Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

UNIVERSIDAD DE CIENCIAS APLICADAS Y AMBIENTALES
U.D.C.A

WORK EXPERIENCE WITHIN MASTER PROGRAM

IN ENVIRONMENTAL SCIENCES

Social Experience Report, D-UWIS,

Biogeochemistry and Pollutant Dynamics

Duration:	1st of September until 5th of December 2014
Employer:	Universidad de Ciencias Aplicadas y Ambientales (UDCA) Campus Universitario Cll. 222 No. 55 - 37. Bogotá, Cundinamarca Tel. (57 1) 668 47 00
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1 Introduction

"Steigst du nicht auf die Berge, so siehst du auch nicht in die Ferne." (Fern-östliches Sprichwort)

To do an internship abroad needs a lot of self-initiative, effort and patience. Although there are institutes that try to facilitate and help you with the process, you encounter tiresome paperwork and exchange of letters to get all permissions. However, it is totally worth it if you take into account the valuable experiences you are going to gain.

1.1 How I found my internship placement

Traveling several months in Latin America in 2013 made me fell in love with the beautiful nature, culture and friendly people there. My goal therefore was to find an internship in this region so that I could obtain not only an impression as a tourist but also from the perspective of a person that is part of the everyday life and work situation. I had various applications running in parallel but finally I was given the opportunity by the institute of IAESTE (www.iaeste.ch) to do this internship in Bogotá. Once signed up on the dateabase on the homepage one has the chance to apply for a wide range of internships abroad. In my case I was actually asked directly by an employee of IAESTE because another student decided not to accept this particular internship in the fields of environmental sciences.

1.2 Employer: Universidad de Ciencias Aplicadas y Ambientales

The University of Applied and Environmental Sciences U.D.C.A. (www.udca.edu.co), under the Ministry of National Education of Colombia is located in Bogotá, which is Colombia's capital. The U.D.C.A. is a private, independent institution of higher education with pluralistic and democratic inspiration. Its mission is based on constitutional principles and legislation on higher education to develop teaching, research and extension in terms of training professionals integrated with social and environmental commitment, leadership capacity and high civic values in those fields of action that contribute to a fair and equitable development of disadvantaged groups in the country.

The U.D.C.A. develops academic excellence through the generation and dissemination of knowledge, respect for human rights, constitutional duties and sustainable human development in aid of Colombian society. The university has 3 locations: campus „Norte“ is located at Calle 222 No. 55 – 37, campus of Finance and Economics located in „Teusaquillo“ and „Calle 72“ which is located in Chapinero.

History

The university began as Corporation School of Veterinary Medicine and Animal Science in 1978, then went on to become University Corporation for Agricultural Sciences – C.U.D.C.A. in 1983. Since 1985 it expanded its range of programs and in 1989 the first classes were hold on the campus. In 1992 the career in inagricultural engineering, in 1993 Sport Sciences, and in 1994 Commercialization Sciences were implemented. In 1995 it changed its name to the University Corporation for Applied Sciences and Environmental (U.D.C.A.). Afterwards the institution continued to grow by launching programs in medicine, nursing and geographical engineering. The university also started to offer post-graduate training in the areas of veterinary medicine, animal husbandry.

Furthermore at the campus „Teusaquillo“ programs offered Economics, Accounting, Business Administration, International Business, Marketing and Finance and Law.

In 2004 the U.D.C.A. was recognized as a university, and the name University of Applied Sciences and Environmental U.D.C.A. was approved in 2005.

Mission

The U.D.C.A. University is a private, independent, pluralistic, democratic, underpinning its institutional work in recognizing the rules which govern it. The university performs the functions of teaching, research and outreach, forming integral professionals in different areas of knowledge, people with high civic values; contributing to fair and equitable development of all members of Colombian society.

The U.D.C.A. is continuing its commitment pursuit of academic excellence, through the transmission, generation, transfer and application of knowledge for sustainable human development at the local, regional, national and international scale.

Vision

The U.D.C.A. will be recognized at the national and international context as a university distinguished by its academic excellence and commitment to social responsibility in the service of sustainable human development.

