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ABSTRACTION IN DRY WEATHER AS AN ALTERNATIVE TO IMPROVE UNITARY SANITARY SEWAGE SYSTEMS IN BRAZIL

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ABSTRACT

The study aims to analyze the feasibility of implementing a dry weather collection system as a technical solution to the challenges related to sewage collection and treatment in unitary systems in Brazil. The proposal seeks to minimize the impacts on Effluent Treatment Plants and protect water bodies, contributing to the fulfillment of the goals of the legal framework for basic sanitation and the Sustainable Development Goals. The methodology adopted involved a literature review, document analysis and a case study. The data were collected from scientific databases, such as Scielo and Scopus, and from official sources. The information was critically analyzed regarding the technical feasibility of capturing in dry weather, and sizing calculations were performed in Excel spreadsheets to simulate the operation of the system in different scenarios. The proposed model considered parameters such as sewage flow, rainfall intensity and operational capacity of the Effluent Treatment Plants. The results of the study included the development of a conceptual design for the dry weather catchment system, with detailed calculations of pure and combined sewage flow. Specific interception points and sizing were defined, such as collection boxes, pumps and operational configurations based on a set point of 190 mg/L of Chemical Oxygen Demand - COD. The system had the potential to reduce the overload in the Effluent Treatment Plants, ensuring a maximum flow of 5452 m³/day and compliance with the parameters of the Resolution of the National Council for the Environment - CONAMA and environmental standards. The study points out that the dry weather collection system is a viable technical solution to improve the efficiency of biological treatment and reduce environmental impacts from the discharge of untreated sewage. However, it is recommended that future research be carried out to prepare a detailed executive project and evaluate the technical, economic and socio-environmental feasibility of the proposed model.

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INTRODUCTION

In Brazil, the sewage collection and treatment system is still precarious in many regions, either because the drainage network system is still of the unitary type, collecting the sanitary network together with the rainwater network, or because of the lack of implementation of systems for the treatment of sanitary sewage according to the National Water Agency (ANA, 2017). As reported by Volschan, 2020, a palliative alternative would be the sewage collection system in sewage time (CTS), which could minimize the impacts on effluent treatment plants (ETEs), as well as on receiving water bodies. With this scenario, it will hardly be possible to achieve the objectives of fully meeting basic sanitation by 2030, as discussed throughout this course conclusion work.

Most drainage networks in Brazilian municipalities have a unitary drainage system, with sewage being discharged into the receiving bodies without treatment (Oliveira, *et al*., 2023). A palliative solution would be the withdrawal in dry weather (CTS) and the runoff through the drainage network sent to ETEs and protecting the receiving bodies (Veról *et al*., 2020).

To support the work, it is necessary to have a view of the context of sanitation in Brazil, highlighting the system of collection and treatment of sanitary sewage, which is presented according to the sources of bibliographic consultations researched.

Brazil has a sanitary sewage collection and treatment system that is still deficient today, and much of this sewage is collected in the municipalities through unitary collection networks covering rainwater and sanitary sewage together, which can cause major problems for the collection and treatment of the WWTPs, (Volschan, 2020).

This research is in line with the commitments made by Brazil to the United Nations (UN), being a signatory to the document of the objectives for the Sustainable Development Goals (SDGs), which advocates in its item 6.0 that aims to offer treated water and sanitation to the entire population (UN, 2015). Another fact that justifies this work was the compliance with the principles that govern the legal framework for basic sanitation, which indicates according to the Federal Basic Sanitation Policy Law No. 14,026, of July 15, 2020 (BRASIL, 2020).

Current legislation stipulates concrete goals for achieving the universalization of water supply and sewage collection and treatment services by 2033, which means that, by the end of 2033, 99% of the Brazilian population should have access to treated water, and 90% to sewage collection and treatment.

This study aims to analyze the feasibility of implementing a dry weather catchment system (CTS) as a technical solution to the challenges related to sewage collection and treatment in unitary systems in Brazil. The proposal seeks to minimize the impacts on WWTPs and protect water bodies, contributing to the fulfillment of the goals of the legal framework for basic sanitation and the SDGs.

Therefore, the study developed in this project is justifiable with regard to the following aspects: reduction of the concentration of pollutants in the sewage that arrive at the WWTP and therefore reduction in the efficiency of the reduction of organic load and in the reduction of social impacts from the adoption of return boxes by the collection system, in view of the amortization of volumes and, consequently, the reduction of returns, and the proposition of a low-cost temporary solution to the detriment of the implementation of an absolute collection system.

