and efficiency of the system.

Table 2*: On-site dimensions of the primary* **leachate** *treatment plant*

Data on in situ values of Primary Treatment dimensions

Treatment	Length (m)	Width (m)	Height of lower base end (m)	Height of the greater base end (m)	Volume (m3)
Lagoon of Sedimentation Primary	50	23.20	3.50	4.50	5000
Lagoon Anaerobic	80	19.70	4	5	5000
Lagoon of Aeration	37	16	4	4.50	1472
Lagoon of Secondary sedimentation	30	17.40	3	4	875

Table 3 details the on-site dimensions of the lagoons at the primary leachate treatment plant, revealing essential characteristics for their operation. The Primary Sedimentation Lagoon, 50 meters long, 23.20 meters wide, and with a volume of 5000 m^3, is in charge of sedimenting suspended solids. The Anaerobic Lagoon, similar in volume but 80 meters long and 19.70 meters wide, facilitates degradation by anaerobic bacteria. The Aeration Lagoon, smaller at 37 meters long, 16 meters wide, and 1472 m^3 in volume, performs the oxidation of organic matter. Finally, the Secondary Sedimentation Lagoon, 30 meters long and 17.40 meters wide with a volume of 875 m^3, is used for sludge settling.

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These dimensions reflect the adaptation of each lagoon to its specific functions within the treatment process.

Table 3. *Dimensions of the physical-chemical plant.*

Data of the in situ values of the physical-chemical plant dimensions

Components	Length (m)	**Width (m)**
Buffer tank	4.54	2.80
Aeration tower	3	1.20
Reaction tank	1.60	1.30
Flocculation and settling tank	5.45	2.80
Tank sludge collector **Flocculator and settler**	1..20	2.80
Reserve tank	2.80	2.80
Sand filter	1.86	1.10
Carbon filter	1.86	1.10

Table 3 presents the in situ dimensions of the Physical-Chemical Plant components, highlighting the differences in size and function of each element. The Lung Tank, measuring 4.54 meters long and 2.80 meters wide, serves as a regulating tank. The Aeration Tower, measuring 3 meters long and 1.20 meters wide, is crucial for the oxidation of organic matter. The Reaction Tank, more compact at 1.60 meters long and 1.30 meters wide, facilitates specific chemical reactions. The Flocculation and Settling Tank, measuring 5.45 by 2.80 meters, and the associated Sludge Collector, measuring 1.20 meters long by 2.80 meters wide, play an essential role in the treatment of particulates and sludge. In addition, a Reserve Tank of 2.80 meters in both dimensions ensures the constant availability of treated liquids. Finally, two filters, a sand filter and a carbon filter, both 1.86 meters long and 1.10 meters wide, provide the final filtration in the process. These dimensions reflect the integration and specialization of each component in the plant, underlining the complexity and efficiency of the physical-chemical treatment.

Table 4. *Dimensions of the physical-chemical plant aeration tower.*

Aeration tower	**Top length (m)**	**Base length (m)**	**Width superior (m)**	**Base width (m)**	**Tray spacing (m)**	**Perforations (mm)**	**Height (m)**

Dish 1 and 3	1.20	0.80	0.85	0.45	0.30	6	0.30
Dish 2 and 5	1.20	0.80	0.85	0.45	0.30	Without perforations (3 mm tube)	0.30
Plate 4	1.20	0.80	0.85	0.45	0.30	6	0.30

Table 4 describes in detail the dimensions of the aeration tower of the physicochemical plant, an essential component for the oxidation of organic matter in leachate treatment. The tower consists of five trays, each with specific dimensions and design features.

Dishes 1, 3 and 4 have identical dimensions, with an upper length of 1.20 meters and a base length of 0.80 meters. The top width is 0.85 meters, while the base width is 0.45 meters. The separation between trays in these plates is 0.30 meters, and each one has perforations of 6 millimeters in diameter, facilitating the distribution of air in the tower. The height of each tray is also 0.30 meters.

