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Effluent Treatment System for Low Loads – Biodigester: Case Study

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***Abstract*— *Water is an extremely important resource for the maintenance of life on earth and several human activities depend on it for its development, such as: agricultural production, industrial activities and energy generation. It is estimated that in a short time this resource, which has already been considered renewable, will be the object of conflict between nations. In order to be able to continue enjoying this asset, measures are needed to maintain the quality of water sources, such as the proper treatment of sanitary sewage for the discharge of water bodies. In this context, the present work aims to present a low load sanitary effluent treatment equipment that can be adopted in homes and industries, the Biodigester by the FIBROMAR company. This equipment has 03 chambers, where the first two work as an RAFA (Ascending Flow Anaerobic Reactor) and the last as an Anaerobic Filter. It was installed for evaluation in an industrial shed receiving the contribution of 10 people during business hours, where in 2015, after 06 months of use, the analyzes performed showed efficiency values in the removal of 87% DBO (61.00 mg/l) and final concentration of RNFT 25.00 mg/l efficiency of the equipment to meet CONAMA No. 430/11 (supplementary No. 357/05) and NT-202-R10 (INEA-RJ). Recently in 2021, the analyzes were repeated to evaluate the system's functioning, the results showed DBO removal efficiency 93% (8.00 mg/l) and Total Suspended Solids less than 10 mg/l, remaining within the parameters of legislation previously evaluated and in line with recent legislation (NOP 45 – CONEMA 90).*

I. INTRODUCTION

Water is an extremely important resource for the maintenance of life on the planet, from simple activities such as consumption to agricultural and industrial production and energy generation. It is considerate a renewable natural resource, however, it is estimated that in a few years it will be the object of conflict between nations (DA COSTA, 2018).

One of the great challenges that humanity will face in the coming years will be to reconcile the expansion of society is using natural resources in a sustainable way (VIEIRA, 2003). Among these resources with enormous importance are water sources, where, according to Jordão & Pessoa (2017), most of the sewage is released into rivers, lakes, bays and oceans, thus altering their physicochemical capacities.

According to Metcalf & Eddy (2016), sewage treatment methods began with a focus on public health and the adverse conditions caused by the discharge of sewage into the environment.

As for effluents of sanitary origin, they need to be treated so as not to generate environmental pollution, avoiding risks to man and his environment (BENJAMIN, 2015).

As an option to minimize these impacts, low load biological treatment systems have been adopted in order to reduce the organic load of the effluent. The best known are septic tanks, anaerobic filters and biodigesters.

The present work aims to present, through a case study, a model of treatment of low loads carried out by a biodigester, which aims to serve small residences (urban and rural), small businesses, restaurants and industries (generation of sanitary sewage).

Thus, we seek to present the academic community with a low-cost option for places with low effluent generation and with high efficiency.

II. DEVELOPMENT

2.1 Literature Review

According to the diagnosis of water and sewage services of the Ministério das Cidades of Brazil based on 2019 year, it indicates that in 54.1% of the country are covered with sanitary sewage collection services, with 61.9% meeting in the urban area and considering the portion of treated sewage, 78.5% go to Effluent Treatment Stations (SNIS, 2020).

According to Chernicharo (2016), it is evident that in the country there is a low rate of coverage of sewage collection networks, however, this is itself does not constitute an aggravating factor for unfavorable sanitary conditions. In developed countries with a large population, they adopt individual systems of treatment and disposal in the soil, however, in Brazil, there is a wide experience in the use of these, but not the technical rigor in the design of the project and operational control, resulting in inefficient systems (CHERNICHARO, 2016).

Domestic sewage consists of 99.9% water, the remaining fraction includes organic and inorganic solids, suspended and dissolved, as well as microorganisms. There is a need to treat sewage for this fraction of 0.1% (VON SPERLING, 2014).

In domestic sewage, the biological and physical-chemical characteristics vary according to the socioeconomic and health classes of the population, the nature of the water used and industrial waste (NUNES, 2014).

