

**DESIGN OF THE CONTROL AND MONITORING OF AN ANAEROBIC
BIOLOGICAL REACTOR IN UNIVERSITY OF PAMPLONA, COLOMBIA.****DISEÑO DEL CONTROL Y MONITOREO EN UN REACTOR ANEROBIO
EN LA UNIVERSIDAD DE PAMPLONA.**

**Ph.D. Aldo Pardo García, MSc. Julio Isaac Maldonado M,
Esp. Freddy Solano Ortega.**

Universidad de Pamplona.

Campus Universitario, Pamplona, Norte de Santander. Colombia

Tel: 57 975 685 303, Fax: 57 975 682 750

E-mail: {apardo13, jimaldonadom, fsolano}@unipamplona.edu.co

Abstract: This paper deals with the design of an anaerobic wastewater treatment plant in the University of Pamplona, using PLC, PC and SCADA systems by means of which the data acquisition, supervision and control is made, additionally the implementation of an didactic automated equipment for education of anaerobic wastewater treatment plants is shown.

Resumen: El trabajo trata sobre el diseño de planta piloto anaeróbica automatizada de tratamiento de agua residual de la Universidad de Pamplona utilizando la automatización industrial basado en autómatas - pc y un sistema mediante el cual se realiza la adquisición de datos, supervisión y control, además se construyó equipo didáctico automatizado para la enseñanza en tratamiento anaeróbico de agua residual.

Keywords: Process control, wastewater treatment, automata, supervisory control, bio control, reactor control.

1. INTRODUCCIÓN

BIOLOGICAL PROCESS DESCRIPTION IN THE ANAEROBIC TREATMENT

The anaerobic treatment is a biological process where anaerobic bacteria initially hydrolyze polymeric substrates present in wastewater and through the action of extra-cellular enzymes produced by fermentive bacteria break them into smaller composed monomeric substrates to be able to cross through the cellular membrane so that then they can be metabolized within the cell.

This is where approximately 80% is fermented in ethanol, in Volatile Fatty Acids (VFA) composed principally by acetate, propionate and butyrate acids plus hydrogen gas (H₂); and then, another group of bacteria denominated acid-genetic take the propionate and butyrate acids and transform them into acetate also.

This is then, together with H_2 , the organic compound used in the substrate of methanogenic bacteria and will then be transformed into methane, carbon dioxide and biomass.

The UASB (Up Anaerobic Sludge Blanket) is a reactor of up flow where the organic material on its way through the covering of sludge composed of a large population of anaerobic bacteria begins its biodegradation. The reactor is composed of three essential parts: a zone of digestion, a zone of sedimentation, and a separator of gas-solids-liquids, (GSL). These are integrated into one column where the primary sedimentation process, the bio-digestion of the sludge and the secondary sedimentation is done simultaneously as a primary and secondary treatment of residual waters achieving efficiency in the removal of organic material up to 82%; this is in comparison to traditional aerobic systems (sludge activated, lagoons, percolator filters, etc.). These have the efficiency of between 60% - 80% with respect to the initial concentration. However, the UASB reactor should have a complementary treatment to increment its efficiency to achieve the major authorized environmental requirements.

2. UASB REACTOR DESCRIPTION

The parts that make up the UASB reactor are the following: the homogenization tank is an independent accessory of the reactor where the neutralization of the pH factor is done in the wastewater to be treated; the feeding systems of the reactor are composed of two peristaltic electric pumps (EP1 and EP2) with constant precision and a variable flow that are impelled with the crude wastewater (Q_{RW}) as well as the recirculated outflow (Q_R) into the reactor and the principle tank is made up of the distributor system of the flow found in the lower part where the flow enters (Q_{INF}) and is distributed in a uniform way; the central part of the reactor is where the anaerobic sludge is deposited and the organic compounds are biodegraded; and in the superior part of the reactor the separator of the three phases (gas, solids and liquids) is found.

Also, the equipment for the measuring of methane employs the method of the "Mariotte's Bottle" (Jim F., 1987) where CO_2 is eliminated and converted

into carbonate to allow the biogas to pass through a filter of small sphere-shaped compounds of NaOH and/or through an alkaline solution with a concentration of 1.5% of NaOH; additionally, the H_2S is removed by passing it through a pyrite iron filter; the volume of methane is equal to the displaced volume of alkaline solution (Appendix: 5). This is automatically determined depend on the measure of atmospheric pressure, temperature and water vapor pressure. The reactor operation is the following: the crude wastewater arrive at the water treatment plant through gravity or pressure and enter into direct contact with two sensors. The first of these sensors determines the concentration of the Dissolved Oxygen (D.O.) which is toxic for the population of bacteria in concentration of more than 2.0 mg/l. The flow continues towards the homogenization tank where the second sensor is installed. This is in charge of controlling the pH in the crude wastewater. This parameter normally should oscillate in the range of 6.8 and 7.4; waters with different pH values should adjust themselves chemically.

