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PROPOSAL FOR MAINTENANCE IN INTEGRATED SYSTEM BIODIGESTERS THROUGH REMOTE MONITORING

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ABSTRACT.
Alternative energy sources have shown to be of great importance in energy generation, as well as in increasingly sustainable and ecological productions. Among these alternatives, biomass, an input from organic matter, is one of the sources that has grown the most in the number of researches and in the number of applied projects. There are some ways to use biomass, the main one being in the form of fuel, such as bio-oil, biodiesel and biogas. Using the gasification technique, the production of biogas can be obtained in different situations and quantities. As a biodigester, biogas can even be produced in rural areas, where sewage treatment is not offered, being then used to treat sewage and also generate energy. For these equipment to be fully operational, human intervention is necessary, that is, maintenance. This maintenance can be done in a corrective, preventive and predictive way, as long as there is information so that the choice of method and action to be taken is as assertive as possible. This work aims to propose the maintenance of Integrated System Biodigesters (BSI) through remote monitoring for the treatment of domestic and animal sewage in rural areas. The model used was the Integrated Biodigestor or Chinese model Biodigestor, as it fits the needs of the study. Regarding remote monitoring, it was necessary to determine the parameters to be analyzed, as well as their respective sensors, so that the equipment can maintain its proper functioning. Through the studied parameters, a table was made that shows the components, its probable failures and which maintenance actions must be carried out so that the system is available and in operation as long as possible.

Keywords: *maintenance, biodigesters, remote monitoring.*

1. INTRODUCTION

After the industrial revolution in the 18th century, there was a significant increase in the concern with sustainable production issues. Whether in relation to the raw material used in production or in the source of energy generated to meet needs. Energy sources are natural or artificial resources used by society to produce some type of energy. This, in turn, is used to facilitate the displacement of vehicles, generate heat or produce electricity for various purposes, such as lighting. Furthermore, they are indispensable for the human way of life we are used to.

Energy sources can be classified as renewable and non-renewable, according to their natural capacity to replenish resources. Non-renewable energy sources are those that depend on geological time scale processes to become available. This means that if they are exhausted, they will take a long time to form again. Oil, coal and natural gas are the main examples of non-renewable energy sources. Renewable energies are energies resulting from renewable resources, that is, they are inexhaustible, such as hydro, tidal, geothermal and new emerging energies, such as solar, wind and biomass.

An important source of renewable energy has been used since the first people started using firewood to cook food and heat up against the winter cold, biomass. Wood is still the most common source of biomass energy, but other energy sources from biomass have also been increasingly used, such as agricultural and forestry residues, organic components from urban and industrial residues, methane gas from landfills and others. This can be used to produce electricity or as a transport fuel and to manufacture products that would normally require the use of non-renewable fossil fuels.

Biomass is any renewable input from organic matter produced in an ecosystem (animal or plant), which can be used in the production of electricity, with only a part of this matter being used as biomass, due to what the ecosystem absorbs for its own maintenance. And just like other renewable energy sources, it is an indirect form of solar energy. Thus, to define biomass for electricity generation, fossil fuels are excluded (EDUARDO & MOREIRA, 2010; MONTEIRO et al., 2013).

There are several types of technologies used for the production of electricity from biomass, but all of them estimate the conversion of organic matter into an intermediate product that will be used in a motive machine, making this machine able to produce mechanical energy by moving up the electric power generator. In general, all existing technologies are applied in cogeneration processes. This cogeneration system makes it possible to synchronously produce energy and heat, and thus allows these systems to be configured in a more coherent way for the use of fuels. However, among the main processes for converting biomass into energy and its use, we can mention: direct combustion, gasification, pyrolysis, anaerobic digestion, fermentation and transesterification (ATLAS, 2008; WWF, 2012;).

Biomass is one of the sources that has grown a lot in Brazil with cogeneration systems in the industrial and services sector, with a tendency to grow over the years. There are several factors for this growth, the main ones being the installed capacity so far and the increase in the potential of sugarcane production, motivated by the growing consumption of ethanol (EDUARDO & MOREIRA, 2010). This form of alternative energy has as its final product biodiesel, charcoal, ethanol, cellulosic ethanol and biogas.