On the other hand, plates 2 and 5, although they share the same external dimensions with the other plates, have a distinctive feature: they do not have perforations, but a 3 mm tube. This suggests a different role in the aeration process, possibly focused on a more controlled air distribution or flow.

These detailed dimensions and specifications reflect the complexity and precision in the design of the aeration tower, indicating the importance of this component in the overall efficiency of the physicochemical treatment plant.

Table 5. *Estimated Leachate Flow Rate produced at the Environmental Complex*

Date	Time range (5h)	Leachate height (m)	Height of rise (m)
Saturday, June 9, 2018	6:00 am	2.52	-
	11:00 am	2.53	0.01
	16:00 pm	2.54	0.01
	21:00 pm	2.549	0.009
	Length (m)	Width (m)	Depth (m)

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Dimensions of the cube	65.42	38.33	5.4

Table 5 provides a detailed estimate of the leachate flow rate produced at the Environmental Complex for June 9, 2018. The data show that, throughout the day, the leachate height gradually increased, starting from 2.52 meters at 6:00 am and reaching 2,549 meters at 21:00 pm. These increases, although small, were constant and significant for evaluating leachate generation. Considering the dimensions of the basin, with a length of 65.42 meters, a width of 38.33 meters and a depth of 5.4 meters, a daily flow of 116 m³ was calculated. This value is within the design capacity of the leachate treatment plant, which is 120 m³/day, indicating that the plant is adequately sized to handle the volume of leachate generated in the complex. The flow generated in the environmental complex is 116 m3/day; the leachate treatment plant is designed to treat 120 m3/day, which means that the design is suitable to treat the volume of leachate generated.

Table 6. *Analysis of leachate from the primary sedimentation pond.*

Type of treatment	Parameters	Unit	Sampling	Entrance	Output	Average output	Average input
Primary sedimentation lagoon	BOD_5	mg/L	Week 1	2610.0	2590.0	2577	2603
			Week 2	2599.0	2570.0		
			Week 3	2600.0	2571.0		
	COD	mg/L	Week 1	4600.0	5440.0	4914	4625,667
			Week 2	4678.0	4602.0		
			Week 3	4599.0	4700.0		
	Conductivity	uS/cm	Week 1	8.40	7.81	7,947	8,150
			Week 2	8.00	8.00		
			Week 3	8.05	8.03		
	pH	-	Week 1	7.40	8.30	8,123	7,217
			Week 2	7.10	8.00		
			Week 3	7.15	8.07		

Table 6 shows the results of the leachate analysis of the Primary Sedimentation Lagoon, revealing consistency in the Biochemical Oxygen Demand (BOD5) and Chemical Oxygen Demand (COD) values, although with a slight decrease in the output. Conductivity values decrease slightly, indicating a small reduction of ions in the water. The pH increases at the outlet, suggesting a slight increase in alkalinity. These results, especially the slight change in BOD5 and COD values, suggest that the sedimentation process in the lagoon is having a minimal impact on reducing the organic load and the overall quality of the leachate, which may be insufficient to meet the required environmental standards.

Analysis of leachate from the anaerobic lagoon.

Type of treatment	Parameters	Unit	Sampling	Entrance	Output	Average output	Average input
Lagoon Anaerobic	BOD_5	mg/L	Week 1	2590.0	2210.0	2577	2213
			Week 2	2570.0	2223.0		
			Week 3	2571.0	2206.0		
	COD	mg/L	Week 1	5440.0	3500.0	4914	3400,667
			Week 2	4602.0	3260.0		
			Week 3	4700.0	3442.0		
	Conductivity	uS/cm	Week 1	7.81	3.45	7,947	3,530
			Week 2	8.00	4.00		
			Week 3	8.03	3.14		
	pH	-	Week 1	8.30	8.85	8,123	8,757

The analysis of the Anaerobic Lagoon, according to Table 7-3, shows an effective reduction of the organic load, evidenced by the significant decrease in BOD5 and COD values at the outlet compared to the inlet. The reduction in conductivity at the outlet suggests an effective removal of soluble ions. In addition, an increase in pH at the outlet is observed, which could indicate the generation of alkaline products during the anaerobic process.