The Organic Matter (**OM**) concentration in terms of Total Organic Carbon (**TOC**) is online an automatically determined at Homogenization tank output, convertible to **COD** (Chemical Oxygen Demand), magnitude greater than 5000 mg/l (Look H. P., 1987) induces the PLC to turn on the peristaltic electric pump EP2 and to recirculate the outflow, the one which must be mixed with the wastewater impelled by the peristaltic electric pump EP1, both conform the reactor inflow; in an opposite case (< 5000 COD mg/l) electric pump EP2 must remain off and the affluent of the reactor must only be neutralized crude wastewater which passes through the anaerobic reactor body where the material organic is removed in a biological way and it is there where it is strategically located the second sensor of pH and the one for the temperature. This last one is highly important for the survival of the anaerobic mesophilic bacteria, which need in order to be able to survive temperatures between 20 - 40°C, preferably 35°C. Changes of temperature in this interval can be tolerated, nevertheless it has been established that in this range the activity and the growth of the bacteria diminishes in a 50% by each 10°C of reduction below the 35 °C and temperatures over 42°C causes a fast deterioration of the bacteria (Frank Z., 1987).

The UASB reactor in its normal operation removes a high percentage of suspended solids (> 90%) and in the outflow and it generally presents low values of **Turbidity** (optical property of particles in suspension to disperse light rays emitted in a straight line and measured from a receiver located in a 90° angle with respect to the light source as a digital or analog signal, measured as Nephelometric Turbidity Units). The amount of sludge produced and stored in the reactor body depends on the characteristics of the wastewater to be treated, the produced sludge characteristics and the drained sludge volume in each purge; and its frequency of purge depends on the parameters of control which are the turbidity in the outflow or the time of operation of the reactor.

The biogas ($\text{CH}_4 + \text{CO}_2 + \text{H}_2\text{S} + \text{other gases}$) is emitted in the top part of the reactor and this can be used after treated or burnt. Being the methane production a control parameter this must be periodically measured. Finally the treated wastewater arrives at the load tank where it can be recirculated, and where the concentration of OM is determined in COT terms in an automatic way, being also convertible in mg COD/l, finishing in this way its treatment.

3. WASTEWATER CHARACTERISTICS

All wastewater to be treated or spilled on a receptor body must be characterized it means the organic and inorganic compounds present on it, must be known its biodegradability, its possible transformation by physical or chemical methods, its toxicity and its inability potential on the physiology of microorganisms. The organic compound concentration in wastewaters are generally measured in terms of the oxygen demand which is necessary for their stabilization or in terms of their carbon content; or using laboratory test such as the Biochemical Oxygen Demand (**BOD**), Chemical Oxygen Demand (**COD**), Total Organic Carbon (**TOC**) and the Total Oxygen Demand (**TOD**). The characterization of inorganic compounds must be done too and other laboratory tests that provide information on the content of the substances that require a special preliminary treatment, such as: Total Suspended Solids, Volatile Solids, Settleable Solids, pH, acidity, alkalinity, etc. Also the

concentration of nutrients like Phosphorus and Nitrogen in their different oxidation stages have to be evaluated and finally the presence and concentration of toxic compounds such as heavy metals and inhibiting compounds that interfere with the treatment have to be evaluated too.

4. UASB REACTOR AUTOMATIC OPERATION

This project was developed by the Research and Develop of Apply Technology Institute (IIDTA) and the Naturals Science and Biotechnology Institute and particularly by students of researching groups of the Electronic Engineering and Natural and Environment Resources Engineering in the University of Pamplona and its line of investigation on wastewater treatment, who collected, processed and evaluated the parameters of operation of the UASB reactor (**VOL**: Volumetric Organic Load), **HRT**: Hydraulic Residence Time, **temperature**, **pH**, **E**: System Efficiency, **Pg**: Methane Production, **VFA/Alkalinity**: relation between Volatile Fatty Acids and Total Alkalinity and **SMA**: Specific Methanogenic Activity of the sludge). All these are important parameters for the study of new and improved technologies, that will allow accelerate and optimize anaerobic processes in starting stages as well as operation stages.