1.3 Responsibilities

I show the following diagram because during my time at the U.D.C.A. I worked under the responsibilities of different persons which made things not only complicated but at times also confusing and inefficient. The first month I worked under the responsibilities of Marco Tulio, the dean of the faculty of environmental sciences. As he had no time for me to specify my work nor to clarify my tasks he sent me to Claudia Uribe, the coordinator of the environmental management and services. There no one actually knew what to do with me so at the end of September I asked to change my tutor from Marco Tulio to Mauricio Romero (the coordinator of environmental quality), who worked in the same office (SIGA-Sede Oriental - "Sistema Integrado de Gestión Ambiental") as I did. He not only devoted time to me but also had ideas for other projects later on. However we waited until the 8th of October until Marco Tulio finally confirmed the change of responsibilities. During the wait I was technically obliged to work for the dean, which was a waste of time as he had no concrete tasks for me.

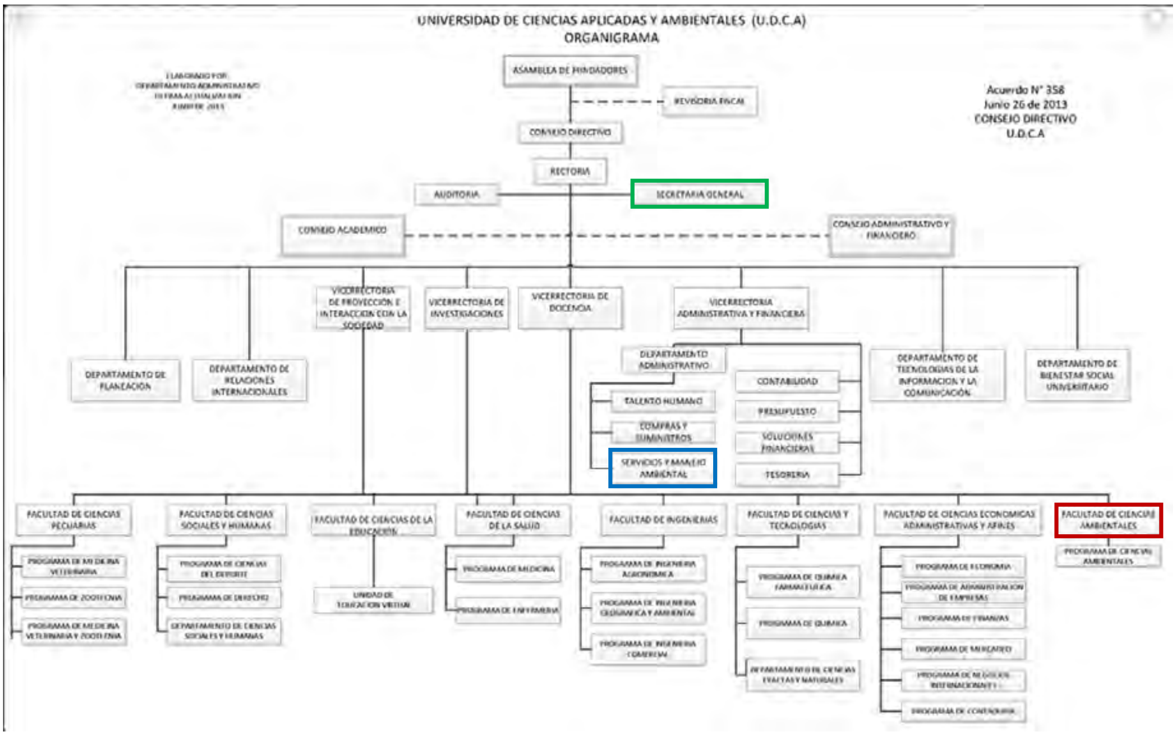


Figure 1: Organigram of the U.D.C.A.

2 Work and project description

The exact topic of my internship was not clear until the first weeks working there. In the original form of the IASTE following description was listed:

IAESTE Colombia

WORK OFFER Ref. No. CO-2014-UDC046

Employer Information

Employer:		*Website:*	http://
Uni. de Ciencias Aplicadas y Ambientales UDCA		*Location of placement:*	Bogotá
		Number of employees:	600
		Working hours per week:	40
Business or products:	Education and Research	*Number of working days per week:*	

Student Required

Field of Studies:		*Study Level:*	
Other		Middle	
Specialization:		*Language required:*	
Public Health,		English	good or
Environmental Development / Environmental Health		English	fair

Other requirements:
Knowledge in Ecosistems, sustainable development, and environmental management.

Work Offered

Work description:
The student must join and participate with research process and get involved with some communitarian projects in two localities: Barrios Unidos and Suba (placed in Bogota), with the main objective to improve and approach the University – government relations through town halls , according to Enviromental health program of the Medicine faculty.