One of the best known ways of using biomass is in the treatment of human and animal waste. This treatment can be done through the use of anaerobic biodigesters. This equipment is a technological center that accelerates the process of decomposition of organic matter called substrate. In an anaerobic biodigester, the products resulting from the decomposition process or anaerobic digestion are presented in gaseous form, biogas, and in liquid form that, depending on the substrate and technology used, can be used as biofertilizers. There are several models and applications of biodigesters around the world. The choice of the best model is made through some factors, such as, for example, the material to be processed, the layout of the space for construction or implementation, and also the technology available for its monitoring.

Managing organic waste through biodigestion means adopting a set of appropriate actions in the stages of collection, storage, transport, treatment, maintenance, final destination and environmentally adequate final disposal. Aiming at minimizing the production of waste, aiming at the preservation of public health and the quality of the environment. And in order to make more assertive decisions regarding biomass, the use of remote monitoring is currently found. In addition, the data collected in the monitoring system is also used in equipment maintenance.

Anaerobic biodigesters for waste digestion are mostly masonry constructions, with simple technology. With the recent use of sensors to measure and detect parameters, interference in the installed equipment in a more assertive and coordinated manner has become possible, because, by having concrete data about its operating parameters, the maintainer knows the right moment to act. To define the correct type of maintenance for each equipment, an assessment of the importance of the equipment for the production cycle and the impacts of a possible stoppage during its operation is necessary.

Maintenance can be classified into corrective maintenance, preventive maintenance and predictive maintenance, which are:

Table 1. Maintenance concepts

Corrective maintenance	It is the type of maintenance performed to recover the original characteristics of machines and equipment that present failures and damages that compromise the efficiency of a process.
Preventive maintenance	It is essential to ensure greater reliability and efficiency in industrial operations, avoiding risks and preventing possible wear and tear on equipment.
Predictive maintenance	It is a methodology based on monitoring and inspecting machinery and equipment to assess their quality indicators. To obtain benefits such as increased equipment availability and cost reduction, the implementation of predictive maintenance must take place through continuous action planning.

Source: Adapted from Raquel Sales (2019)

Due to little information available in the scientific literature and the growing need to use alternative energy sources and the maintainability of these equipment, this work aims to propose, through bibliographic study and field work, possible maintenance actions based on the collected parameters through remote sensing in a biodigester installed in a rural area for the treatment of domestic and animal sewage.

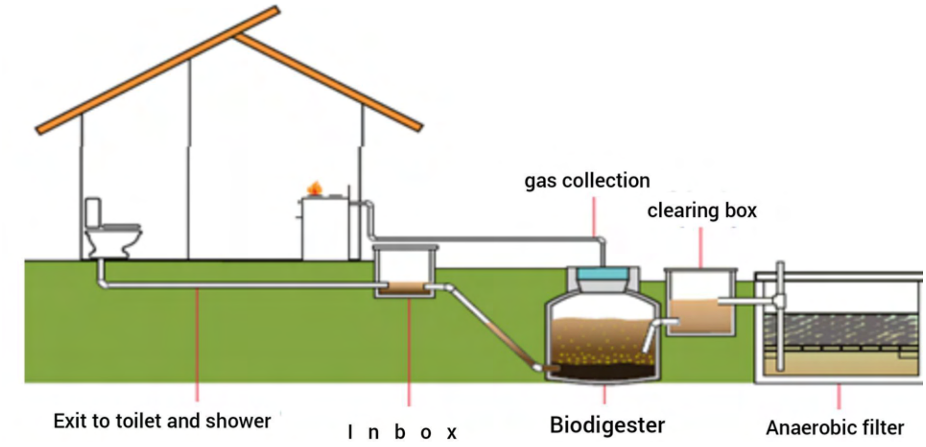
2. METHODOLOGY

This article is characterized by being an experimental research of a qualitative theoretical nature. As a maintenance proposal for biodigesters, focusing on monitoring and applying predictive, preventive and corrective measures in order to provide improvement in the operating conditions of the installed system.

In general, these equipment consist of a closed chamber where the anaerobic digestion of organic matter takes place (in the absence of oxygen) and a gasometer that stores the biogas produced. Biogas can be used as cooking gas, using a pipe installed on top of the gasometer. (Tonetti et al., 2018). Or, depending on the technology and plant where it will be used, for co-generation of electricity.