The control parameters measured by the sensors and online equipments, they sent digital or analogue signals which are received by the PLC, according to a previous programming, compare, evaluate, and depends to the obtained results it executes actions through its outputs modules and in the supervision of the process use the Wonderware's InTouch. The OM concentration determination is realize online by a digital TOC meter, measuring the CO_2 from the incineration of the OM present in the sample problem or by means of the chemical oxidation, using the technique of catalytic combustion up to 680°C combined with a Non Dispersive InfraRed detection (NDIR), these data are correlated with COD inflow or COD outflow, by constants (K_1 and K_2) in simultaneous determinations. On the other hand, the valuations at laboratory level of the VFA/Alkalinity rate (Jenkins, S.R., 1983) and SMA (Jim F., 1987) of the sludge directly are introduced to the PLC like a digitized data.

The actions that the PLC executes are operative ones in real time, according to the evaluation of each parameter in their pre-established normal range.

4.1 Input data

$K_1 = 0.95$; $K_2 = 0.93$
 Volumetric Organic Load (VOL) = 6 g COD / L-day Range = $\pm 10\%$
 HRT = 24 hours Range = $\pm 10\%$
 pH = 7.0 Range = 6.8 – 7.4
 Temperature = 35 °C: Range = $\pm 5^\circ\text{C}$
 Dissolved Oxygen (D.O.) Maximum = 2.0 mg/l
 Turbidity: Maximum = 150 NUT
 Operating Time = 15 days
 Purge Time: EV4 = 3 min; EV5 = 3.5 min; EV6 = 4 min.
 Methane Production (Pg) = 350 ml / g COD
 Range = (-) 20%
 Efficiency (%): Minimum = 50% Maximum = 80%
 VFA /Alkalinity Minimum = 0.2; Maximum = 0.35
 SMA > 0.5
 Methane tank: $\Delta H = 0.30$ m; Superficial area = 0.25 m²

4.2 Evaluation and automatic actions

When the O.D sensor determines a value greater than 2.0 mg O₂/l concentrations it produces to the PLC the immediate order to suspend the Q_{RW} input to the reactor, and initiates its spilling by the bypass ordering to close electro-valve EV1 (On/Off) and to open electro-valve EV2 (On/Off), remaining in these positions both valves until the O.D. in the wastewater diminishes into a permissible range.

In anaerobic reactors the pH value can oscillate between 6.8 – 7.4 (Rojas O. CH., 1987); if the pH value (inflow or outflow) is outside this range, the PLC executes the process control ordering to open electro valve EV 3A (On/Off) or EV 3B (On/Off) in order to mix the crude wastewater with an acid solution (H₂SO₄) or alkaline (NaOH) in the Homogenization tank to the 1.5% until pH problem recovers its suitable range.

The adjustments of the VOL applied and/or of the HRT (Hydraulic Residence Time) were obtained by means of increase or reduce of the Q_{INF}. This action was obtained increasing or reducing the speed in the peristaltic pump EP1 (who impulse the crude wastewaters) and of the electric pump EP2 in case of outflow recirculation (>5000 COD_{RW} mg/l).

$$\text{VOL (kgCOD/day)} = Q_{\text{INF}} * \text{COD}_{\text{INF}} / \nabla_{\text{reactor}}; \text{TRH} = \nabla_{\text{reactor}} / Q_{\text{INF}};$$

$$Q_{\text{INF}} = Q_{\text{RW}} + Q_{\text{R}};$$

Q_{RW} = crude wastewater flow; Q_R = recirculated outflow

When **Temperature** sensor installed in the reactor body reports temperatures inferior to 30°C the PLC commands to open the electro-valve EV11 (On/Off) that allows the gas (that feed the heater on the reactor) flow, and in a simultaneous way the flame ignition is ordered, that will remains until the reactor acquires the temperature within the pre-established operation range.

If there is sludge loosening in the reactor appears an **Turbidity** increase in the outflow indicating the need to purge, the moment when the PLC commands to open the electro valve EV4 (On/Off) during a predetermined time to purge the sludge and later it is closed, an later in sequentially way the electro-valves EV5 (On/Off) and EV6 (On/Off) also makes the purge; recommending that the total volume of drained sludge be lower than 20% of the Total Volume of sludge in the reactor. Another control parameter of the sludge purge is the UASB operation time. The PLC orders the handling of the valves of sequential way when one of the parameters is registered first.