Figure 2: Original form of the work offer by the IAESTE institution

Obviously this description is totally vague and I didn´t know exactly what exactly I had to expect. A few days before arriving in Bogotá I was sent a working plan that looked like this:

No.	ACTIVIDAD	Progreso %											Septiembre				Octubre				Noviembre			
		10	20	30	40	50	60	70	80	90	100	PARAMETROS	1	2	3	4	1	2	3	4	1	2	3	4
1	Revisiòn de documentacion, auditorias ambientales, agendas y actas											Programado												
												Realizado												
2	Elaboración de Cronograma de Actividades - Gestión de Residuos Solidos con énfasis en orgánicos putrescibles											Programado												
												Realizado												
3	Visita al Remanso analisis de procesos que se llevan a cabo allí relacionado directamente con el manejo y disposición de los Residuos Sólidos con potencialidad de recuperación energética.											Programado												
												Realizado												
4	Evaluación, medición y consolidación de información de cantidad y potencialidad de recuperación de energía a partir de residuos orgánicos en la UDCA											Programado												
												Realizado												
5	Proponer alternativas de manejo y aprovechamiento de algunas actividades que se realizan en el Remanso que se pueda llevar a cabo con la disposición de los residuos sólidos ORGÁNICOS Y CONVENCIONALES, DISEÑO DE PROTOTIPO DE BIOREACTOR ANAERÓBICO											Programado												
												Realizado												
6	Costeo de prototipo de bioreactor anaeróbico para Residuos Sólidos putrescibles de origen orgánico para la UDCA.											Programado												
												Realizado												
7	Registro de observaciones obtenidas y de experiencias colombianas de tecnología apropiada para recuperación energética a partir de residuos.											Programado												
												Realizado												
8	Revisión y/o elaboración de Formato de caracterización de residuos orgánicos											Programado												
												Realizado												
9	Registro de observaciones obtenidas - Ruta de Residuos Solidos Reciclables.											Programado												
												Realizado												
10	Apoyo para optimización de gestión y manejo de residuos orgánicos en la UDCA											Programado												
												Realizado												
11	Programación de caracterización de residuos solidos - orgánicos											Programado												
												Realizado												
12	Proyecto manejo residuos orgánicos -											Programado												
												Realizado												
13	Entrega de acta - Reunion de evaluación de caracterización de Residuos Sólidos - registro fotográfico											Programado												
												Realizado												
14	Ruta de Residuos Peligrosos - Electronicos											Programado												
												Realizado												
15	Entrega total resgistro de rutas de residuos solidos ORGÁNICOS de la U.D.C.A											Programado												
												Realizado												

DIRECTOR ACADEMICO DEL TRABAJO: MSc. MARCO TULIO ESPINOSA, DECANO FACULTAD DE CIENCIAS AMBIENTALES U.D.C.A, LIDER GRUPO RED RESIDUOS/RECURSOS

Figure 3: Original working plan received a few days before arriving

Finally I had a rough idea of how my following months are going to look like. Apparently they hired me to do the stocktacking and characterisation of the residues within the university and to design a prototype of an anaerobic bioreactor which uses part of the organic waste. As this field was new to me (especially the engineering part) I had to do a lot of research during the first weeks not only to understand the process that take place but also to get an idea how to construct such a system at minimum costs and with as few aterals as possible. The informations gathered are listed in the following chapter.

2.1 Theoretical background

As my main goal was the design of a an anaerobic bioreactor prototype I had to know not only the biochemistry of the processes that take place but also the construction of different types of biodigesters and possible configurations and adjustments.

2.1.1 Anaerobic digestion

Anaerobic digestion is a collection of processes by which microorganisms break down biodegradable material in the absence of oxygen (Guyer & Zehnder, 1983). Anaerobic digestion occurs naturally in soils and in lake and ocean sediments (Koyama 1963). This is the source of marsh gas methane as discovered by Volta in 1776 (MacGregor & Keeney, 1973).

Nowadays anaerobic digestion is widely used as a source of renewable energy. The process produces a biogas, consisting of methane, carbon dioxide and traces of other ‘contaminant’ gases (Guyer & Zehnder, 1983). This biogas can be used directly as fuel, or upgraded to natural gas-quality biomethane. The byproduct, a nutrient-rich digestate, can be used as fertilizer.