METHODOLOGY

The work was based on bibliographic and other research that included the analysis of data and information on the subject in scientific articles (Scielo and Google Scholar), database of official agencies (ANA, SMMA, INEA, MS, INMET) and bibliometric analysis in the *Scopus* database and other sources, using keywords in English referring to the theme.

CASE STUDY

In this work, the capture that comes from the sanitary basin upstream of the pumping collection box was studied, which will receive pure sanitary sewage on days without rain and combined with rainwater during the rainy months, which are from November to February, which according to the rainfall indices of the municipality, are the ones with the highest intensity, during this period, the automatic activation system of the pumping pump must be turned off according to the parameter of the concentration of chemical oxygen demand (COD), informed by the ion analyzer. In periods of low rainfall, the automatic system will activate the pump, directing the combined sewage (EC) to the ETE station.

The automatic activation system was configured with a *set point* (190 mg/L) established from consultation with the capacity dimensioned in the WWTP project to treat sewage.

The present study consists of a conceptual model based on a hypothetical scenario. Having as initial analysis, the water body and the collection network. A step further, it is proposed to intercept the unitary collection network, directing the flow of sewage diluted with rainwater to a pumping equalizer box, which will later send the (EC) to a treatment plant.

Regarding the research design, the study has an applied nature, because, according to (Thiollent, 2009, p.36), it is intended to elaborate diagnoses, identify problems and find solutions, in addition to meeting the demands of clients or institutions, regarding this classification the study developed a protocol to be applied in municipalities that wish to implement the CTS system.

The approach of this study has a qualitative and quantitative (combined) character, with a view to describing and comparing variables, in addition to articulating measurable variables. In addition, the attribution of meaning was carried out through a model called case study.

Regarding the procedures used, the bibliographic research, documentary research and the case study stand out. All the procedures mentioned above had as their object of study the sanitary sewage and the sewage collection systems, as well as the unitary networks and the dry weather collection system (CTS).

The details of the research procedures will be addressed in the following items.

DATA COLLECTION

Regarding the theme investigated, the data collection took place through indexed databases, such as *Scientific Electronic Library Online* (*Scielo*) and *Scopus* owned by *Elsevier*, in addition to legislation and official bodies, from March to November 2024.

DATA ANALYSIS

The data obtained through bibliographic research and on the websites of official agencies underwent critical analysis, verifying the feasibility for the installation of the CTS system in the municipality under study.

DATA PROCESSING

The data treatment goes through calculations through formulas and Excel spreadsheets, already consolidated in ABNT standards and in the literature, such as calculation of the flow of sewage generated, runoff flow in the locality, dimensioning of equalizer boxes and pumps.

OBJECT OF STUDY

The object of study comprised the collection of sewage and rainwater done jointly through drainage networks, in the so-called unitary collection systems.

DEVELOPMENT OF THE PROTOCOL

For the proposal established in this study, a protocol and field was developed in order to script all actions for the adequacy of unitary networks such as dry weather capture (CTS) under control of combined sewage direction (CE) of a receiving and equalizing box equipped with an analyzer ion system that will activate the sewage pump, depending on the COD set point parameter.

RESULTS

CONCEPTUAL DESIGN OF THE CTS SYSTEM WITH ELEVATING EQUALIZER BOX FOR DEMONSTRATIVE PURPOSES AND DIMENSIONING OF THE DOMESTIC SEWAGE FLOW

The flow rate was calculated by applying equation 1, with the data entered in an EXCEL spreadsheet, generating table 1.