Methane Production Rate: is measured (after eliminating CO₂ and the H₂S of the biogas) in a designed container according to the Mariotte's Bottle principle (Appendix 5), and it is calculated like the relationship between the volume of produced methane and the required time to move the level of the alkaline solution to a ΔH height, registered by the levels sensors. In order to fit the methane production in reference conditions is register within the container the atmospheric pressure (digital barometer), the temperature (digital thermometer) and the steam water pressure (digital psychrometer). Alkaline solution

replacement in the Mariotte's Bottle: On time zero activated by the minimum level sensor and at the same time the electro-valve EV9 (On/Off) is closed, and the electro-valves EV7 (On/Off) and EV8 (On/Off) are opened, PLC takes its commands to facilitate the tank filling to atmospheric conditions. The maximum level sensor indicates to the PLC the moment at which the tank has been filled, commanding the closing of electro-valves EV7 and EV8 and opening of electro-valve EV9 and beginning of the methane production quantification that is finished when the minimum level sensor is activate.

When the methane production measured in reference conditions inferior to 350 ml/g COD (Jim F., 1987), it is indicated that the reactor has problems (toxic presence, adverse environmental conditions, substrate characteristics variation, etc.) that make to the PLC proceed according to the programmed, ordering a differential reduction (5% every time) of the EP1 speed during an equal time to the new HRT, which has to elapse before making a new evaluation of the methane production and according to its new production, according these the PLC will again reduce or increase EP1 speed in sequential way, until the CH₄ production stabilize within the pre-established range. Let us remember that when modifying the EP1 speed also modifies the Q_{INF} and therefore the applied VOL that can later be increased while the methane production increases.

The removal **Efficiency** in the OM ($E(\%) = [(K_1 \times \text{TOC}_{\text{INF}} - K_2 \times \text{TOC}_{\text{OUT}}) / (K_1 \times \text{TOC}_{\text{INF}}) * 100]$) is a parameter that allows quantify the biodegradation obtain by the microbiological population to the provided substrate, evaluating their activity under the operative conditions of the reactor, which during its starting step presents representative efficiency variations and that once obtains stable conditions it becomes normal in a percentage generally superior to 50%, which it is increased as the VOL is reduced. For this project the reactor obtains stable conditions when efficiency is greater than 50% with an oscillation no superior to 5%, registered in a continuous way during one week. In this project PLC only makes corrective actions once that the reactor obtains stable conditions, ordering the VOL reduction or the increase and modifying the flow through the differential variation on the speed in EP1.

When the reactor obtains the pre-established Maximum Efficiency (the input data are update) the PLC suspends VOL modifications.

Recirculation Control: The recommendation of (Look H. P., 1987) is adopted like control of operation in the peristaltic pump EP2, he established that when the concentration of O.M (COD_{RW}) in the crude wastewater is inferior to 5000 mg/l it is not necessary to recalculate the outflow, therefore EP2 must remain off, in opposite case the inflow will depend on a percentage with Q_{RW} (COD ≤ 5000 mg/l) that keeps correlation with the VOL. **VFA/Alkalinity Rate:** Is pre-indicator of the behavior of the microbiological activity in the reactor and its buffer capacity. When this relation is increased over 0.35 (Rojas O. CH., 1987) indicates a high VFA presence that cannot quickly be biodegraded and tends to acidify the reactor given the low buffer capacity. To solve this problem two mechanisms are used:

- a) If there is outflow recirculation the first command that the PLC orders it is to modify the recirculation flow, by means of a speed reduction in the EP2, diminishing the re-entrance of outflow acidity and a speed reduction in the EP1 to generate a reduction of the applied load.
- b) In case that VFA/Alkalinity rate is greater than 0.4 is required to neutralize the VFA and the PLC orders to incorporate to the reactor and low volume of a alkaline solution to help to the recovery of the buffer capacity of the reactor, getting alkalinize the crude wastewater by means of the immediate handling of electro-valve EV3B, that remains open until this relation is in the pre-established range.

During the starting stage of the reactor, the SMA is a parameter that allows knowing the quality the sludge that this forming in terms of the transforming capacity the organic matter into methane, so this value must increase in time, reaching values greater than 0.5 g COD - CH₄/g SSV-day.

When SMA of the sludge in the reactor registers a significant reduction an attended expert evaluation must be done to determine the cause of the diminution of the quality of sludge, to take actions from a temporal manual operation of the reactor, to even the PLC reprogramming.

