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Feasibility study for the design of a wastewater treatment plant with effluent from the main rainwater canal No. 37 located in the Tarqui parish of Guayaquil canton.

Estudio de factibilidad para el diseño de una planta de tratamiento de aguas residuales con efluente del canal principal de aguas lluvias No 37 ubicado en la parroquia Tarqui del cantón Guayaquil.

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Abstract
About 80 - 85% of the global pollution is a product of human activities; the pollution that the open rainwater canals in the north of Guayaquil, which collect effluents from 558 hectares and a channel of 8.64 km that starts in the upper part of the sector known as Flor de Bastión, to finally discharge into the Daule River. The channels are in a very poor state, with unhealthy conditions, bad odors, insect proliferation, loss of biodiversity, and siltation, the most affected being the receiving body, which casts doubt on the capacity of this body of water to purify itself over time. To evaluate the effluent, a sample was taken at the end of the concrete-lined open trapezoidal canal called "Canal No. 37", followed by its characterization in terms of physical and chemical parameters; it does not comply with the maximum permissible limits for discharge into a freshwater body, and the implementation of a wastewater treatment plant is considered a corrective solution.

Keywords:
Main canal, pollution, effluent, Wastewater treatment plant (WWTP), Receiving body.

Resumen
Alrededor de 80 - 85% de la contaminación global es producto de las actividades humanas; la contaminación que soportan los canales abiertos de aguas lluvias en el norte de Guayaquil, en el cual se recogen los efluentes provenientes de 558 hectáreas y un cauce de 8,64 Km que se inicia en la parte alta del sector conocido como Flor de Bastión, para finalmente descargar en el río Daule. Se evidencia el pésimo estado en los que se encuentran los canales, insalubridad, mal olor, proliferación de insectos; pérdida de biodiversidad y azolvamiento, siendo el mayor afectado el cuerpo receptor y esto pone en duda con respecto a la capacidad que tiene este cuerpo de aguas de auto depurarse a través del tiempo. Para la evaluación del efluente, se realizó una muestra puntual al final del canal trapezoidal abierto revestido de hormigón denominado "Canal No 37" seguido de la caracterización de la misma en cuanto a parámetros físicos y químicos, no cumple con los límites máximos permisibles para descarga a un cuerpo de agua dulce, considerando como solución correctiva la implementación de una planta de tratamiento de aguas residuales.

Palabras claves:
Canal principal, contaminación, efluente, Planta de tratamiento de aguas residuales (PTAR), Cuerpo receptor.

1. Introducción

The disposal of liquid waste from human activities into watercourses is not a modern issue. What has changed is the magnitude of discharges, the occupation of space, and the uses of the resource. This has led, on one hand, to incompatibilities for human use and, on the other, to the destruction of habitats. Among the various problems, the extreme case is the exhaustion of the surface watercourse's capacity to absorb the discharge, and the most dramatic case is the contamination of groundwater resources, which are not visible. [1].

If the goal is sustainable development, the technical response is a combination of treatments to extract

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suspended solids and reduce levels of non-toxic contaminants, along with the proper disposal of the discharge into the watercourse. In the case of point sources, the quality of discharges must be controlled so that it is compatible with other uses and minimizes negative effects on sensitive habitats. This does not imply the complete treatment of wastewater, but rather the necessary and sufficient treatment to complement dilution after discharge [2].

Water is an element of nature, part of natural ecosystems, and is fundamental for the sustenance and reproduction of life on the planet as it is an indispensable factor for the development of the biological processes that make life possible. We all need it, not just for drinking. Our rivers and lakes, our coastal, marine, and groundwater, are valuable resources that must be protected. [3].

Environmental pollution is not a phenomenon of the 20th century; it has always existed as a fundamental part of nature. However, in recent years it has become a serious issue. Until a few decades ago, it was not considered a problem because it had barely been proven how serious the matter is, which is evident from the negative effects on the environment and health. Pollution is one of the most important environmental problems for our world, and it originates when an imbalance is created in the environment due to the addition of any substance in such quantity that it produces harmful effects on humans, animals, plants, or materials exposed to doses that exceed acceptable levels in nature. [4].