Table 1: Calculation of the flow of sewage generated per day

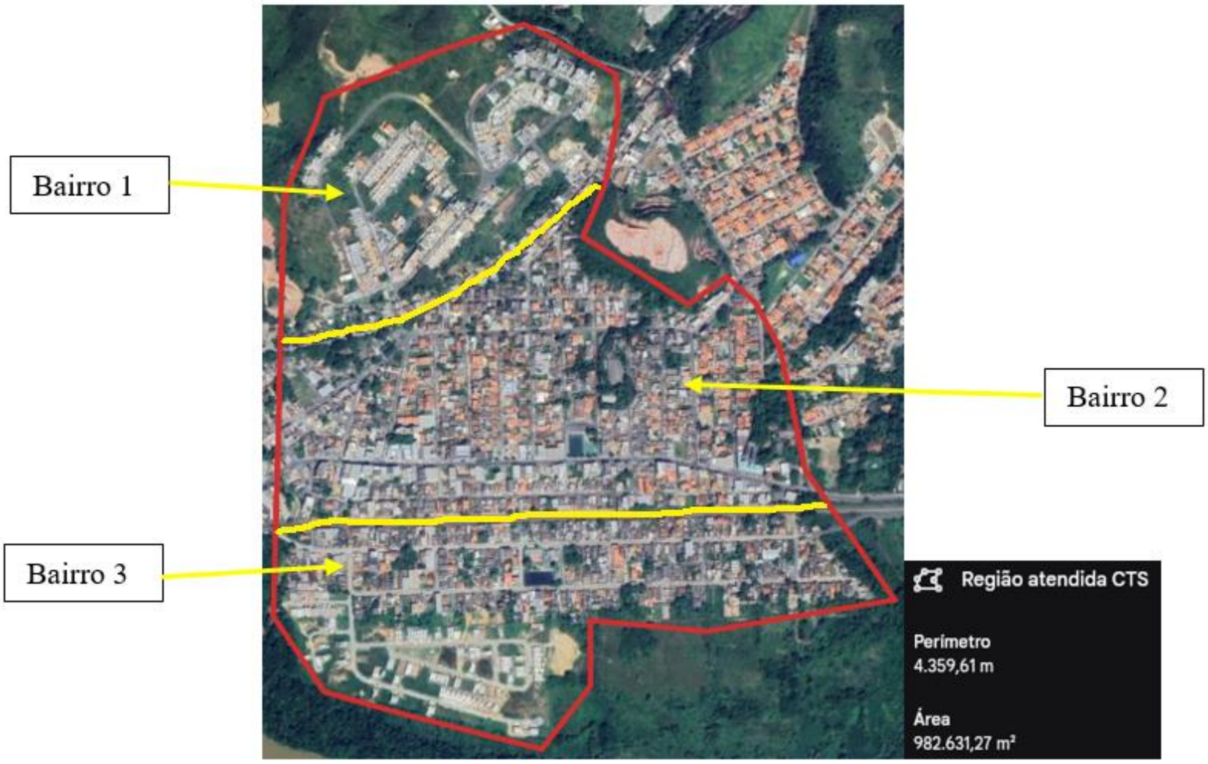
Local	Propulação (hab.)	Consumo *per capita* (L/hab.dia)	Vazão de esgoto (m³/dia)
Bairro 1	1000	130	187,2
Bairro 2	2000		374,4
Bairro 3	3000		561,6
Total	6000		1123,2

Source: The authors (2024).

For the design of the surface runoff, the following data were used:

- Area to be served 0.983 km², as shown in figure 1, obtained from Google Earth. Figure 1 shows the area delimited for the implementation of the dry weather catchment system (CTS). The definition of this region is essential for the planning and dimensioning of the necessary interventions, considering the flows of sewage and rainwater in the locality.

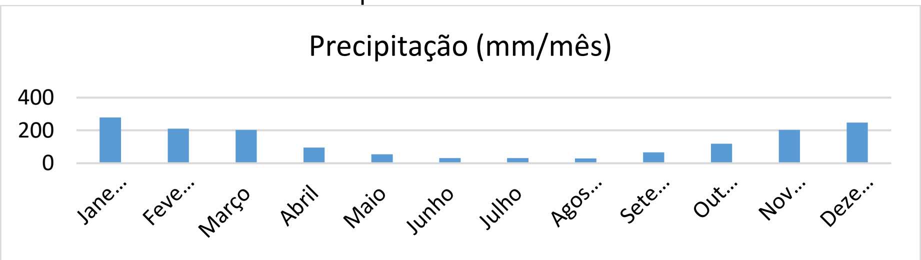
Figure 1: Region to be served by the CTS



Source: Google Earth, adapted

The period was one of intense rains, November to January, according to graph 1 generated by Climatempo data.

Graph 1: Rainfall indices



Source: Climatempo, 2024 – Adapted

The calculation of the flow in the rainy months using equation 2, EXCEL spreadsheet that generated table 1.