The biodigester used as a study source in this work is a treatment unit for toilet water, domestic sewage and fresh manure. It can be found as an Integrated Biosystem or Chinese Model Biodigester. This model has characteristics that are suited to the needs of the family benefiting from the implementation of the technology, such as, for example, a group of families in the same land and the raising of pigs and horses.

Figura 1. Esquema do Biossistema Integrado



Fonte: Tonetti *et al*. (2018)

For remote monitoring, it was first necessary to define which parameters should be analyzed to keep the equipment functioning properly, and thus, define which sensors would be used. As this is a pilot project, we sought to use as many parameters as possible to assess the behavior of the biodigester, in which the selected parameters were: temperature, flow, pressure and volume/level. Temperature is directly related to the percentage of methane in the constitution of biogas, because when the fermentation process takes place at higher temperatures, it will ensure a greater calorific value to the mixture (ARAÚJO, 2017). Other parameters, such as flow and pressure, are related. directly with the flow of biogas produced and transported to consumer homes. Subsequently, the company will carry out an analysis in order to determine if, in fact, all the parameters mentioned above will be necessary or just some of them. And based on the selected parameters, a survey was carried out (Table 2) to choose which sensor(s) would best fit as a tool for the analysis of the pilot project for remote monitoring of rural biodigesters.

Table 2. Survey of sensors

Parameters	Sensor
Temperature	Pt100 or LM35
Flow rate	Hydrometer equipped with pulse sensor
Pressure	Pressure transmitter
Volume/Level	Ultrasonic sensor

Source: Authors (2021)

From the study and research of which sensors could be used to analyze the established parameters, it was determined that factors such as lower acquisition cost and ease of being found on the market would be taken into consideration as a choice criterion.

The hydrometer was the chosen meter for flow monitoring, where the value is given by the sum of the rotations of an internal disk, the movement caused by the pressure difference between the opposite sides of the hydrometer. The pulse sensor is activated by a magnet integrated into the internal disk, each revolution generates a pulse directly related to the amount flown per revolution. The temperature sensor is a two-wire Pt-100 thermocouple with a measuring range from -200 to 600ºC, as it has a higher cost, the second option is the LM35 sensor with a smaller measuring range ranging from -55 to 150ºC. The fluid to be measured has solid particles, the ultrasonic level meter is able to obtain good accuracy in this type of environment, as it is based on the echo time that an emitted sound wave takes to return to the meter. The pressure generated by the production of biogas is monitored by a pressure transmitter with an internal diaphragm, through its deformation, the deflection generated is transformed into a measurement unit by an electronic system.

After choosing the biodigester model and the sensors that would be used in it, a survey was carried out on which maintenance would likely be employed through the data collected in the remote monitoring. In general, the greatest attention of this study was given to predictive maintenance, where the use of technology helps to predict problems and/or failures in machinery or equipment. However, due to the scarcity of information available in the literature relating biosystems for the treatment of rural sewage, this study used broader premises, involving possible interventions of predictive, preventive and corrective maintenance.

3. RESULTS

The object of study of this work is an Integrated Biosystem model biodigester that is in the final phase of construction by company C, located in Horizonte/CE. Once completed, the company will start implementing remote monitoring, where the selected sensors will be installed and will send information to a dashboard. Through it, the person in charge will be able to make more assertive decisions regarding the maintenance of the equipment. This highlights the relevance of this work, as the study will serve as a database for company C. This model is part of a pilot project in rural basic sanitation of the company and because of this, the data are experimental and decisions made will make up the initial test.