However, the lagoon operation is deviating from the original design. The 10 HP pump is pumping leachate at a flow rate of 50 m^3/hour, but it is being operated for 5 hours per day, resulting in a daily total of 250 m^3, which exceeds the design flow rate of 120 m^3/day. This overoperation could be causing a lower efficiency in the treatment

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process, since the hydraulic retention time is reduced, not allowing the anaerobic processes to occur optimally.

Table 8. *Analysis of leachate from the Aerobic Lagoon.*

Type of treatment	Parameters	Unit	Sampling	Entrance	Output	Average output	Average input
Lagoon Aerobia	BOD_5	mg/L	Week 1	2210.0	1621.0	1625,667	2213
			Week 2	2223.0	1630.0		
			Week 3	2206.0	1626.0		
	COD	mg/L	Week 1	3500.0	3000.0	2986,333	3400,667
			Week 2	3260.0	2960.0		
			Week 3	3442.0	2999.0		
	Conductivity	uS/cm	Week 1	3.45	3.81	3,770	3,530
			Week 2	4.00	3.50		
			Week 3	3.14	4.00		
	pH	-	Week 1	8.85	8.88	8,753	8,757
			Week 2	8.62	8.68		
			Week 3	8.80	8.70		

The analysis of the Aerobic Lagoon, according to the Aerobic Lagoon Leachate Analysis Table, shows a considerable performance in the reduction of the organic load, as reflected in the decrease of BOD5 and COD values from the inlet to the outlet. This decrease suggests that the aerobic process is working effectively in the degradation of organic matter.

Conductivity, an indicator of the presence of dissolved ions in the water, shows a slight increase at the outlet, which could indicate a concentration of ions as a result of the treatment process. This may require additional attention, depending on discharge standards and specific treatment objectives.

As for the pH, it remains relatively stable between the inlet and outlet, indicating that the aerobic process is not causing significant fluctuations of acidity or alkalinity in the leachate. This is favorable for maintaining the balance of the biological process in the lagoon.

Table 9. *Analysis of leachate from secondary sedimentation.*

Type of treatment	Parameters	Unit	Sampling	Entrance	Output	Average output	Average input
Lagoon of Sedimentation Secondary	BOD_5	mg/L	Week 1	1621.0	1504.0	1625,667	1471
			Week 2	1630.0	1400.0		
			Week 3	1626.0	1509.0		
	COD	mg/L	Week 1	3000.0	2910.0	2986,333	2843
			Week 2	2960.0	2820.0		
			Week 3	2999.0	2799.0		
	Conductivity	uS/cm	Week 1	3.81	5.39	3,770	5,223
			Week 2	3.50	5.00		
			Week 3	4.00	5.28		
	pH	-	Week 1	8.88	8.65	8,753	8,603
			Week 2	8.68	8.56		
			Week 3	8.70	8.60		

Table 9 reflects an analysis of the leachate from the Secondary Sedimentation Lagoon, showing a slight decrease in BOD5 and COD levels, indicating a partial removal of organic matter. However, the change is not significant, suggesting limited efficiency in the removal of organic contaminants. In addition, an increase in conductivity is observed, implying an increase in soluble salt concentrations, an aspect that may require additional attention. The pH remains relatively stable, which is positive, but the overall efficiency in reducing the pollutant load appears to be moderate. This analysis suggests that, although there is some treatment effectiveness, improvements or additional steps may be necessary to achieve the desired discharge standards.