59% of the total water consumption in developed countries is for industrial use, 30% for agricultural consumption, and 11% for domestic use, according to the first United Nations report on the development of the world's water resources, Water for All, Water for Life. By 2025, water consumption for industrial use will reach 1,170 km³/year, a figure that stood at 752 km³/year in 1995. The production sector is not only the biggest consumer but also the most polluting. Over 80% of the world's hazardous waste is produced in industrialized countries, while in developing nations, 70% of the waste generated in factories is discharged into water without any prior treatment, thus contaminating the available water resources. [5]

These figures provide an idea of the importance of wastewater treatment and reuse in the industrial sector worldwide, and even more so in countries that close their water resource balance with red numbers. This is the case of Spain, the European nation with the highest water deficit. [6].

"Water, along with air, land, and energy, constitutes the four main natural resources essential for the existence and development of mankind." Since the beginning, humanity has used water as a resource to achieve levels of development that have greatly facilitated human life. Initially, water was used by humans to meet personal needs and, in turn, for agriculture. Over time, the development of water as a means of transportation began, facilitating communication between countries and, consequently, economic development. Water was also used as a receptor for the liquid waste produced by humans, driving machines that enabled the cleaning and removal of all types of waste generated by human development. [7].

Water is one of the most abundant chemical substances in nature, occupying the largest volume on Earth, and is represented in various types of water bodies. Of the total amount of water on the planet, 97.43% is found in saltwater bodies, about 1.725% is frozen in glaciers and other polar ice, and 0.768% is freshwater in lakes, rivers, and groundwater. [6].

Wastewater is commonly classified into two types: industrial and municipal. In many cases, industrial wastewater requires treatment before being discharged into the municipal sewer system; as the characteristics of this wastewater vary from one industry to another, the treatment processes are also highly variable. However, many of the processes used to treat municipal wastewater are also employed with industrial wastewater. Some industrial wastewater has characteristics compatible with municipal wastewater, allowing it to be discharged directly into public sewer systems. [7].

Fresh and aerobic municipal wastewater has a kerosene-like smell and a gray color. Older wastewater is septic and fetid, characterized by a hydrogen sulfide odor similar to that of rotten eggs. Septic wastewater is black in color. The temperature of wastewater is higher than that of drinking water, ranging between 10 and 20°C, due to the addition of heat to the water in building plumbing systems. [3].

The city of Santiago de Guayaquil, the capital of Guayas Province in the Republic of Ecuador, located in the northwestern region of South America, is situated at the discharge of the Guayas River basin into the Pacific Ocean to the east and is bordered by the Estero Salado to the west. It is a coastal city with easy access to the Pacific Ocean through the Gulf of the same name. It is located at latitude 2°19' south and longitude 79°53' west, at an average elevation of 4 meters above sea level, and has a predominantly flat topography. However, there are areas with gentle slopes in Urdesa, Alborada, Sauces, and northern sectors of the city. [8].

Guayaquil stands out among Ecuadorian cities for its high use of mass transit, total density, and diverse population. The city's port is one of the most important on the eastern Pacific coast. 70% of the country's private exports pass through its facilities, and 83% of imports enter through them. Additionally, due to its position as a commercial center, the city is traditionally known as the country's "economic capital," owing to the number of businesses, factories, and commercial establishments throughout the city.

Guayaquil is the most populous city in the country, home to 15.8% of Ecuador's total population according to the 2010 INEC Census. As the most important commercial center in the country, it is one of the main population attraction centers. Population expansion has occurred spontaneously without much planning throughout history. Since the 1960s, newly arrived residents in the city have mainly settled in informal land occupations, without infrastructure, and thus in precarious sanitary and safety conditions. Urban expansion in popular settlements towards the west of the city has surpassed the physical limit imposed by the CEDEGE canal and the Urban Ordinance limit published in R. O. 828 on December 9, 1991. [9].

Due to its proximity to the ocean, the direction of flow in the two receiving bodies varies with the tides. The Gulf of Guayaquil contains a mix of marine and freshwater, constituting a rich environmental ecosystem of great economic and tourist importance for Ecuador. Guayaquil is one of the most important cities in Ecuador as the main hub of social and economic development. In recent decades, it has experienced significant urban growth, leading to complications such as urban waste pollution, storm drainage system collapse, urban air pollution, energy production and consumption, among others. [8].