5. SCADA DESIGN AND SIMULATION

For the animation of the anaerobic wastewater treatment pilot plant a SCADA system was used, in this case the InTouch version 7.1 of Wonderware Factory Suite. The InTouch allows both, the monitoring and control sensors and actuators to be according to the process. The SCADA poses tools for animation and communication, they facilitate online collection the of process data in the plant. The management unit includes a computer and its software SCADA, the InTouch, the PLC NAIS FP0-C10RS and the FP0-E8RS expansion. The data interchange between the PLC and InTouch was made with a communication driver FP_DDE developed by Wonderware, through the interface series RS232. The SCADA developed to run on Windows which allows control and supervision in real time, in such way the operator always has information at any moment he wishes, or through historical trends, data bases, e.g. The Tags are signals or variables defined by the designer, and they are used with the different types of Wizards and scripts in the InTouch software. The name of each Tag represents a single variable in the InTouch, which is internally handled by the program or by means of an access name. This access name also is defined in the DDE (Dynamic Data Exchange) server to communicate with the in and out signals of the PLC (PLC).

Front panel: A Graphical screen formed by the synoptic of the plant, on which the information of all the sensors and actuators communicated through the PLC is shown. From this screen we can access to others screens that form the visualization and control software.

Historical Trend: The measurement of the sensors appears in tendency graphs, in which the operator will be able to monitor the values, sent to the PLC by each sensor 24 hours a day, as well as the accurate measure made by the sensors. **Help:** The description of the abbreviations and variables used in the anaerobic process and in the software. A brief description of the automatic operation of the anaerobic wastewater pilot plant was made. And, it is also given the operation range of the process variables.

InTouch provides two types of trends objects: Real-time and Historical. Both trend objects can be configured to display graphical representations of

multiple tagname over time. Real-time trends allow us to chart up pH and temperature data values, and the Historical trends allow us to determine the process behavior in a climate like the one in Pamplona city, such data values were employed in the teaching of natural resources engineering.

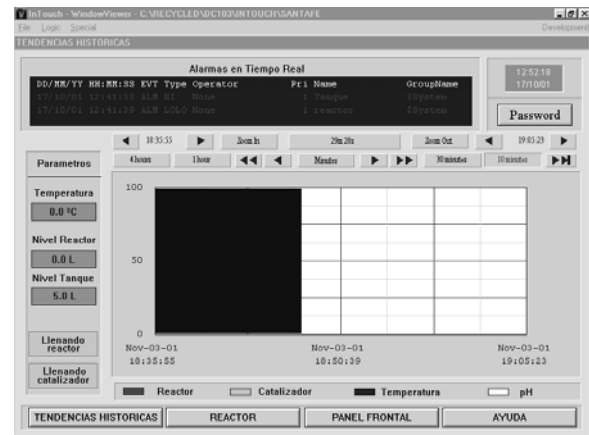


Fig. 1. General view of process system (Constructed didactic prototype).

5.1 UASB Reactor

This screen shows the reactor operations, the state of operation of the sensors (pH, temperature) and actuators (electric valves and pumps) and the conditions of the UASB reactor for correcting the process possible faults, using the actuators.

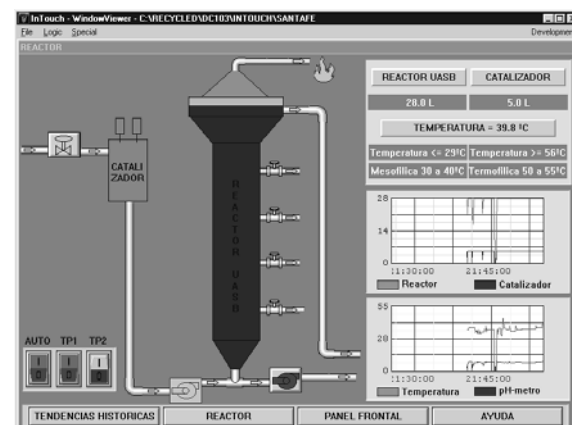


Fig. 2. SCADA control and supervision screen of the constructed didactic prototype

The programming was developed in FPSOFT software, of Matsushita Electric Works, Ltd (MEW). The FPSoft perform real time monitoring of all the program operations; this is ideal for debugging during the programming and the program execution.