2.1.1.1 Processes

There are four key biological and chemical stages of anaerobic digestion (Amaya et al., 2013):

1. Hydrolysis
2. Acidogenesis
3. Acetogenesis
4. Methanogenesis

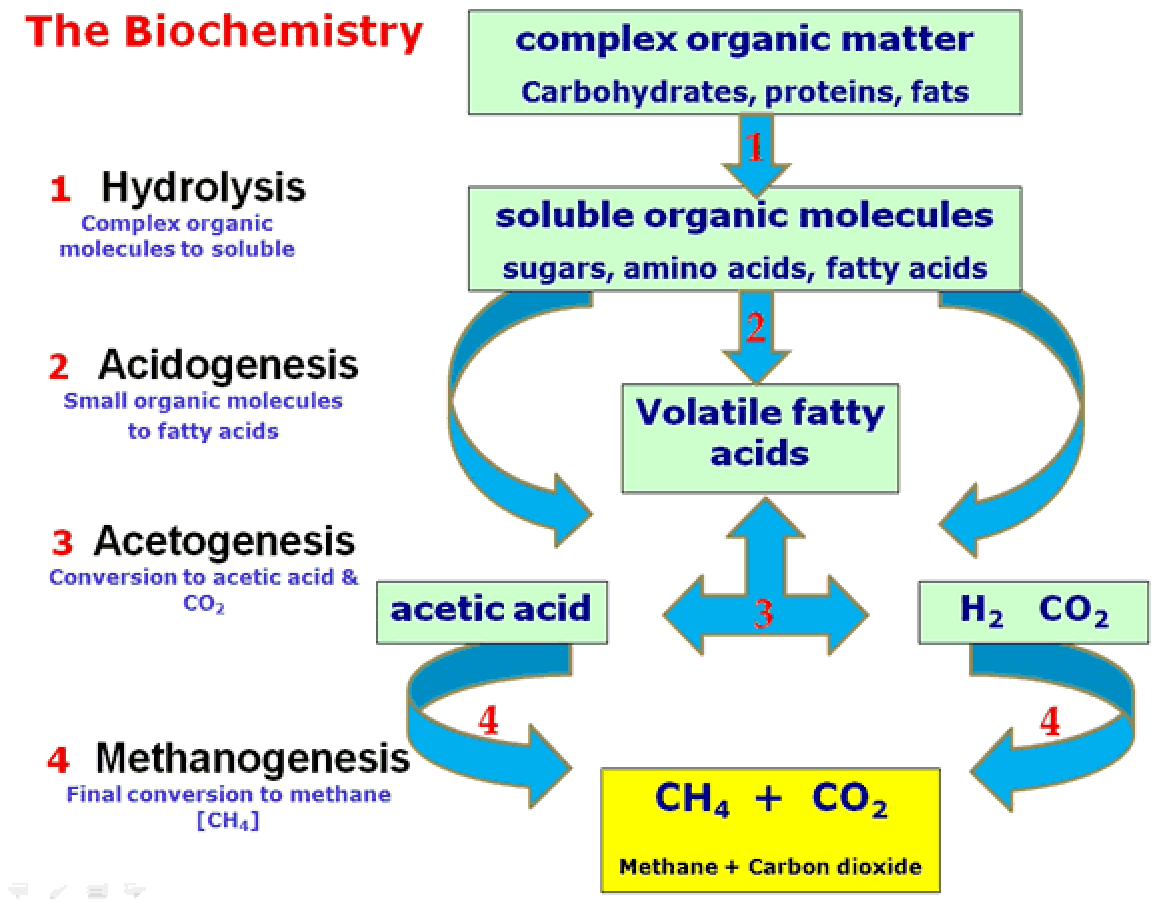


Figure 4: Key process stages of anaerobic digestion (Amaya et la., 2013).

In most cases, biomass is made up of large organic polymers. For the bacteria in anaerobic digesters to access the energy potential of the material, these chains must first be broken down into their smaller constituent parts. These constituent parts, or monomers, such as sugars, are readily available to other bacteria. The process of breaking these chains and dissolving the smaller molecules into solution is called hydrolysis (see step 1 in figure 4). Therefore, hydrolysis of these high-molecular-weight polymeric components is the necessary first step in anaerobic digestion (Lettinga, 1995; Nallathambi, 1997). Through hydrolysis the complex organic molecules are broken down into simple sugars, amino acids, and fatty acids.

Acetate and hydrogen produced in the first stages can be used directly by methanogens. Other molecules, such as volatile fatty acids (VFAs) with a chain length greater than that of acetate must first be catabolised into compounds that can be directly used by methanogens (Lettinga, 1995).