Lehmann and Medeiros (2019), describe the parameters for urban waters with high, medium and low concentrations. Regarding DBO, the values presented for high, medium and low are with the concentration in mg/l between 300, 250 and 120, respectively.

When raw sewage accumulates making it septic, the decomposition of the organic matter contained therein leads to the production of unpleasant by-products, such as the generation of bad odors, in addition to the various microorganisms that develop in the human intestine (METCALF & EDDY, 2016).

One of the main causes of pollution to water bodies and organic matter, the microorganisms present in its metabolic processes, consume dissolved oxygen for its use and stabilization (VON SPERLING, 2014).

According to Jordão & Pessoa (2017), one of the most used methods to measure the amount of organic matter presents is through is the determination of the Biochemical Oxygen Demand (DBO). This determination measures the amount of oxygen required to biologically stabilize the organic matter in a given period of time (05 days).

Biological unit processes are used primarily for the removal of biodegradable, colloidal and dissolved organic substances dispersed in sewage by biological activity (METCALF and EDDY, 2016).

The treatment method using the biodigester has existed for more than two centuries, with good responses regarding treatment, waste use and energy use (FRIGO et al., 2015).

The biodigester is a closed chamber where the organic material is placed in an aqueous solution, which undergoes the anaerobic decomposition process, with the decomposition of organic matter accumulated in the upper part of the layer as a product (DEGANUTTI et al., 2002).

According to Chernicharo (2016), in the process of anaerobic digestion, it is considered as an ecosystem where several groups of bacterial colonies act in the process of converting organic matter into methane, carbon dioxide, water, hydrogen sulfide, ammonia and other bacterial cells.

Low load digesters are built in a single compartment and do not have mixing mechanisms, usually the process of digestion, sludge densification and supernatant formation occurs (CHERNICHARO, 2016).

Considering the treatment of effluents by anaerobic digestion, residential systems called septic tanks follow the same principle as biodigesters. Historical research records that in 1860 Jean Louis Mouras invented the septic tank by making a compartment in masonry before entering the sinkhole. The effluents from a residence in Veoul in France were sent, where the house opened 12 years later did not have the number of solids that was imagined (JORDÃO & PESSOA, 2017).

According to Jordão & Pessoa (2017), the septic tank is a compartment intended to treat one or more homes with simplicity and reduced cost, seeking to treat the effluent in proportion to its simplicity and cost.

As treatment systems for high loads, anaerobic sludge blanket reactors (UASB, RAFA, RAMA, RALF among others) are adopted. at 10 hours, resulting in the efficiency of organic matter around 70% (CHERNICHARO, 2016).

According to the Brazilian Association of Technical Norms (ABNT, 1993), the usual detention times in septic tanks vary from 12 to 24 hours, where they are also oriented on the contribution adopted to each activity and sludge generation, as well as relating parameters related to temperature.

Also adopting the anaerobic digestion process, anaerobic filters have been widely used for complementary treatment to septic tanks according to concepts maintained in NBR 13.969/97 (CHERNICHARO, 2016).

Anaerobic filters, although they can be used as the main treatment unit, are more suitable as post-treatment units, giving the treatment high operational safety and quality in the final effluent (CHERNICHARO, 2016).

In NBR 13.967/97, the anaerobic filter is defined as a compartment where a biological reaction takes place, consisting of an empty lower layer and an upper layer filled with a filter bed where the fixation of facultative organisms that act in the degradation of organic matter acts. It also addresses the dimensioning of the unit, filling material and dimensions of the compartments (ABNT, 1997).

According to Metcalf and Eddy (2016), anaerobic filters can be classified as fixed bed reactors, where the bed can be filled with some type of matter, such as stone, ceramic or more commonly used plastic material, and its flow can be ascending or descending.

According to Chernicharo (2016), for the dimensioning of larger treatment units, applied to post-treatment of effluents from anaerobic reactors, hydraulic detention times ranging from 5 to 10 hours can be adopted. related to the type of filter media and bed height.

