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The Pig Manure Anaerobic Digestion. A tubular biodigester characterization in the Ecuadorian Amazon.

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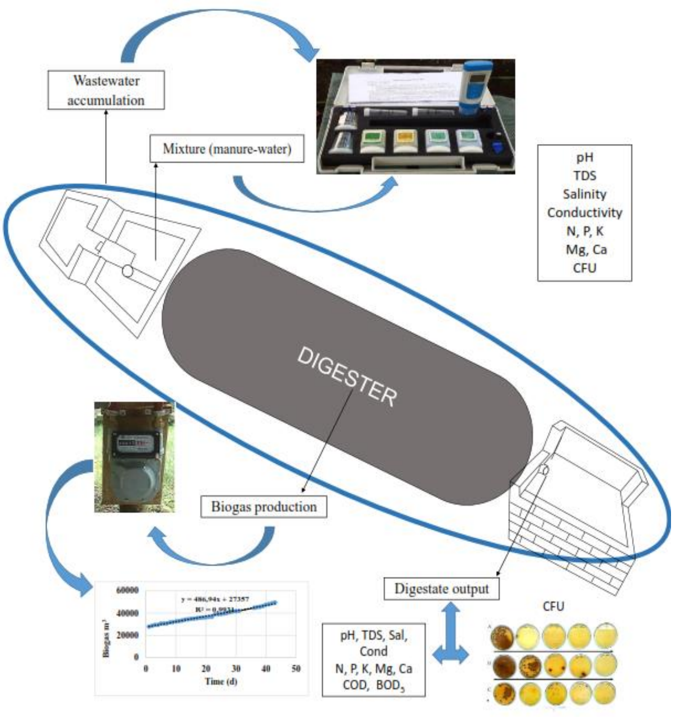
Graphical Abstract



Abstract.

The objective of the research was to characterize the anaerobic digestion process of a biodigester that works with pig manure in the Ecuadorian Amazon. The study was carried out for eight weeks in the Center for Research, Postgraduate and Conservation of the Amazon, belonging to the Universidad Estatal Amazónica. The research stages focused on the quantification of the substrates production present in porcine sections, physicochemical and microbiological parameters characterization of the anaerobic digestion process and operational parameters determination. 51.41 L per day of waste and water mixtures were generated, the physicochemical characteristics of the input mixtures (Wastewater process+ Manure) and output (Digestate + Biogas) were quantified and compared. The main results show that there is a decrease in organic loads during the anaerobic process, but even the values of nitrogen (N), phosphorus (P), potassium (K) and secondary nutrients are low compared with other similar studies. In conclusion, the application of anaerobic digestion practices and technologies can reduce the organic loads coming from anthropogenic activity residues but it is necessary to control the feeding and physicochemical parameters of the process so that the discharges comply with the maximum permissible limits for fresh water discharges and agricultural, according to environmental national regulations.

Keywords: Organic matter; nutrients; anaerobic digestion; contamination; digester; digestate; biogas.

Introduction

Given the relatively high loads of nutrients and pathogens, animal wastes such as pig manure, have been identified as a source of microbiological and chemical pollution, therefore, an optimal treatment is necessary to stabilize such wastes [1,2]. If not treated, several microorganisms and soluble organic compounds present in the manure, can diffuse through the soil contributing to the pollution of groundwater. Due to the production of greenhouse gases such as methane, hydrogen sulfide and carbon dioxide, untreated manure can also contribute to the global warming [3-5]

A technology usually applied to treat this type of wastes is anaerobic digestion (AD), a technology capable of producing energy (biogas) when used to treat wastes with high organic loads [6,7]. AD have been used since 40 years ago in the treatment of pig manure in Germany and it constitute a robust technology with a relative low footprint [8]. The biogas produced by AD processes is comprised mainly by methane and carbon dioxide, therefore it can be used as source of heat and energy [9,10]. If AD technology is correctly applied, it can produce biosolids (sludge with low pathogen content), capable to be used as fertilizer given its relatively high content of macro and micronutrients [11]. According to the available literature, the performance of the different AD processes (attached or suspended), can be affected mostly by temperature and pH, however, the health of the microbial communities and the operation conditions play central roles during the degradation of pollutants [5,12,13].