The biological process of acidogenesis results in further breakdown of the remaining components by acidogenic (fermentative) bacteria. Here, VFAs are created (see step 2 in figure 4) along with ammonia, carbon dioxide, and hydrogen sulfide, as well as other byproducts (Lettinga, 1995).

The third stage of anaerobic digestion is acetogenesis. Here, simple molecules created through the acidogenesis phase are further digested by acetogens to produce largely acetic acid, as well as carbon dioxide and hydrogen (see step 3 in figure 4; Lettinga, 1995).

The terminal stage of anaerobic digestion is the biological process of methanogenesis. Here, methanogens use the intermediate products of the preceding stages and convert them into methane, carbon dioxide, and water (see step 4 in figure 4; Martin, 2010). These components make up the majority of the biogas emitted from the system. Methanogenesis is sensitive to both high and low pH values and occurs between pH 6.5 and pH 8 (Amaya et la., 2013)

The remaining, indigestible material the microbes cannot use and any dead bacterial remains constitute the digestate.

A simplified generic chemical equation for the overall processes outlined above is as follows:

$$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$$

Methane gas production in fermentation

Acetic acid can also undergo a dismutation reaction to produce methane and carbon dioxide (Nallathambi, 1997). Namely the acetoclastic methanogenesis:

$$CH_3COO^- + H^+ \rightarrow CH_4 + CO_2 \qquad \Delta G° = -36 \text{ kJ/reaction}$$

This disproportionation reaction is catalysed by methanogen archaea in their fermentative metabolism. One electron is transferred from the carbonyl function (e–donor) of the carboxylic group to the methyl group (e– acceptor) of acetic acid to respectively produce CO_2 and methane gas (Nallathambi, 1997).

2.1.1.2 Configuration and adjustments

Anaerobic digesters can be designed and engineered to operate using a number of different process configurations:

- Batch or continuous
- Temperature: Mesophilic or thermophilic
- Solids content: High solids or low solids
- Residence time

Batch or continuous

Anaerobic digestion can be performed as a batch process or a continuous process.

In a batch system, biomass is added to the reactor at the start of the process. The reactor is then sealed for the duration of the process. In its simplest form batch processing needs inoculation with already processed material to start the anaerobic digestion (Amaya et al., 2013). In a typical scenario, biogas will be formed with a normal distribution pattern over time. Operators can use this fact to determine when they believe the process of digestion of the organic matter has been completed.

As the batch digestion is simple and requires less equipment and lower levels of design work, it is typically the cheaper setup (Nallathambi, 1997). Using more than one batch reactor at a plant can ensure constant production of biogas.

In continuous digestion processes, organic matter is constantly added (continuous complete mixed) or added in stages to the reactor (continuous plug flow; first in – first out). Here, the end products are constantly or periodically removed, resulting in constant production of biogas (Nallathambi, 1997).

Temperature

The two conventional operational temperature levels for anaerobic digesters determine the species of methanogens in the digesters (Song et al., 2004).

- Mesophilic digestion takes place optimally around 30 to 38 °C, or at ambient temperatures between 20 and 45 °C, where mesophiles are the primary microorganism present.
- Thermophilic digestion takes place optimally around 49 to 57 °C, or at elevated temperatures of up to 70 °C, where thermophiles are the primary microorganisms present.

A limit has been reached in Bolivia, with anaerobic digestion in temperature working conditions of less than 10 °C. However the anaerobic process is very slow, taking more than three times the normal mesophilic time process (Herrero, 2007).

Mesophilic species outnumber thermophiles, and they are also more tolerant to changes in environmental conditions than thermophiles. Mesophilic systems are, therefore, considered to be more stable than thermophilic digestion systems.

In contrast, while thermophilic digestion systems are considered less stable, their energy input is higher, with more biogas being removed from the organic matter in an equal amount of time. The increased temperatures increase reaction rates, and thus faster gas yields. Operation at higher temperatures facilitates greater pathogen reduction of the digestate (Song et al., 2004).

Solids content

The mixture ratio between water and solid content can vary a lot resulting in different substrates (high solid content → dry, stackable substrate; low solid content → wet, pumpable substrate). Depending on the system chosen (batch or continuous) the mixture ratios are somehow predefined. Using a continuous system for example without any pumping system does not allow one to use a high solid content as the substrate might be too thick to pass the digester continuously.

Residence time

The residence time in a digester varies with the amount and type of feed material and the configuration of the digestion system. In a monitored batch system it can be easily found out empirically. In a continuous system, however, a similar experimental setup has to be found in the literature to get an estimate of the retention time and consequently an idea of the volume of the daily load.