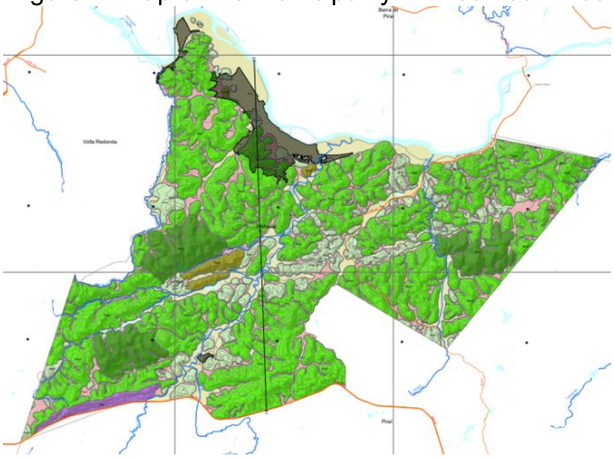
Table 1: Calculation of the flow rate in the rainiest months

Local	Área de contibuição (m²)	Índice pluviométrico Dez,Jan,Fev (mm)	Número de dias chuvosos	Total m³/dia
Bairro 1	156130	245,3	90	425,5
Bairro 2	655276	245,3	90	1786,0
Bairro 3	298652	245,3	90	814,0
Total	1110058	735,9	270	3025,5
Esgoto Combinado				4148,7

Source: The authors (2024).

After consulting the rigeo.sgb.gov.br website, the topography of the place to be installed is verified The map of the municipality, presented in figure 2, highlights the contour lines, which are fundamental for topographic analysis. This information is indispensable for the strategic choice of the installation locations of the components of the CTS system.

Figure 2: Map of the municipality with contour lines



Source: rigeo.sgb.gov.br

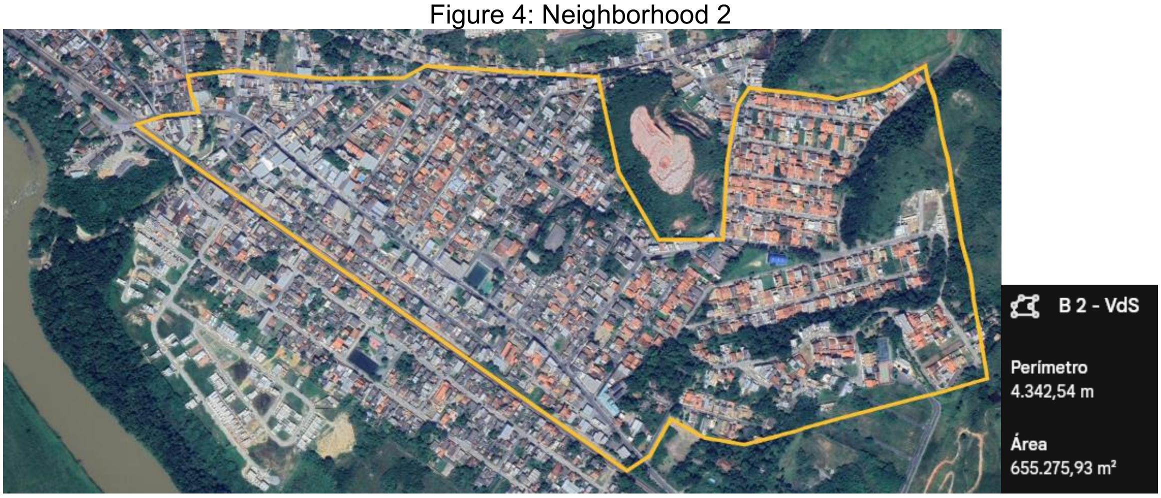
The images generated by Google Earth were verified and the best places to install the interception points were delimited, according to figure 2. Figure 3 illustrates Neighborhood 1, located in the upper part of the toilet, in a strategic area for the initial collection of sewage on days of dry weather. This neighborhood plays a crucial role in the CTS system, as it is one of the regions closest to the source of the runoff. Its location allows the early interception of the flow of sewage, significantly reducing the organic load that would be transported to water bodies or denser urban areas. In addition, the neighborhood has favorable characteristics for the installation of equipment necessary for the initial control of the system.