For the release of treated effluents, according to CONAMA 430 (Brasil, 2011), the parameters for the release of effluents of sanitary origin the parameter referring to the concentration of DBO in the maximum limit of up to 120 mg/l, and the limit may exceed in the case of effluent with a minimum efficiency of 60% of DBO or through a self-purification study that shows that the receiving body is capable of receiving the remaining concentration without compromising its quality.

The competent environmental agency may, at any time, add other conditions to the treatment and make them more restrictive, aiming at the conditions of the receiving body and even requiring new environmentally appropriate technologies (Brasil, 2011).

According to NT-202-r10 (FEEMA-RJ, 1986), it established standards for the release of liquid effluents for potentially polluting activities, as for the release criteria referring to DBO, the legislation established that specific guidelines should be followed.

For several years, the legislation that directed the release parameters regarding the removal of carbonaceous organic matter was DZ-0215.r4. According to DZ-0215.r4 (INEA-RJ, 2007) the DBO removal parameters varied according to the total daily organic load of the enterprise, ranging from 30% (organic load less than 5.00KgDBO/day) to 85% (organic load greater than 80.00KgDBO/day) of removal, recommending which type of technology could be adopted to achieve the desired efficiency.

Recently, the CONEMA resolution (State of Rio de Janeiro, 2021) approved legislation that establishes the criteria for sanitary sewage discharge standards in the state of Rio de Janeiro, being applied to all buildings (residential, commercial, ports, concessionaires and treatment). of sanitary sewers) NOP 45 – INEA-RJ, fully amending DZ-0215.r4 and NT-202-r10.

According to NOP 45 (INEA-RJ, 2021), new parameters for DBO removal, among other ranges, these two stand out where it establishes concentration limits of 120 mgO2/L and total suspended solids of 110 mg/l for higher organic loads at 80 Kg.DBO/day, the DBO concentration values at the outlet have a limit of 40mg.O2/L and total suspended solids of 40mg/l, where the former differs from DZ-0215.r4 where the limit is 180mg.O2 /L was replaced making it more restrictive and the upper bound was kept.

The equipment used in the case study was a biodigester made by the FIBROMAR Group. This equipment is characterized by a single tank developed in FRP (Fiberglass Reinforced Polyester), where through the cylindrical section, the equipment is divided into 03 equal parts. Where in the first 02 chambers, an ascending flow septic tank is configured and 01 chamber is composed of an Ascending Flow Anaerobic Filter in a total volume equivalent to 1,000L. In Fig. 1, we can see the floor plan of the treatment system and its divisions.

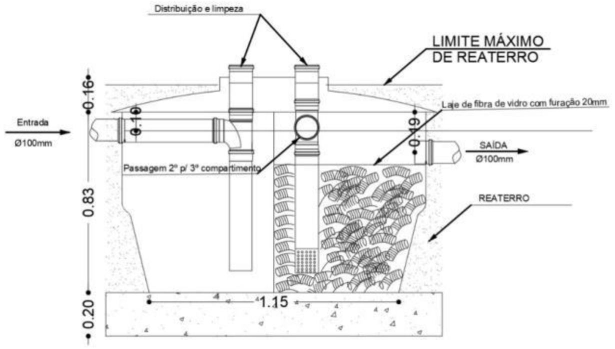

Fig. 1: Plant drawing of the equipment with the divisions of the lowlands. Source: Company's technical department of FIBROMAR.