2.1.1.3 Substrate

The most important issue that needs to be initially addressed when setting up an anaerobic digestion system is the feedstock to the process. Almost any organic material can be processed with anaerobic digestion (Nallathambi, 1997). However, if biogas production is the aim, the level of putrescibility is the key factor in its successful application (Yadvika et al., 2004). The more digestible the material, the higher the gas yields possible from the system.

Feedstocks can include biodegradable waste materials, such as waste paper, grass clippings, leftover food, sewage, and animal waste (Nallathambi, 1997). The length of time required for anaerobic digestion depends on the chemical complexity of the material. Material rich in easily digestible sugars breaks down quickly where as intact lignocellulosic material rich in cellulose and hemicellulose polymers can take much longer to break down. Anaerobic microorganisms are generally unable to break down lignin, the recalcitrant aromatic component of higher plant biomass (Benner, 1989)

Another key consideration is the carbon to nitrogen ratio of the input material. This ratio is the balance of food a microbe requires to grow; the optimal C:N ratio is 20–30:1. Excess N can lead to ammonia inhibition of digestion (Richards et al., 1991).

2.1.1.4 Potential inhibition

The anaerobic digestion process can be inhibited by several compounds, affecting one or-more of the bacterial groups responsible for the different organic matter degradation steps. The degree of the inhibition depends, among other factors, on the concentration of the inhibitor in the digester. Potential inhibitors are ammonia, sulfide, light metal ions (Na, K, Mg, Ca, Al), heavy metals, and some organics (chlorophenols, halogenated aliphatics, N-substituted aromatics, long chain fatty acids), etc. (Chen et al., 2008).

2.1.1.5 Benefits of anaerobic digestion

Biogas

Matter	%
Methane, CH_4	50–75
Carbon dioxide, CO_2	25–50
Nitrogen, N_2	0–10
Hydrogen, H_2	0–1
Hydrogen sulfide, H_2S	0–3
Oxygen, O_2	0–2

Figure 5: Typical composition of biogas (Weiland, 2010).

The methane in biogas can be burned to produce both heat and electricity. In general biogas is combustible and can be used as cooking gas. Excess electricity can be sold to suppliers or put into the local grid. Electricity produced by anaerobic digesters is considered to be renewable energy. Biogas does not contribute to increasing atmospheric carbon dioxide concentrations because the gas is not released directly into the atmosphere and the carbon dioxide comes from an organic source with a short carbon cycle (Weiland, 2010).

Biogas may require treatment or 'scrubbing' to refine it for use as a fuel (Yadvika et al., 2004).

Digestate

Another product of anaerobic digestions is a liquid (methanogenic digestate) rich in nutrients, which can be used as a fertiliser, depending on the quality of the material being digested (Holm-Nielsen et al., 2009). Digester liquor can be used as a fertiliser to supply vital nutrients to soils instead of chemical fertilisers that require large amounts of energy to produce and transport. The use of manufactured fertilisers is, therefore, more carbon-intensive than the use of anaerobic digester liquor fertiliser. Levels of potentially toxic elements (PTEs) should be analytically determined. The levels will depend on the quality of the original feedstock. In the case of most clean and source-separated biodegradable waste streams, the levels of PTEs will be low. In the case of wastes originating from industry, the levels of PTEs may be higher and will need to be taken into consideration when determining a suitable end use for the material (Holm-Nielsen et al., 2009).

Waste treatment

Anaerobic digestion is particularly suited to organic material, and can be used for effluent and sewage treatment (Holm-Nielsen et al., 2009). However the quality of the liquid fertilizer byproduct may suffer from a substrate switch from manure or kitchen waste to sludge.

2.2 Situation at the U.D.C.A.

As one of the first tasks I made an inventory of all the organic waste that is produced at the campus of the U.D.C.A. The university's faculty of veterinary medicine treats a lot of animals. That is why some parts of the campus have the appearance of a zoo. These animals are responsible for the large fraction of organic waste. The data given in the following table are estimates based on the experience of the persons reliable for each specific part of the university.

Source	**Quantity**	
	Kg/day	**%**
Green space	7	1,1
Individual organic residues (e.g. fruits)	5	0,8
Sports field	25	4,1
Gardens / "Remanso"	10	1,6
Pigs	15	2,5
Rabbits	10	1,6
Dogs	8	1,3
Horses	240	39,3
Cows	250	41,0
Kitchen waste	40	6,6
Total	610	100,0

Figure 6: Quantity of daily produced organic waste from different sources at the U.D.C.A.