The sanitary sewer system in the city of Guayaquil consists of 3,926 km of collectors and 61 wastewater pumping stations, covering over 90% of the service area. The city has separate sanitary sewer and storm drainage systems. The sanitary sewer networks are designed to discharge into the Daule-Guayas rivers, while the storm drainage is designed to discharge into the Estero Salado. Approximately 280,000 m^3/day (3.24 m^3/s) of wastewater is generated in Guayaquil during the dry season and 350,000 m^3/day (4.05 m^3/s) during the rainy season. [8]

2. Materials and methods

Considering the different types of field design, it should be noted that this study presents an experimental design type. "An experiment consists of subjecting the study object to the influence of certain variables, under controlled and known conditions by the researcher, to observe the results each variable produces in the object" [10]

The tests carried out during the research process are defined in physical, organoleptic analysis, and wastewater sample analysis based on standardized methods recognized nationally and internationally.

Samples were taken under the NTE INEN 2176 standard, which establishes guidelines on sampling techniques used to obtain the necessary data in quality control analyses of natural, polluted, and wastewater for characterization. The analyses were conducted in the Chemical Engineering Laboratory of the University of Guayaquil, complying with the requirements for certification by the Ministry of Environment and the regulations governing the studies made for this research. See references.

2.1 Calculation of flow rate

To calculate the water flow rate (m/s) converging in the lower basin (m^3/s), the float method will be used during fair weather (summer season), with little wind and calm flow.

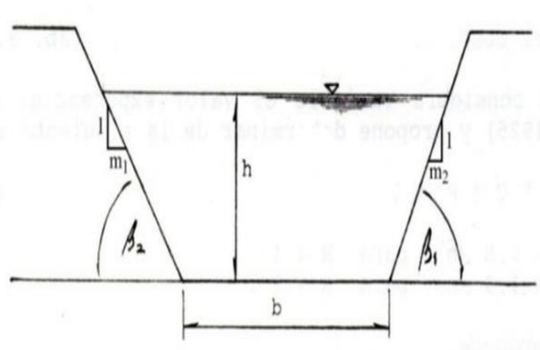

Figure. 1. Geometric variables of a trapezoidal channel.
Source: Own

Procedure

a) A straight section of the canal, free of aquatic plants, was selected to ensure the float moves easily and steadily.
b) A distance of 30 meters between two points was measured using a measuring tape.
c) The average depth and width of the canal were determined, being 1.4 m and 9 m, respectively.
d) To determine the average water velocity, the time taken by the float to cover the 30-meter distance was recorded using a stopwatch.

$$v = \frac{d(m)}{t(sec)} \quad (1)$$

$$v = \frac{30}{138} \quad (2)$$

$$v = 0{,}22\ m/s \quad (3)$$

a) To determine the flow rate, the average water velocity is multiplied by the width and depth of the canal.

$$Q = v * Width * Depth\ of\ the\ canal \quad (4)$$

$$Q = 0{,}22 \frac{m}{s} * 1{,}8m * 7m \quad (5)$$

$$Q = 2{,}7 \frac{m3}{s} \quad (6)$$

3. Analysis of Results

With all the processed data, an analysis and interpretation will be conducted, after which these results will be compared and extrapolated to the WWTP model. The characterization of wastewater origin in a stormwater channel is a complex task. In this case, it was concluded that the flow rates at the time and place where the sample was taken discharged directly into the Daule River with a high level of contamination. Waters, particularly surface and wastewater, are susceptible to changes to varying degrees as a result of physical, chemical, or biological reactions, indicating the need for analysis in the channels flowing through the drainage canal and directly into the river.

Table 1 Comparative table of the results obtained from the analysis vs. the discharge limits to a freshwater body

Parameter	**Expressed As**	**Unit**	**Sample Result**	**Maximum Permissible Limit**	**Compliance**
Hydrogen Potential	pH	-	7.77	6 to 9	YES
Color	Real Color	Color Units	4680	-	NO
Turbidity	-	NTU	9920	-	NO
Surfactants	Methylene Blue Active Substances	mg/l	254	0,5	NO
Chemical Oxygen Demand	COD	mg/l	17318	400	NO
Suspended Solids	-	mg/l	7100	250	NO
Oils and Greases	Hexane Soluble Substances	mg/l	122	30	NO
Hexavalent Chromium	Cr +6	mg/l			YES
Floating Material	Visible	-	-	Absence	NO

Source: Own

As part of the Orquídeas sub-basin decontamination project, after an in-depth analysis of the research results, the ideal WWTP model for the drainage canal inflow was determined, featuring a primary treatment system consisting of a screening area, grit chamber, and primary sedimentation tank.