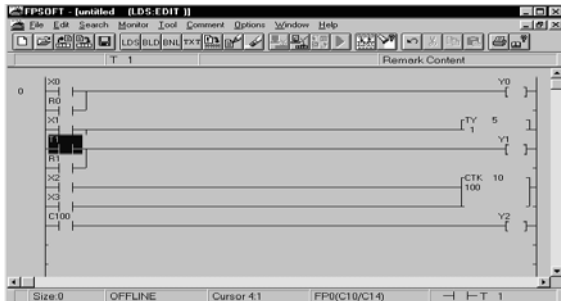


Fig. 3. Ladder diagram

Basically, the SCADA program creates a data base with the process variables (TAGS) and the driver is the one in charge to read and to write these data in the PLC. It is recommendable to use communication cards of the same PLC manufacturer to avoid communication problems. The protocol FP_DDE Server, version 2.02 developed by the Aromat Corporation were used in order to access to the communication between PLC and the SCADA.

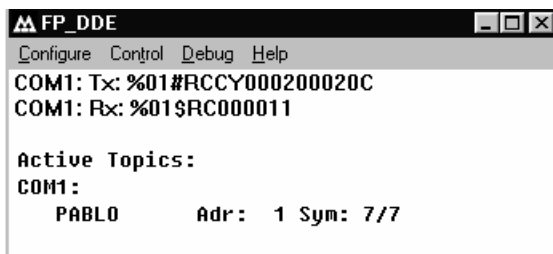


Fig. 4. FP_DDE communication drive visualization screen.

5.2 InTouch I/O Address

The DDE Protocol identifies a data item using a three term address. The DDE three term address are the Application name, the Topic name and the Item name. **Application name:** Identifies the InTouch runtime program that contains the data elements. **Topic name:** this is the word always used when reading/writing to a tagname in the InTouch data base. The user creates the names for the Aromat Fp and uses these names as the names of the topic in the DDE reference.

Item name: Is the actual tagname defined for the item in the InTouch tagname dictionary. For example, to access to data value in InTouch from Excl, a DDE remote reference formula would be entered in the cell into which the data value is to be written: =VIEW/TAGNAME/'ActualTagName'.

6. CONCLUSIONS

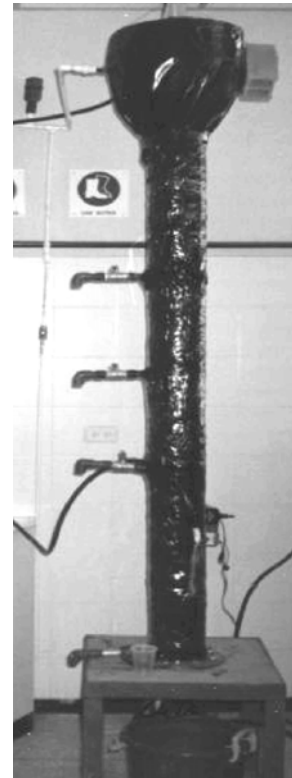
The integral design of a real UASB reactor control according to different parameters like pH, temperature, volumetric laid-down load, the methane production, Oxygen Chemical Demand, Volatiles acids greasy/alkalinity will be developed by the **Automation and Control**, and the **Natural Resources** investigation groups of our university. In the appendix is show the table 1, with the relations of the equipments and elements used in the scale model.

The implementation of the didactic prototype of a control and monitoring of an anaerobic biological reactor were used by the students of natural resources and electronic engineering of the UNIVERSITY OF PAMPLONA, with excellent educational results.

REFERENCES

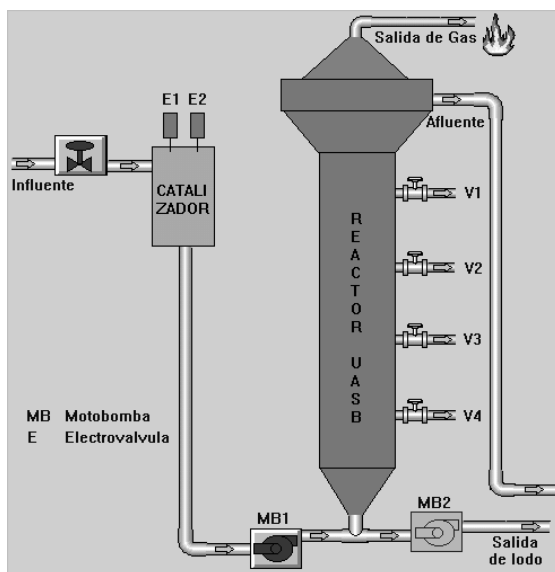
- Bates, Roger. (1973). *Determination of pH: Theory and Practice*, John Wiley and Sons, New York.
- Electrónica Industrial y Automatización*. Termocuplas. (2000). Revista N° 20. Cekt S.A., Colombia.
- Frank Z. (1987). Agricultural University, Wageningen, The Netherlands, Manual of the course: Starts up and Operation of systems UASB Microbiology. Pag. A-13 Cali, Colombia.
- Jenkins, S. R., Morgan, J. M., Sawhyer, C. (1983). Monitoring Anaerobic Sludge Digestion and Growth by a simple Alkalimetric Titration. In J.Wat. Poll.Cont.Fed., pg 55 May.
- Jim F. (1987). Agricultural University, Wageningen, The Netherlands, Manual of the course: Starts up and Operation of systems UASB. Measurement of parameters. Pag: C1-15. Cali, Colombia.