Figure 3: Neighborhood 1

Source: Google Earth, adapted

Neighborhood 2, represented by figure 4, is located in an intermediate area of the toilet basin and has a relevant function in the catchment system in dry weather. Its position allows the continuity of the intercepted flow in Neighborhood 1 and helps in the management of sewage volumes combined with rainwater during the rainy season. This neighborhood was included in the planning because it has adequate topographic and structural conditions for the installation of intermediate equalizer boxes and pumps, ensuring the efficiency of the system in transporting waste to the Sewage Treatment Plant.

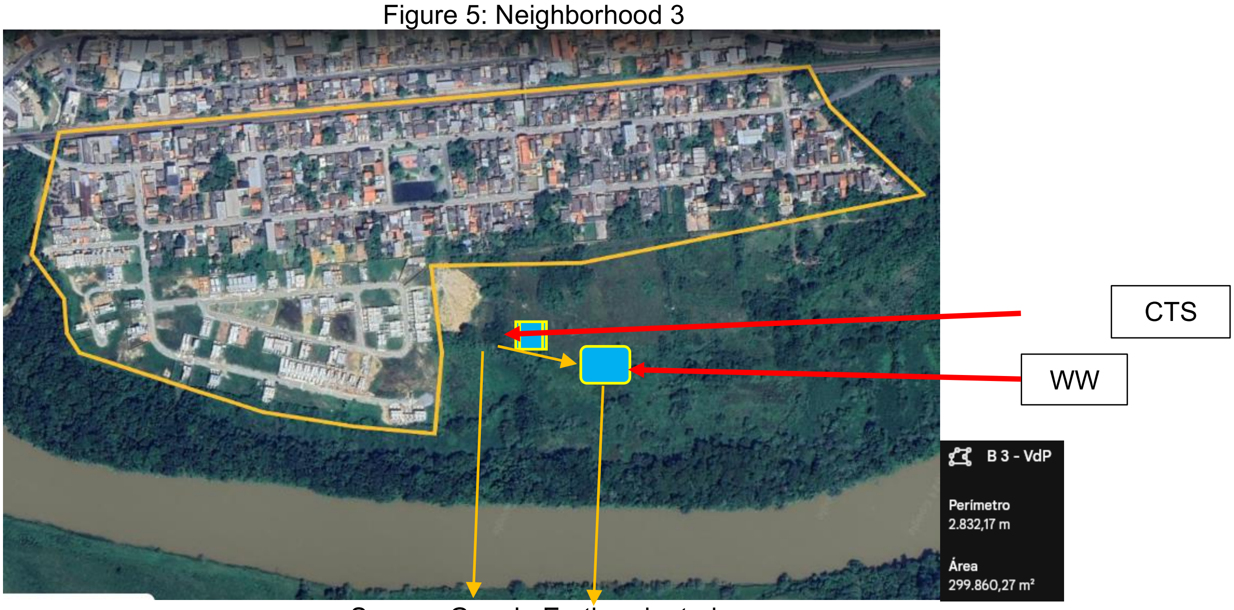
Figure 4: Neighborhood 2



Source: Google Earth, adapted

Located in the lowest part of the toilet, Neighborhood 3 (figure 5) was chosen as the end point of the CTS system, being the place destined for the installation of the Sewage Treatment Plant (ETE). This area has favorable characteristics, such as proximity to the receiving water body and ease of expropriation due to the low density of buildings. In addition, its location allows the system to work efficiently, directing the combined sewage from the entire basin to the WWTP, where it will be treated before being disposed of. The choice of Neighborhood 3 reinforces the objective of minimizing the environmental and social impacts associated with the release of untreated sewage.

Figure 5: Neighborhood 3



Source: Google Earth, adapted

Preliminary calculations were carried out for the sizing of the pumps in the conditions of pure sewage and combined sewage, namely:

- Useful volume pure exhaust (dry weather) (Vu)

$$Q_e = \frac{1123\,\frac{m^3}{dia}}{\frac{24h}{dia}} = 46{,}8\,\frac{m^3}{h} \therefore \frac{46{,}8\,\frac{m^3}{h}}{3600\,\frac{s}{h}} = 0{,}013\ m^3/s$$

Where Tr = 2h:

$$Vu = Q_e * T_r = 46{,}8\,\frac{m^3}{h} * 2h = 93{,}6\ m^3$$

Length = 10 m Largura = 5 m Height = 2 m Vcx = 100m³

- \- Combined exhaust useful volume (Vu)

$$Q_e = \frac{5272\,\frac{m^3}{dia}}{24\,\frac{h}{dia}} = \frac{220\,\frac{m^3}{h}}{\frac{3600s}{h}} = 0{,}061\ m^3/s$$