In order to improve the contact between the anaerobic microorganisms, a new AD approach based in a low–cost tubular reactor was designed and build up [14]. So, this short communication aims to describe the pollutant removal efficiency of the tubular reactor as well as to quantify the energy production that can be obtained from the system.

Materials and Methods

Area of study

The present study was carried out in the CIPCA, belonging to the Universidad Estatal Amazónica, located in the Province of Pastaza and Napo, Ecuadorian Amazon Region. It is located near to the Piatúa and Anzu rivers between 01º00’01”and 17º53’05” south latitude, with an altitude of 523 meters above sea level. The type of climate is tropical rainy and corresponds to a formation of Amazon rainforest, with rainfall throughout the year; average annual rainfall of 1092 mm and temperature of 24 °C.

Sampling and biodigester description

The tubular biodigester with a capacity of $11m^3$, was built of polyethylene geomembrane by the technical staff of the Catalan Organization “Energía sin fronteras”. Pig manure was collected daily from raising pigs, together with the residual waters of the CIPCA swine program. The feed was stirred manually for approximately 3 min before adding it to the biodigester. Sampling was done at three different points, 1) wastewater accumulation pond (WW), 2) manure + wastewater (MW), and 3) digestate outlet (O). the liquid and semi-solid samples (manure) were collected and homogenized, later they were transferred to the laboratory to determine the different parameters.

Physical-chemical and microbiological analysis of the anaerobic digestion process

The total solids (TS) determination was carried out using the gravimetric method (Standard Methods No. 2540 B. total dry solids at 103 - 105 ° C) [15]. 100 mL of the sample placed in the evaporation dish is heated to 320 °C to evaporate all the water, then take to the drying oven until the constant weight remains. The solids fraction was calculated by the difference of the initial weight. In the case of the volatile solids (VS) determination the gravimetric method was used (Standard Methods No. 2540 E. Fixed and volatile solids calcination at 550 °C). The sample was incinerated in the muffle at 550 ° C for 15 minutes. The volatile fraction was obtained by weight difference [15]. The measurement of pH and conductivity was made in the field in situ, for it was used the portable multi-parameter PC60 Premium Multi-Parameter Tester (pH/EC/TDS/Salinity/Temp) APERA INSTRUMENTS, LLC, calibrated and tested at the laboratory.

Determination of total and ammoniacal nitrogen. 1 g of sample was placed in digestion tube, then 20 ml of concentrated sulfuric acid and the Kjeldahl tablet were added at a temperature of 380 °C and digested for two hours. The tube was immersed in 35 ml of boric acid (2%) solution with three drops of Tashiro’s indicator. Then, 60 ml of sodium hydroxide (45.4%) was added and distilled for 10 minutes. Finally, it was titrated with 0.2 N sulfuric acid until it changed color from green to purple. It was calculated based on the mL of sulfuric acid spent in the titration (sample and control), the acid normality and the sample volume. The phosphorus (P), potassium (K), magnesium (Mg) and calcium (Ca) determinations were made in the DR 2800 spectrophotometer, based on the calibration standards, the verification was carried out and the corresponding measurements were made.

The Chemical Oxygen Demand (COD) determination (Standard Methods 5220-D Colorimetric Method Reflux Closed) [15]. 50 ml of sample was placed in a 500 ml reflux balloon, and 1 g of mercury sulfate (HgSO4) was added in agitation with 5.0 ml of sulfuric acid. It was mixed with 25 ml of 0.250 N potassium dichromate solution and placed under recirculation, then the remaining sulfuric acid (70 ml) was added through the end of the condenser and the measurement was made. In the meantime, Biological Oxygen Demand (BOD) Determination (Standard Methods 5210 B. 5-Day BOD Test), BOD5 was calculated from the difference between initial and final dissolved oxygen (DO) for 5 days [15].