- Lettinga, G., otros. (1983). Anaerobic treatment of raw domestic sewage at ambient temperatures using a granular bed UASB reactor. En: *Biotechnology and bioengineering*.**25**:1701-23.
- Lettinga, G., otros. (1984). High rate anaerobic wastewater treatment using the UASB reactor under a wide range of temperature conditions. Wageningen, The Netherlands, /S.d./ 27 p.
- Lettinga, G., van Nelsen, A.F.M., Hobma, S.W., de Zeeuw, W. & Klapwijk, A. (1980). *Use of the upflow sludge blanket (UASB) reactor concept for biological wastewater treatment*.
- Look H. P. (1987). Agricultural University, Wageningen. The Netherlands. Manual of the course: Starts up and Operation of systems UASB. Pag E – 2. Cali - Colombia.
- Rojas O. CH. (1987). University of the Valle. Manual of the course Starts up and Operation of systems UASB. Relationship Volatile Fatty Acids - Alkalinity. Pag.D1-24, Cali, Colombia.
- Timothy J. Maloney . (1997). *Electrónica Industrial Moderna*. Tercera edición, Prentice Hall,, Mexico.
- Vallejo, H. D. (1999). *Saber Electrónica*. Controladores Lógicos Programables (PLC). N° 126. Editorial Televisa, Colombia.

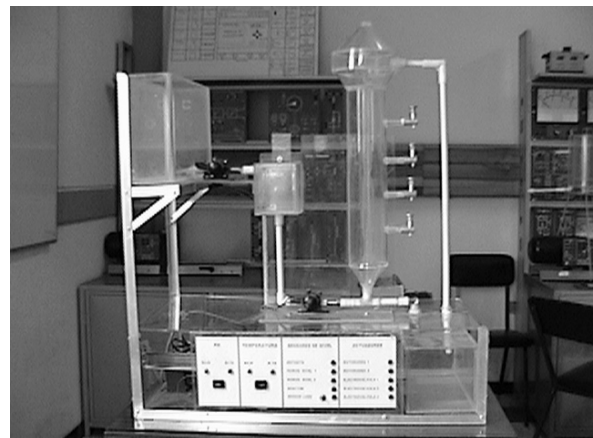


Appendix 2: Constructed didactic equipment in water treatment laboratory.