The vacant lot where the project would be developed is owned by the Municipality of Guayaquil. It covers an area of 2.8 hectares, bordering to the north with private lands of the "Las Orquídeas" residential area, to the east with the

Mucho Lote stabilization ponds, to the south with Calle 24ª NE, and to the west with the “Dolores Cacuango” Educational Unit.

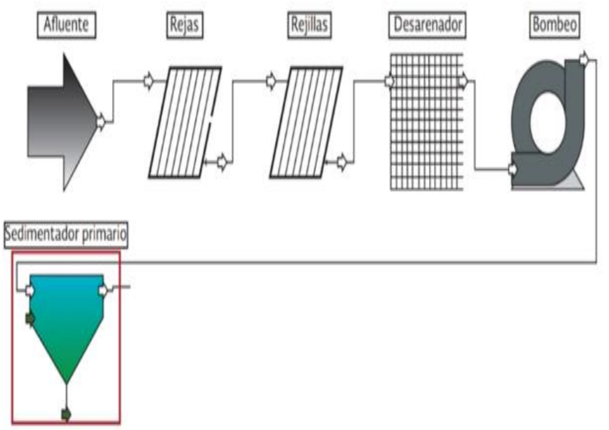

Figure. 2. Process flow diagram (pre-treatment units are located before pumping).
Source: Own

The mentioned WWTP will include pre-treatment facilities. The screening operation is used to remove coarse material, generally floating or suspended waste contained in raw wastewater, which can clog or damage pumps, pipes, and plant equipment or interfere with the proper operation of processes. Coarse screens are used to prevent large solids such as stones, logs, wood pieces, rags, plastic bottles, and in general all kinds of bulky waste carried by the storm sewer system. The cleaning grates are manual and inclined at 45 to 60 degrees relative to the horizontal to facilitate the removal of waste.

Grit removal involves separating sand from other materials present in the water, especially organic matter, in such a way that the retained sand does not carry other materials, which is generally very difficult. In longitudinal grit chambers, the flow velocity is designed to be approximately 0.30 m/s to settle typical sand particles from municipal wastewater.

Its operation consists of ensuring that the water circulates at low speed (less than 0.30 m/s) to allow the sedimentation of particles, and its maintenance involves removing sand from the bottom at least once a day.

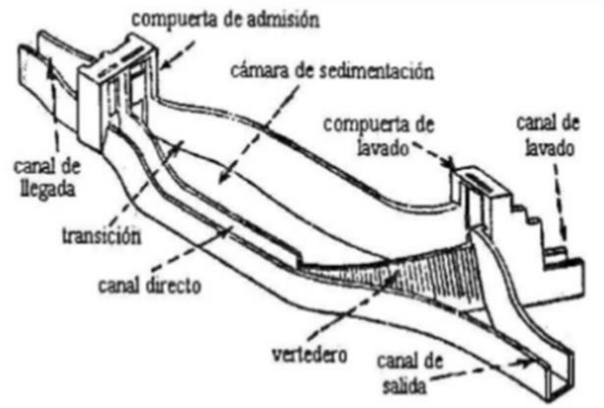

Figure. 3. Basic elements of a grit chamber
Source: Own

Primary sedimentation reduces the organic load in water treatment processes by removing a large amount of suspended solids and floating materials from the wastewater inflow.
When operated efficiently, primary sedimentation can typically remove up to 90 percent of settleable solids, 40 to 60 percent of suspended solids, and 20 to 40 percent of the biochemical oxygen demand entering the sedimentation tank, offering a clearer effluent and more consistent wastewater preparation for discharge into a freshwater body.
Based on these criteria, the WWTP is designed to meet the needs of an area of 588 hectares.