Tr = 2h

$$Vu = Q_e * T_r = 220\,\frac{m^3}{h} * 2h = 440\ m^3$$

Length = 19 m Largura = 12 m Height = 2 m Vcx = 456 m³

- Area of pure sewage suction pipe:

Speed = 1.5 m/s

$$\text{ATsuc} = \frac{\frac{0{,}013 m^3}{s}}{1{,}5 \frac{m}{s}} = 0{,}0087\ m^2$$

- Area of combined sewage suction pipe:

Speed = 1.5 m/s

$$\text{ATsuc} = \frac{\left(0{,}061 \frac{\text{m}^3}{\text{s}}\right)}{1{,}5 \frac{m}{s}} = 0{,}041\ m^2$$

- Pure sewage suction diameter (Dsuc)

$$\text{Dsuc} = \left(\sqrt{\frac{4 * 0{,}0087}{\pi}}\right) * 1000 \ = 110 \text{ mm}$$

- Discharge diameter for pure drip (Dde)

Discharge diameter will be arbitrated as the value just below that calculated for suction according to Sobrinho, 1999, p355.

Dde = 90 mm

- Combined sewage suction diameter (Dsuc)

$$\text{Dsuc} = \left(\sqrt{\frac{4 * 0{,}041}{3{,}14}}\right) * 1000 = 228\ mm$$

- Discharge diameter for combined drip (Ddec)

Discharge diameter will be arbitrated as the value just below that calculated for suction according to Sobrinho, 1999, p355.

Ddec = 150 mm

- Power of pumps for pure sewage (Pot)

$$Pot = \frac{Qe.H.\gamma}{3600.efBB} = \frac{47 * 22 * 1000}{3600 * 75} = 4{,}0\ cv$$

- Combined sewage pump power (Pot)

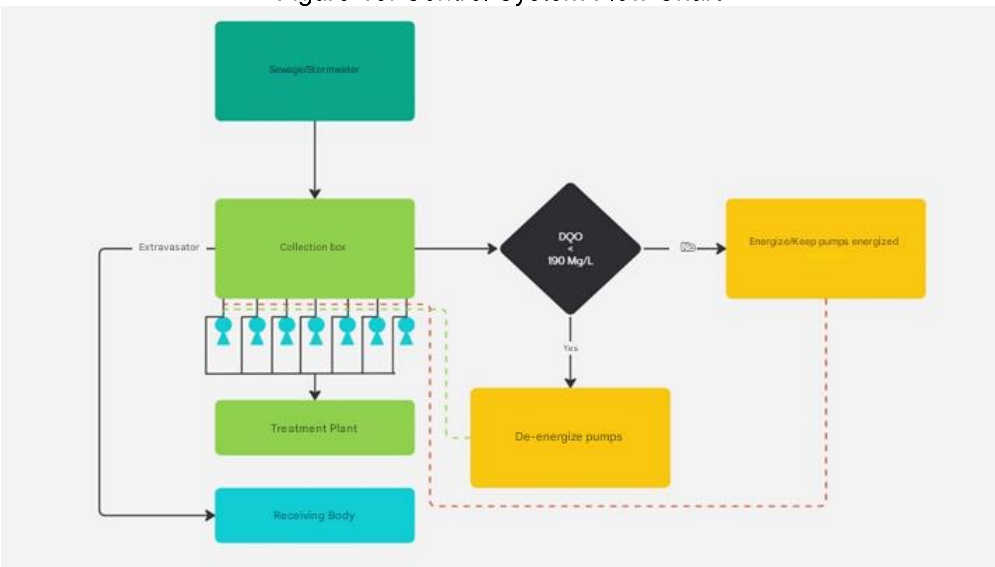
$$Pot = \frac{220 * 22 * 1000}{3600 * 19{,}7} = 68{,}25\ cv$$

For the calculated power of 68.25 hp, in order to meet the maximum flow, seven *SULZER* PE 80/2D-E 50/2" pumps with a nominal unit power of 10.7 hp are indicated, which will be activated according to the increase in flow, in view of the installation of floats with level sensors (see annex A).

APPLICATION OF THE CONTROL SYSTEM

The control system can be seen in Figure 18.

Figure 18: Control System Flow Chart



Sources: Authors (2024).