Currently the majority of the organic waste gets dumped to various landfill-like compost heaps. There it rots for several months to be finally used as humus for gardening purposes on the campus. As the production of humus exceeds the demand by far the piles are growing larger. As the dung of horses and cows account for 80% of the input of the total organic waste the focus was on reducing this amount by digesting parts of it anaerobically and gaining biogas thereby.

2.3 Projects planned

Working together with Mauricio Romero we first revised the working plan and finally worked out some projects at the end of September:

No.	ACTIVIDAD	Aktivitäten	PARAMETROS	Septiembre				Octubre				Noviembre			
				1	2	3	4	1	2	3	4	1	2	3	4
1	Dirección por el campus/ Asignación del escritorio / Conocer las diversas áreas de responsabilidades y sus representantes	Führung durch den Campus / Schreibtischzuordnung / Kennenlernen der verschiedenen Zuständigkeitsbereiche und deren Vertreter	Programado												
			Realizado	✓											
2	Acompañar la ruta de recolección de residuos orgánicos / distinguir y determinar fuentes	Begleiten der Sammelroute von organischen Abfällen/ Quellen ausmachen und bestimmen	Programado												
			Realizado	(✓)											
3	Buscar prototipos adecuados / viables de biorreactores anaeróbicos (investigaciónes en el web)	Recherche nach geeigneten/realisierbaren Prototypen von anaeroben Bioreaktoren	Programado												
			Realizado		✓										
4	Elaboración de Cronograma de Actividades	Ausarbeiten des Zeitplans der Aktivitäten	Programado												
			Realizado		✓										
5	Propuesta de diseño de dos prototipos de biorreactores anaeróbicos (2 proyectos)	Vorschlag für Design zweier Prototypen für anaerobe Bioreaktoren (2 Projekte)	Programado												
			Realizado		(✓)										
6	Definir la configuración experimental exacta / Definición de los objetivos	Festlegung des genauen Versuchsaufbaus/ Festlegung der Ziele	Programado												
			Realizado		(✓)										
7	Lista detallada de todos los materiales necesarios para los dos proyectos	Detaillierte Auflistung aller benötigten Materialien beider Projekte	Programado												
			Realizado		(✓)										
8	Estimación de los costos de ambos proyectos	Kostenvoranschlag für beide Projekte	Programado												
			Realizado												
9	Obtener todos los materiales y la construcción de las instalaciones	Besorgen aller Materialien und Aufbau der Anlagen	Programado												
			Realizado												
10	Inicio del experimento / prototipo "Canecas"	Start des Experiments/Prototyps "Canecas"	Programado												
			Realizado												
11	Inicio del experimento / prototipo "Salchicha"	Start des Experiments/Prototyps "Salchicha"	Programado												
			Realizado												
12	Recopilar datos en varios intervalos (temperatura, pH, volumen de producción de biogás, contenido de metano)	Sammeln verschiedener Daten in Intervallen (Temperatur, pH, Volumen der Biogasproduktion, Methangehalt)	Programado												
			Realizado												
13	Análisis de los datos y resultados	Analyse der Daten und Resultate	Programado												
			Realizado												
14	Desarrollo de un formato para la caracterización y cuantificación de los residuos orgánicos en la U.D.C.A.	Ausarbeitung eines Formats zur Charakterisierung und Quantifizierung der organischen Abfälle an der U.D.C.A.	Programado												
			Realizado												
15	Realización de las mediciones y caracterizaciones	Durchführung der Messungen und Charakterisierungen	Programado												
			Realizado												
16	Saldo global de las rutas de los residuos orgánicos / cálculo del potencial completo de generación de energía a partir de estos residuos en la U.D.C.A.	Gesamtbilanz der Routen von organischen Abfall / Kalkulation des kompletten Potenzials an Energiegewinnung aus diesen Abfällen an der U.D.C.A.	Programado												
			Realizado												
17	Saldo final y Conclusión	Schlussbilanz & Fazit	Programado												
			Realizado												

Figure 7: Revised working plan.