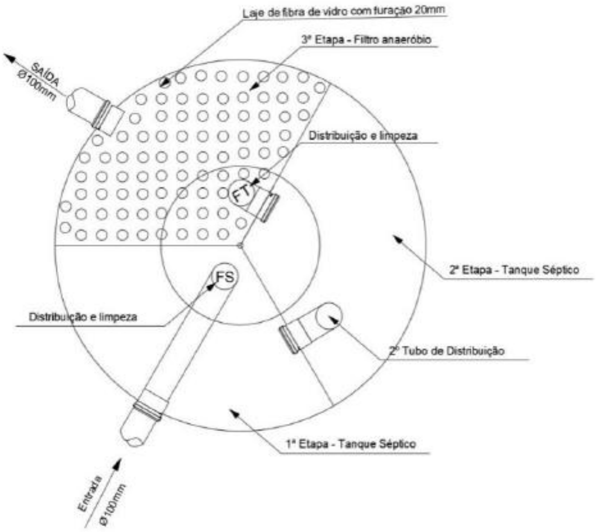

Fig. 2: Cutaway drawing of the transition from the 2nd (Upflow Septic Tank) to 3rd (Upflow Anaerobic Filter) Chamber. Source: Company's technical department of FIBROMAR

In Fig. 2, it can be seen in section how the passage from the 2nd chamber to the 3rd chamber is made, where the compartment corresponds to the anaerobic filter, the filtering medium adopted in the equipment is the plastic corrugated (conduit). According to Chernicharo (2016), plastic materials have an advantage over the gravel adopted in conventional filters due to their low density, providing bed mobility and reducing the risk of clogging, as well as their greater contact surface for bacterial colony formation (100 m²). /m³).

2.2 Methodology

For the development of the work, the biodigester was applied to treat the sanitary effluents of a part of the factory corresponding to a bathroom where 05 people used it during business hours (08:00h to 17:00h - Monday to Friday), at first, the results found were obtained after 08 months of implantation. In the second moment, this analysis was repeated to evaluate the system implemented after 06 years of installation.

It is important to emphasize that during this period the operational procedures for the correct functioning of the system occur regularly (removal of the annual portion of the excess sludge).

This equipment was installed in the industrial bathroom of the factory environment where daily around 10 employees use the treatment system from 07:00h to 17:00h. It is noteworthy that the installed system had a period of 6 months until the collection of the first sample to be analyzed for the maturation of the bacterial colony, where, according to Chernicharo (2016) the biological system takes from 03 to 06 months for acclimatization. of organic matter without performing the inoculation. In Fig. 3(a) and 3(b) we can observe the moment of collection.

It is important to emphasize that the collections were made in simple ways (one sample at the entrance and another at the exit) to evaluate the treatment capacity. As can also be seen in Fig. 3(a) and 3(b) by a collection point through a tap installed in the tank in the first and third chambers.

Fig. 3: (a) shows the time of collection of the raw influent; (b) the treated effluent. Source: Company's technical department of FIBROMAR.

In the first performance of the analyzes carried out in 2015, the parameters of D_5BO_{20} e RNFT were analyzed to evaluate the removal efficiency and as the equipment was installed in the municipality of Pinheiral-RJ, the results were compared with the values required in the DZ-215- r4, NT-202-R10 and CONAMA 430/11.

In this second analysis carried out in 2021, the results found were compared with the parameters established in NOP 45-INEA-RJ, which was prepared in February 2021 and entered into force in August 2021 (180 days after its elaboration).

III. RESULTS AND DISCUSSION

A simple collection was carried out in the equipment inlet pipe and at the outlet at the same time and taken to the accredited laboratory for analysis in November 2015. It can be verified in Table 01 in the following parameters D_5BO_{20} and RNFT:

Table 01: Input and output sample results (06 months after system installation).

Parameter	Input	Output	Efficiency	DZ-0215-r4	NT-0202-R10	CONAMA 430/11
BOD (mg/l)	469,2	61,00	86,99%	180	180	120
RNFT (mg/l)	-	25,00	-	180	-	-

Source: Technical Department of the company FIBROMAR – Result presented by Test Report No.: 21842.2015.A- V.0 – AMPRO Industrial Analysis – Date 10/02/2015.