Figure 2 - BSI work

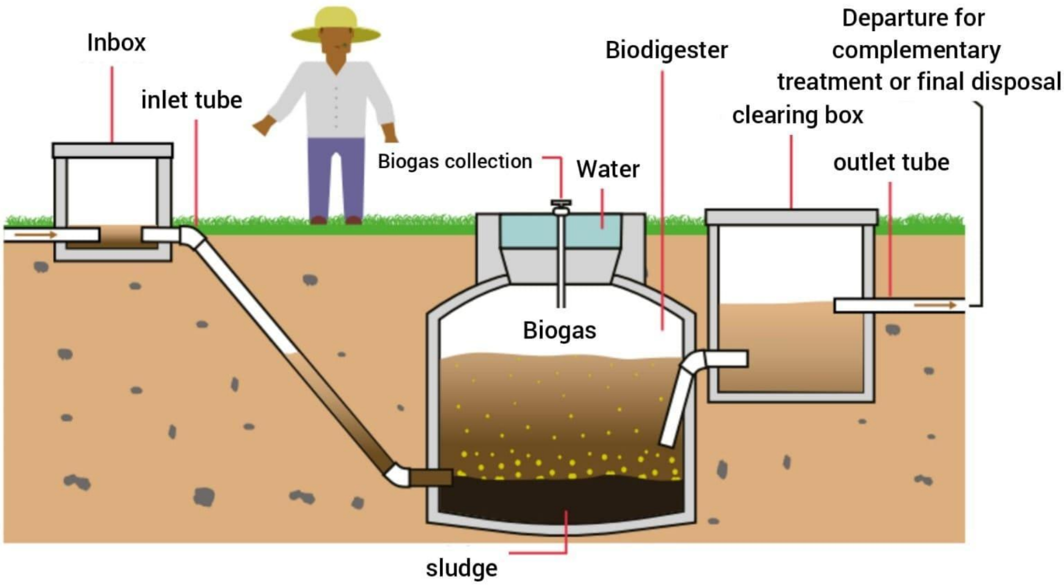
Source: Authors (2021)

Figura 3 - BSI 85% finalizado

Source: Authors (2021)

In Figure 4 we have the scheme of the system in operation. The discarded organic matter goes first to an inlet box, then to the biodigester where chemical reactions and biogas collection take place, then to a compensation box followed by an outlet pipe, leading to an anaerobic filter or complementary treatment.

Figure 4. Integrated Biosystem Scheme



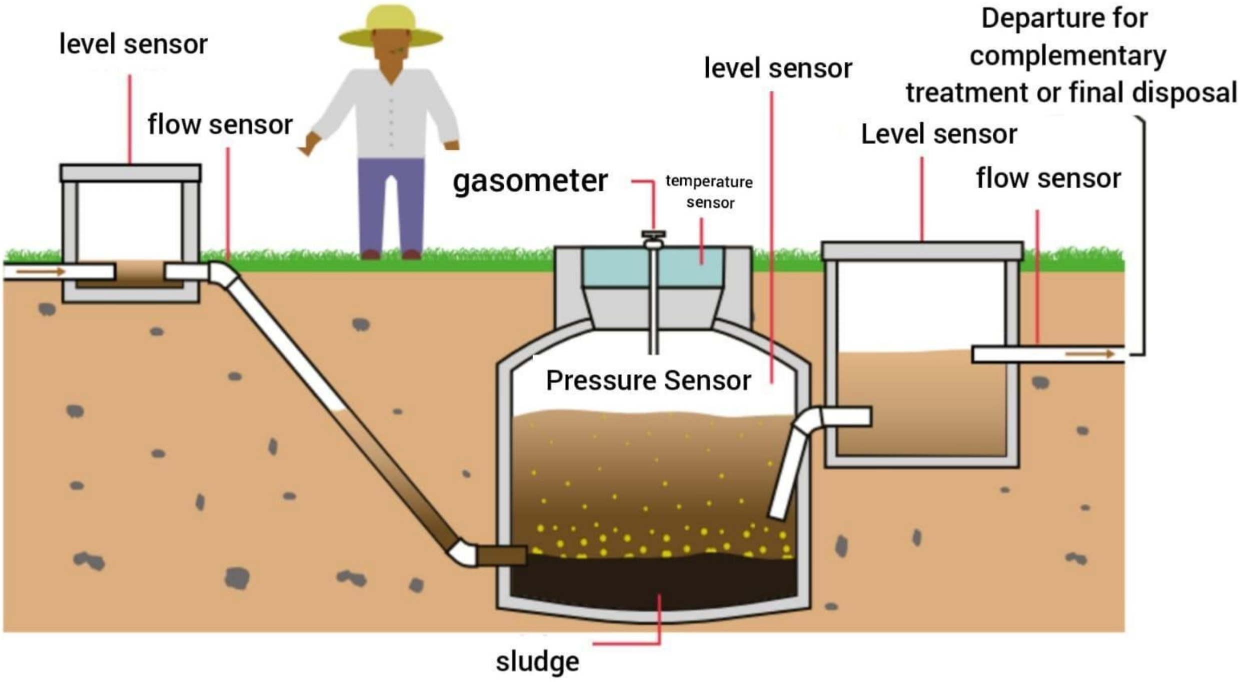
Source: Tonetti *et al*. (2018)