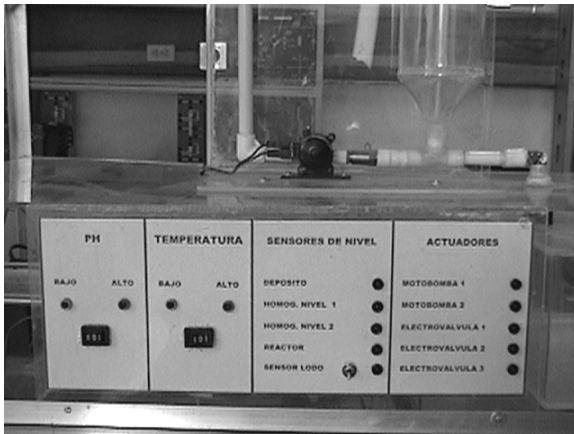
APPENDIXES



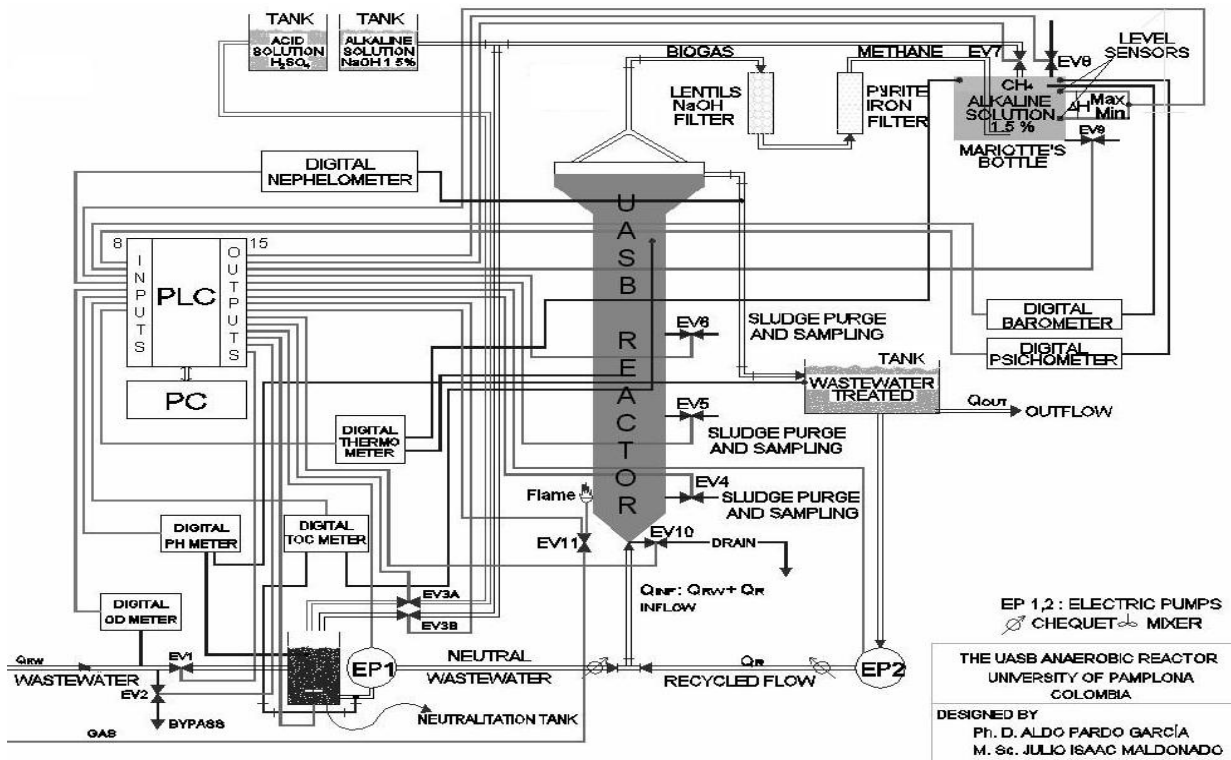
Appendix 1: SCADA control and supervision screen of the constructed didactic prototype.



Appendix 3: Constructed didactic prototype (scale model).



Appendix 4: Details of the constructed didactic prototype.



Appendix 5: Schematic design of the UASB Anaerobic Reactor

Table 1 Equipment and elements used in the scale model

Name	Characteristics
Reactor UASB	Constructed in acrylic. It has 4 outputs to sample from sludge and liquid. One (1) gases inverted cover.
FP0C10RS	Reduced size. Expandable. 2.7K for 32 I/O, 0.9 microseconds (ms) by program step. 1 ms for 500 instructions. 24 volts. Technical support. Economic.
FE0E8RS	4 inputs and 4 outputs, all digitals. 24 V.
IBM	Free serial port, CPU PIII, 700 MHz, 256 MB RAM Memory, 30 GB HDD, SVGA monitor.
INTOUCH	With 60000 variables. 2000 graphical objects, License, DDE, (In Control, I/O server, etc). Easy programming.
FP_DDE	Protocol FP_DDE Server version 2.02, Run on Microsoft Windows, developed by Aromat Co. Easy programming.
FPSOFT	Real and graphical operators. Programming in: Ladder or Boolean mode. It is possible to program digital variables, registries, comparisons, signals, etc. Real time monitoring.
Electric valve	127V-50/60Hz. Water pressure range of 0.2 to 8.5 bars. Easy manipulation.
Electric pump	24 -Volt Electric Pump, 2 A.
pH sensor	SCOTT HANDYLAB. Between 0 – 14, Resolution 0.01, Precision 0.02.
Thermocouple (K type)	Imax =10 mA. Linear between 0° and 1200°C. Adjustable Gain Factor between 24 and 250. Bipolar feeding of $\pm 15V$, 20 mA. Thermocouple material of chromium-aluminum. Sensitivity of 40.6 V/°C. Temperature Range of -270 to 1200 °C.
Thermocouple signal amplifier	Under current consumption: Voltage range (4 to 36 V), thermocouples type E, J, K, R and T compatibility, maximum deviation of 0.5°C.