Table 2. List of flows present in the study

Daily Flow	19008 m^3
Average Flow	792 m^3/h
Maximum Flow	9972 m^3/h
Peak Flow	3600 m^3/h
Suspended Solids	7100
BOD5	356 ppm
Daily Flow	19008 m^3

Source: Own

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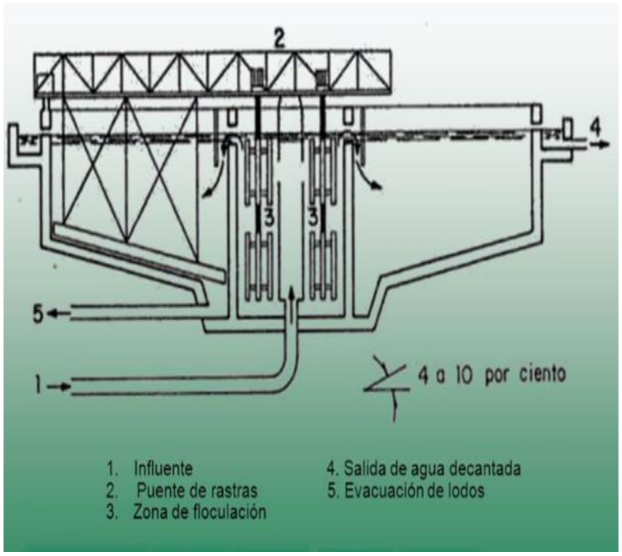

Figure. 4. Primary circular sedimentation tank.
Source: Own

4. Conclusions

The flow rate and the physical-chemical characteristics of the wastewater from the main channel of "Las Orquídeas" stormwater system were determined, with an average flow rate of 792 m^3/h. The float method was used to calculate the velocity, and the geometric sections of the open trapezoidal concrete-lined canal were measured to determine the cross-sectional area through which the fluid flows. For the effluent evaluation, a composite surface sample was taken over two consecutive days every eight hours on November 16 and 17, 2019, at the end of the open trapezoidal concrete-lined canal No. 37, under the Ecuadorian Technical Standard (NTE INEN 2176:2013). A wide-mouthed bottle was submerged in the water, filled completely, and sealed to ensure no air was above the sample, which was then transported to the laboratory on November 18, 2019.

The processed data determined that the effluent sampled did not meet the maximum discharge limits to a receiving body.

A sanitary bypass design was established, consisting of primary treatment systems, including a screening system, grit removal, pumping station, and a primary circular sedimentation tank, preventing contaminants from entering the ocean through the Daule River.

The presence of toxic and persistent substances in the analyzed runoff and discharges poses a serious threat to our ecosystem and public health, requiring clear and urgent measures to control and regulate their use.

A wide variety of resources are available to mitigate the contaminating effects, but it is also necessary to raise public awareness of environmental pollution.

It was concluded that for the installation of an efficient WWTP, complementary works are needed, such as the lining of the final section of the stormwater drainage system D, pumping stations, achieving 100% inter-household connections in the area of influence, tide control structures, maintenance easement, redesigning the Mucho Lote sewage lagoon system, and implementing sustainable urban drainage systems.

References.

[1] APHA, AWWA, WPCF, Standard Methods for the Examination of Water and Wastewater., Washintong, 1998.

[2] J. Escobar, «La contaminación de los ríos y sus efectos en las áreas costeras y el mar.,» CEPAL, Santiago de Chile, 2012.

[3] E. &. Metcalf, Ingeniería de aguas residuales. Tratamiento, vertido y reutilización,, Madrid: McGraw-Hill, 1995.

[4] Belzona Inc., Tratamientos de aguas residuales, Copenhague, 2010.

[5] E. C. Valdez, Ingeniería de los sistemas de tratamiento y disposición de aguas residuales, Mexico: Fundación ICA, A.C, 2003.

[6] A. R. Fernandez-Alba y P. Letón, «Tratamientos avanzados de aguas residuales,» CITME, España, 2017.

[7] J. Roa Márquez, Fundamentos básicos de los procesos ambientales para ingenieros., Caracas: Fondo Editorial Unet, 2001.

[8] EMAPAG, DESCRIPCIÓN GENERAL DEL PROYECTO UNIVERSALIZACIÓN DEL ALCANTARILLADO SANITARIO Y TRATAMIENTO DE A GUAS RESIDUALES DEL SISTEMA SUR DE

LA CIUDAD DE GUAYAQUIL - PLANTA DE TRATAMIENTO DE AGUAS RESIDUALES "LAS ESCLUSAS" Y SUS COMPONENTES COMPLEMENTARIOS., Guayaquil, 2011.

[9] Interagua, «AJUSTE Y REVISIÓN DEL PLAN MAESTRO AGUA POTABLE; ALCANTARILLADO SANITARIO y ALCANTARILLADO PLUVIAL,» Tomo II, Guayaquil, 2015.

[10] C. Sabino, El proceso de investigación, Caracas, Venezuela: Panapo, 1992.