After checking resolution 430 of the National Council for the Environment (CONAMA) and on the CETESB website, the parameters for the discharge of sanitary sewage are reached, the COD value proportional to 2:1 of the value quoted for the BOD is reached, as described below:

DBO5,20 = 120 mg/L DQO = 240 mg/L

DEFINITION OF THE MAXIMUM ARRIVAL FLOW AT THE WWTP FOR THE SET POINT

The reference was the studies Teixeira et al. (2017), which found, after several collections and analyses, the COD values for rainwater in natura, ranging from 45 mg/L to 86 mg/L; for this purpose, the study used a mean value of 65 mg/L.

For the application of the set point for COD, the values researched by Leite et al. (2019), maximum COD found for sanitary sewage of 580 mg/L, were used. These data were used in the simulation of the calculation with a set point of 190 mg/L of COD for the application of the CTS.

To calculate the arrival flow at the WWTP, the following data were used:

- DQOa = 65 mg/L, DQOeb = 580 mg/L, Qe = 1123 m³/dia, set point =190 mg/L
- Where:
- COD a: Chemical Oxygen Demand of Stormwater
- COD: Chemical Oxygen Demand of raw sewage
- Qe: Sewage flow

Calculation:

$$190\frac{mg}{L} \leq \frac{\mathrm{x\,.\,65 + 1123\,.\;580}}{\mathrm{(x + 580)}}$$

$$190x + 110200 \leq 65\mathrm{x} + 651340\ \therefore 190\mathrm{x} - 65\mathrm{x} \leq 651340 - 110200$$

$$125x \leq 541140\ \therefore x\ \leq \frac{541140}{125}\ \therefore x\ \leq 4329\,m^3/dia$$

- WWTP capacity (4329 m^3 + 1123 m^3) /day ≤
- Capacity of the WWTP 5452 m^3/day ≤

Sizing the collection box

- - Combined exhaust useful volume (Vu)

Qe = (5272 m^3/dia) / 24 h/he = 220 m^3/h / 3600 s/h = Qe = 0.061 m^3/s

Tr = 2h

$$Vu = \left(220\frac{m^3}{h}\right) * 2 - 440\,m^3$$

Length = 19 m Largura = 12 m Height = 2 m Vcx = 456 m^3

LIST OF THE MAIN ELEMENTS OF THE DESIGNED SYSTEM

With a view to the best visualization of the results obtained in the design carried out, the demonstrative table 03 was elaborated.

Table 3: Summary of the designs

Parameters	Value	Quantity
Pure sewage flow rate	46.8 m^3/h – 0.013 m^3/s	------------
Length of residence	2 h	------------
Useful volume of pure sgotten	93.6 m^3	------------
Dimensions of the collection box for pure sewage	C: 10 m L: 5 m H: 2 m	------------
Tank volume for pure sewage	100 m^3	------------
Combined sewage flow rate	220 m^3/h – 0,061 m^3/s	------------
Useful volume of combined spur	440 m^3	------------
Dimensions of the collection box for combined sewage	C: 19 m L: 12 m H: 2 m	01 unit
Combined sewer box volume	456 m^3	------------
Speed	1,5 m/s	------------
Pure sewage suction pipe area	0.0087 m^2	------------
Combined sewage suction pipe area	0,041 m^2	------------

Suction diameter pure sewage	110 mm	------------
Pure drip discharge diameter	90 mm	------------
Combined sewage suction diameter	228 mm	------------
Combined drip discharge diameter	150 mm	------------
Pure sewage pump power	4.0 hp	01 unit
Combined bilge pump power	68.25 hp	7 pumps *SULZER* PE 80/2D-E 50/2 10.7 hp

Source: The Authors (2024).

CONCLUSION

In view of the scenario exposed for sewage collection and treatment in Brazilian municipalities, the capitation in dry weather presents itself as a technical alternative with the potential to meet the standards for the discharge of liquid effluents, enabling their biological treatment.

The conception of the present project, unlike the studies on the CTS system analyzed, aims at the efficiency of the biological treatment system, establishing means so that the volume captured does not negatively interfere with the quality of the final effluent. In this way, reducing the impact of the launch on receiving bodies.

The project presented did not intend to completely exhaust the topic addressed, and therefore future scientific and extension research was suggested, in order to prepare and implement an executive project, as well as a technical and economic feasibility study and evaluation of socio-environmental impacts.

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