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Table 10. Effluent *leachate analysis*

Sampling	**Parameters**	**Unit**	**Affluent**	**Limit Maximum Permissible**
07-01-2018	Chlorides	mg/L	1110	1000
	Color Real	Color units	44.9	Inappreciable in 1/20 dilution:
	Ammonia nitrogen	mg/L	745	30.0
	Suspended Solids Totals	mg/L	696	130
	Oils and fats	mg/L	1.0	30
	Total Phosphorus	mg/L	25	10
	Total Nitrogen Kjedahl	mg/L	250	50
	Total solids	mg/L	4344	1600
	Fecal Coliforms	MPN/100 ml	150	2000
	Cadmium	mg/L	<0.0010	0.02
	BOD5	mg/L	2700	100
	COD	mg/L	4780	200
	pH	-	7.97	6-9

Table 10 on the characterization of the influent leachate revealed several parameters that exceed the maximum allowable limits, indicating significant environmental concerns. The levels of chlorides, ammonia nitrogen, total suspended solids, total phosphorus, total Kjedahl nitrogen, and total solids greatly exceed the established standards. Specifically, ammonia nitrogen and total solids levels are alarmingly high compared to permitted limits. Although cadmium and oil and grease levels remain within limits, the Biochemical Oxygen Demand (BOD5) and Chemical Oxygen Demand (COD) are extremely high, indicating a high concentration of organic matter and a considerable contaminant load in the leachate. The pH of the leachate is within the acceptable range, but the overall data suggest an urgent need for more effective treatment and management to reduce these contaminant levels and protect the environment.

Table 11. *Analysis of leachate discharged vs. Agreement 097-A Table 9: "Discharge limits in a freshwater body".*

Sampling	Parameters	Unit	Effluent	Limit Maximum Permissible	Compliance of the discharge regulation
07-01-2018	Chlorides	mg/L	6.7	1000	COMPLIANCE
	Color Real	Color units	Inappreciable in dilution 1/20:	Inappreciable in 1/20 dilution:	COMPLIANCE
	Ammonia nitrogen	mg/L	28	30.0	COMPLIANCE
	Suspended Solids Totals	mg/L	9	130	COMPLIANCE
	Oils and fats	mg/L	<0.3	30	COMPLIANCE
	Total Phosphorus	mg/L	0.28	10	COMPLIANCE
	Total Nitrogen Kjedahl	mg/L	46	50	COMPLIANCE
	Total solids	mg/L	157	1600	COMPLIANCE
	Fecal Coliforms	MPN/100 ml	90	2000	COMPLIANCE
	Cadmium	mg/L	<0.0001	0.02	COMPLIANCE
	BOD5	mg/L	52	100	COMPLIANCE
	COD	mg/L	109	200	COMPLIANCE
	Conductivity	uS/cm	385	-	-
	pH	-	9	6-9	COMPLIANCE

The analysis of the leachate discharged, according to Table 11, shows that all parameters analyzed comply with the maximum permissible limits according to Agreement 097-A for discharge into freshwater bodies. The levels of chlorides, ammonia nitrogen, total suspended

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solids, oils and fats, total phosphorus, total Kjedahl nitrogen, total solids, fecal coliforms and cadmium are considerably below the allowable limits. Likewise, Biochemical Oxygen Demand (BOD5) and Chemical Oxygen Demand (COD) are well within acceptable limits, which is indicative of effective treatment of the leachate prior to discharge. The pH is also in the acceptable range. This set of results demonstrates effective compliance with environmental regulations for leachate discharge, reflecting proper management and treatment of these wastes prior to release into the aquatic environment.

The analysis of the results of the Landfill operation reveals an efficient management in terms of modules and capacity. Currently in its third module, the design of this phase is aligned with the previous ones, ensuring uniformity in storage capacity until the end of its estimated useful life in 2025. The leachate treatment plant is designed to handle a flow rate of 120 m^3/day, which is perfectly in line with the current flow rate of 116 m^3/day, indicating that the plant has the necessary capacity to efficiently treat the leachate generated.