In the inlet box and compensation box, the monitored variable is the fluid level. In the inbox this level is controlled by the input and output volumes. In the compensation box, it varies according to the internal pressure of the biogas generation chamber, the higher the pressure, the higher the level in the box, until reaching the height of the outlet pipe, making the flow to the next stage of treatment . If there is an increase in the level, one of the causes may be the clogging of the pipes. Corrective intervention will be the unblocking of the clogged access and regularization of the flow. Predictive maintenance consists of checking, at a certain time interval, if the material level is within the upper and lower limits of the project.

In the biodigester chamber, the controlled variables will be pressure, temperature, flow and level, each with its degree of importance to the process. Periodic monitoring and proper maintenance guarantee the correct functioning of the set in the long term. The adequate pressure must be preserved for the good flow of the gas in the outlet piping, occurring at this stage the flow measurement by the installed equipment, and for the level to be stable as considered and suitable for the best operation. It is worth emphasizing the verification of the sealing of the entire biodigester, so that it can be guaranteed that there is no leakage of biogas. As well as making periodic checks on the amount of sludge produced inside the biodigester chamber, linking to this problem the implementation of preventive maintenance. For this, it is necessary to monitor the amount of waste supplied to the system and the amount of sludge produced, and based on such data, survey the equipment downtime so that the corrective action can be taken.

In view of the above, it is necessary to use predictive maintenance linked to planned corrective maintenance, which will take as a basis all the parameters captured by the sensors in order to decide the best time to carry out proper maintenance on the equipment that make up the biodigester. More directly, table 3 shows what was generated in the maintenance of BSI model biodigesters through a pilot project implemented in the city of Horizonte/CE.

Figure 5. Sensor layout scheme



Source: Tonetti et al. (2018)

Table 3. Survey of sensors

	Maintenance plan
Maintenance Interval	Maintenance must be done annually. If possible, in a non-rainy season.
Maintenance Strategy	In the case of this equipment, preventive, predictive and corrective maintenance can be performed. ● Preventive: Inspection of the gas collection box seal. ● Predictive: Through company C's mobile system measuring volume/level, temperature, flow and pressure. ● Corrective: At any time if any failure is verified, either by inspection by the beneficiary family or through data collected

	by the sensors.
Severity of Failures	In general, the detected failures are simple to resolve, with no recurrence and no severity.
Inspection Interval	● Preventive: fortnightly ● Predictive: in real time through the mobile app ● Corrective: if necessary
Maintenance staff	The maintenance of the Biodigestor model BSI is done first by the family where it is built and, if technical support is needed, company C is called. In company C, the team consists of 1 Environmental Engineer, 1 Agronomist, 1 IT Technician, 1 Control and Automation Engineering intern and 1 Mechanical Engineering intern. For correction services, the company has an outsourced team.

Source: Authors (2021)

4. CONCLUSION

Alternative renewable energy sources are accelerating and advances in this type of technology are motivated in all countries due to the severe consequences in relation to the environmental impacts produced by non-renewable energies such as oil, natural gas, mineral coal and nuclear fuels , due to the fight against global warming. Given this concern with non-renewable energies in relation to their environmental impacts caused and the growing demand for energy around the world, the great challenge over the years will be the production of more energy while emitting less greenhouse gases (AGUILAR et al., 2012; SANTOS, 2015).

Biomass, in turn, has presented itself in an increasingly interesting way, as the matter that would previously be production residue or even waste that is mostly untreated, such as, for example, human and animal waste, become input. for power generation. In addition, the use of biodigesters in rural areas promotes well-being for villages that previously would have their water table polluted due to rudimentary cesspits.

In order for biodigesters to perform their role satisfactorily, it is necessary to have periodicity in their maintenance. Having data for decision making is extremely important. In addition, knowing what to do with the analyzed data can even prevent accidents and prolonged equipment downtime.

In a society that is increasingly concerned about its natural resources and their use, it is important to know and apply technologies, such as biodigesters, which can serve as an alternative to what is being done. The impact that these devices can generate is linked to the environment, the technological and the social sphere. Because, rural families almost never have access to sewage treatment. Because of this, research and innovations in alternative energies and ways to keep them in full operation are necessary.

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