It is observed that the parameter referring to DBO had a removal efficiency of 86.99%, a result above what is requested by the DZ-215-r4 (InEA-RJ effluent treatment guideline), a standard that requires the treatment minimum of 30% removal for organic load below 5.00 Kg.DBO/day and 65% for organic load between 5 and 25 Kg.DBO/day. The result also meets the requirements of CONAMA 430/11 (Federal directive) which requires 120 mg/l for sanitary effluents and requires at least 60% of DBO removal by means of a self-purification study of the receiving body.

As for the RNFT parameter, it appears that the value of 25.00 mg/l is lower than the values established in the DZ-215-r4.

In the second analysis carried out in June 2021, 06 years later, it evaluated the parameters of DBO, COD, SS, SST, mineral oils and vegetable oils. Table 02 shows the results found below:

Table 02: Input and output sample results (06 years after system installation).

Parameter	Input	Output	Efficiency	NOP 45 - INEA RJ	CONAMA 430/11
BOD (mg/l)	122,00	8,00	93,44%	120	120
COD (mg/l)	155,50	77,20	50,35%	-	120
Sedimentable Solids (mL/L)*	0,50	<0,10	80,00%	1	1
Total Suspended Solids(mg/l)*	11	<10	9,09%	110	Ausência
Mineral Oils (mg/l)*	<5,00	<5,00	0,00%	20	20
Vegetable Oils and Animal Fats (mg/l)*	<5,00	<5,00	0,00%	50	50

Source: Technical Department of the company FIBROMAR – Result presented by Test Report No.: 47792/2021- 0.A - Analytical EP - Date 06/25/2021.

It is observed that in relation to DBO, despite the value found is close to the concentration of light sanitary sewage, the results showed an efficiency of 93.44%, with the results within the parameters established by NOP 45 - INEA-RJ. It can be observed that for the other parameters of settling solids and total suspended solids the values also comply with current legislation, however, their input values are very low. It is important to emphasize that in Fig. 3(a) it shows the collection of raw effluent was carried out by a faucet installed on the side of the equipment. Thus, the low values found at the entrance of the equipment are justified because as the flow is ascending, the material collected has already undergone a first process of degradation and sedimentation of the first chamber.

The values referring to mineral oils and vegetable oils and fats present a very low concentration due to the activity of not having generation of these compounds in the activity performed.

This efficiency in the treatment is justified by the process adopted in the treatment having the configuration of the ascending flow, promoting the contact of the organic load with the sludge blanket where the bacterial colony is installed in the first two compartments, different from the conventional septic tanks where the flow is horizontal. decanting and non-contact with the sludge blanket. In the 3rd chamber, where the compartment referring to the anaerobic filter is located, the adoption of low-density material with a high specific area, which is the anaerobic filter, allows for a better polishing in the system and as the material is mobile, clogging does not occur. of the bed. The improvement in efficiency presented from the first to the second analysis can be justified by the stabilization of organic matter due to the long period of installation of the system and the periodic maintenance that occurs regularly (removal of excess sludge).

In Fig. 04 below, it is possible to observe the visual aspect of the effluents collected at the entrance and exit of the equipment.

Fig. 4: Comparison of samples – On the left side the raw effluent and on the right side the treated effluent. Source: Prepared by the author (2021).

IV. CONCLUSION

The equipment provided by the company FIBROMAR meets guaranteed DBO and RNFT removal efficiency, surpassing conventional treatment processes. The adoption of upward flow has significantly influenced the increase in DBO removal from conventional systems. The conduit used as a filtered medium is an alternative that also influences the improvement of efficiency and prolonging the useful life of the equipment. Regarding the analysis parameters the equipment complied with both old and current legislation, in the federal and state.

With this, it can be said that for low organic loads the equipment safely meets the current environmental requirements and is ideal for places with low number of contributors such as residences and small standards.

In this work, only one aspect of the by-products of anaerobic digestion was analyzed, the treated effluent. As a suggestion for future works, it is of great value for those equipments at agricultural communities with the use of the generated sludge for fertilization. The generation of methane (CH4) and its forms of use within the property would also be evaluated, thus being an alternative for sustainable use and quality of life for local residents.

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