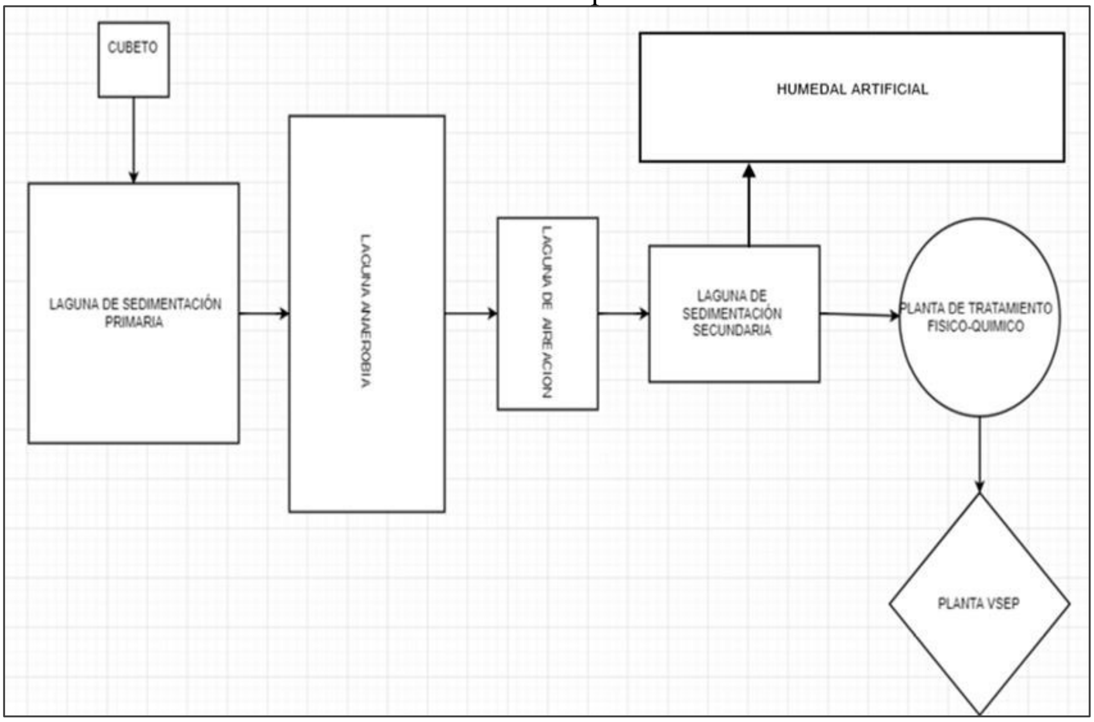
However, during on-site verification, minor variations in the dimensions of the primary treatment lagoons were detected compared to the original plans. These variations include a reduction in the width of the primary sedimentation lagoon and anaerobic lagoon, and an increase in the dimensions of the aeration lagoon and secondary sedimentation lagoon. These discrepancies, although small, can have implications for treatment efficiency.

In addition, it was observed that the primary sedimentation lagoon receives a flow of 250 m^3/day, significantly exceeding the design flow of 120 m^3/day. This excess flow reduces the hydraulic retention time, altering the sedimentation process and negatively affecting the efficiency of the plant. This overloading can lead to inefficient leachate treatment, which could have environmental and operational consequences. Therefore, it is crucial to address these challenges to ensure leachate treatment efficiency and the long-term sustainability of the Landfill.

Redesign proposal for optimization

Several key activities were carried out to develop the leachate treatment plant redesign project at the Environmental Complex for Solid Waste Disposal in Canton Santo Domingo. These included the characterization of the leachate generated, a complete evaluation of the structure, functionality and effectiveness of the existing treatments, and the precise measurement of the volume of leachate produced. A detailed study of the site was also carried out and the financial resources available from the Autonomous Decentralized Municipal Government of Santo Domingo were analyzed. All these elements were considered essential to formulate an effective proposal for the redesign of the plant (Figure 1).

Figure 1: Redesign of the leachate treatment plant of the environmental complex.