Coliforms and Escherichia Coli Determination (Standard Methods 9221 B. Membrane Filtration) [15]. A solution of peptone water and criterion dehydrated culture media, sowing was performed in 9 ml tubes each. The growth of each colony was quantified, as CFU = # colonies x dilution/sample volume, for the T. coliforms and E. coli determination.

Results and Discussion

Manure Generation and biodigester feeding

The manure daily average of the study days was 6.66 kg from the gestation area and 3.56 kg in the pre-fattening area. This section is an important factor in the pigs feeding, which is based on balanced feed supplements plus fodder, twice a day. The daily load was made based on the excreta total amount produced combinated with the wastewater of raising pigs. It was mixed with a ratio of 4:1, (water-manure). In the case of water, it comes from the water used in the cleaning process carried out in the swine farms. From the substrates quantification it was possible to estimate the average capacity of 51 L of biomass that supports the bioreactor of 11.04 m^3.

Physical-chemical and microbiological characterization

All measurements were made at the three sampling points defined in the methodology. The pH measurement had a variation between 6.66 - 8.2, the digestate pH was totally neutral (7 - 7.02). These values are consistent with the literature, as mentioned by Pilarska *et* al. [16] pH affects the microorganisms growth, so, increasing pH would result in increased toxicity, with the optimal pH range for anaerobic digestion between 6.8 - 7.2. In the case of conductivity, the value was low, initially 4.6 mS/cm and reduced by 29%, at the process end with 3.32 mS/cm, which indicates that the bacteria are consuming the soluble compounds of the substrate. Table 1 shows other physicochemical and microbiological parameters of the biodigester.

Table 1 Results of the physical-chemical and microbiological characterization.

Parameter	WW	MW	O
Total Solids (mg/L)	506	28212	2450
Ash (mg/L)	319	22204	1860
Total volatile solids (mg/L)	187	6008	590
Phosphorus (ppm)	53	1275	290
Total Nitrogen Kjendahl (TKN) (ppm)	229.79	15051.13	373.42
Ammonia nitrogen (ppm)	57.44	287.27	201.07
Potassium (ppm)	0.00029	0.001322	0.000546
Magnesium (ppm)	0.0012	0.001172	0.000224
Calcium (ppm)	0.01248	0.00576	0.00123
COD (mg / L)	2161	7546	1982
BOD_5 (mg/L)	1113.61	2487.61	1082.11
Total coliforms	$2.2x10^5$	countless	$2.6x10^5$
E. Coli	$1.12x10^6$	countless	$8.2x10^5$

Environmental legislation regarding the discharge of wastewater in Ecuador is established under agreement No. 097-A [17]. This regulation establishes the permissible limits and prohibitions to discharge to the water bodies. When reviewing the values obtained and comparing the environmental regulations, the Mg, K, Ca and pH comply with the established range, the others exceed the permissible values. However, there is a considerable reduction between the input values of (Wastewater and Manure + Wastewater) and the digestate output parameters (it is possible to reduce the pollutant load by 28% of the material transformed), which indicates that the process influenced on nutrients mineralization and polluting loads reduction in the pig breeding process.

The biogas specific production was obtained through the data of the gas meter installed on the outside of the biodigester. The maximum/minimum values were 4.5 m^3 and 1.2 m^3 respectively. The production variation is associated to the feeding differences in the different days of study, because the digestate and the biogas production, are variables that depend directly on the quantity and characteristics of the residues that are fed to biodigestor (manure).

Conclusions

The biomass production in 43 days of study was 2211 L and feeding rate of 51.41 L/d approximately. This amount is adequate for the design capacity that is 11.04 m^3. The digester physicochemical parameters (pH, Conductivity, K, Mg, Ca) comply with the maximum permissible limits for fresh and agricultural water discharges, as established in the Ecuadorian regulations. However, (TS, N, P, COD, BOD5 and coliforms) are slightly deviated from the values recommended for discharges to the tributary due to the subtrates feed variability. It is suggested to use the digestate produced in agriculture to recover nutrients for crops and soil and to avoid the Amazonian water courses eutrophication.

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