The proposal focuses on optimizing the leachate treatment plant, including several stages as shown in Table 12:

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Table 12 *Stages to optimize the leachate treatment plant*

Stage	Shares	Objectives
Primary Treatment	Lagoon management to treat 120 m3/day. Maintenance and periodic cleaning. Implementation of bacteria.	Increase treatment efficiency. Maintain operational capacity.
Physical-Chemical Plant	Acquisition of a dosing pump. Addition of coagulants and flocculants. Use of sand and carbon filters.	Improve treatment of 90 m3/day of leachate. Optimize the separation and purification process.
VSEP Plant	Improvement of primary and physical-chemical treatment. Reduction of maintenance and extension of membrane life.	Reduce operating costs. Improve treatment efficiency.
Design of New Stages	Modification of the reservoir tank. Design of an artificial wetland.	Adapt infrastructure to new needs. Implement sustainable and efficient solutions.
Redesign Calculations	Installation of flow pump. Calculation of reaction constant, area, and wetland dimensions.	Ensure effective design of the artificial wetland. Optimize the performance of the new system.

It also provides a detailed breakdown of the strategies adopted for the optimization and redesign of a leachate treatment plant, highlighting a holistic and proactive approach. In the Primary Treatment stage, actions focus on efficiently managing the lagoons to treat 120 m3/day, complemented by regular maintenance and the introduction of specialized bacteria. This approach not only seeks to improve treatment efficiency but also to maintain the system's operational capacity, which is essential for effective leachate management.

At the Physical-Chemical Plant, the acquisition of a dosing pump and the implementation of coagulants, flocculants, and sand and carbon filters show an effort to optimize the treatment of 90 m3/day of leachate. These actions are vital to improve the separation and purification processes, which are crucial in the elimination of a wide range of contaminants.

On the other hand, improvements at the VSEP Plant, such as the optimization of primary and physicochemical treatments and the reduction of maintenance work, are aimed at reducing operating costs and increasing treatment efficiency. This reflects a strategy of resource optimization and technological improvements for a more efficient and economical management of leachate treatment.

The inclusion of the New Stage Design, such as the modification of the holding tank and the design of an artificial wetland, indicates an effort to adapt the infrastructure to current and future needs, integrating sustainable and efficient solutions. The implementation of an artificial wetland is particularly noteworthy, as it represents an innovative and environmentally friendly approach to leachate treatment.

Finally, the Redesign Calculations, which include the installation of a flow pump and detailed planning of the constructed wetland, underscore the importance of effective design and optimization of system performance. This level of planning detail is crucial to ensure the long-term efficiency and sustainability of the treatment plant.
Taken together, these steps demonstrate a commitment to continuous improvement and adaptation to changing needs in leachate treatment, combining advanced technology, efficient management and environmental sustainability.

4. Conclusions

After performing a detailed characterization of the leachate treatment plant, significant deficiencies were identified in the primary treatment. The sedimentation ponds showed a removal efficiency well below expected standards, with minimal percentages of BOD5 and COD removal. This inefficiency is attributed to poor operation, lack of maintenance and inadequate staff training.
The efficiency of the Physical-Chemical Treatment Plant could not be evaluated since it is not in operation. On the other hand, the VSEP Treatment Plant proved to be efficient, with high BOD5 and COD removal rates, although its operation entails high operating and maintenance costs, reducing the useful life of the membranes.
As for the structural evaluation, minor variations were observed in the dimensions of the lagoons compared to the design drawings. However, all lagoons were found to be full of sludge and the treatment was operating beyond its designed capacity, requiring urgent maintenance.
The physicochemical plant showed no significant structural differences, but was found to be inactive and without adequate dosing of coagulants and flocculants. The VSEP plant, although efficient, faces challenges due to the treatment of raw leachate, which increases operating costs.
It was determined that the leachate flow generated is manageable by the primary treatment, but a dosing pump is required in the physical-chemical plant. In addition, a treatability test was carried out in this plant, concluding that aluminum polychloride is effective in reducing turbidity to the required levels.

Finally, an artificial wetland was proposed as a viable and efficient solution to treat the excess flow, designing a system that meets environmental and economic needs, and improves the landscape, while managing flow fluctuations and effectively removing pollutants.

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