2.3.1 Project “Canecas”

The idea of this project was to use old barrels and transform them into small functioning batch bioreactors. The goal of this project was:

• To check (at minimal cost) if the anaerobic fermentation works

• To know which substrate serves the best / produces the most biogas or methane

• To know how biogas production versus time develops

• To check if the produced biogas can be used as domestic fuel

Barrels of a volume of 160L (120L volume of a mixture out of manure and water and 40L space for air)				
Substrate	30L cow dung 90L water	30L horse dung 90L water	30L kitchen waste 90L water	1:1 mixture out of kitchen waste and dung (15L each) 90L water

Figure 8: Proposed substrate load for the „Canecas“ project.

The load is constituted by a mixture of 25 % organic material and 75% water. A space of 40L in the digester is left for the biogas to be developed. This mixture ratio has shown the maximum biogas production in several studies (Yadvika et al., 2004; Wang et al., 2012; Oparaku et al., 2013). Our proposed design was based on the system of Shaun Hermans (2011) with a few adaptions. We preferred to do a discontinuous system so we could setup the reactors without input and output pipes. Further we planned more space for the biogas within the digester as indicated above. The idea was to apply thermometer, pH meter and barometer at the digester or the gas outlet respectively to monitor the three parameters temperature, pH and pressure over time.

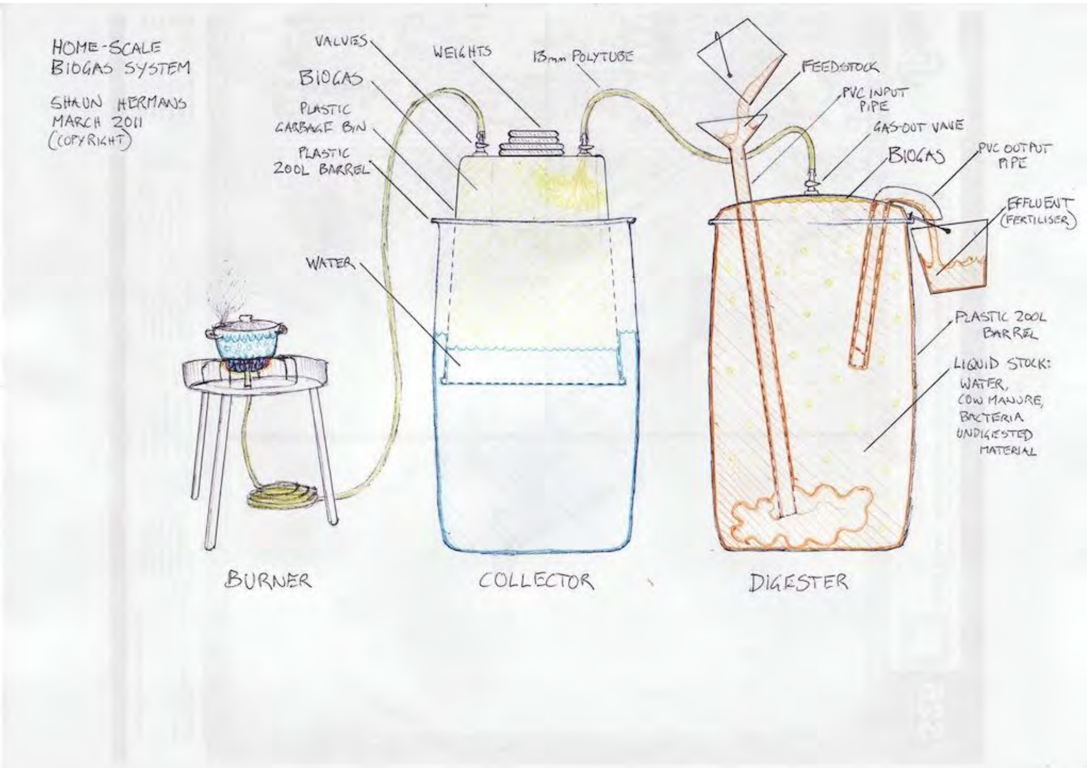


Figure 9: Proposed experimental setup of the “canecas” (after Hermans, 2012).

We proposed 4 different load mixtures to fill the barrels. The idea was to do at least duplicates to obtain information about the respective potential with statistical relevance.

The retention time was estimated using the data given in Herrero (2008) and was around 35 days.

Región característica	Temperatura (°C)	Tiempo de retención (días)
Trópico	30	20
Valle	20	30
Altiplano	10	60

Figure 10: Tiempo de retención (Herrero 2008)

The material needed for this experiment was listed and sent with the project proposal to the departement responsable at the U.D.C.A.

Material	**Unidades**
CANECAS METALICAS DE 160 LITROS / CON TAPA Y EMPAQUE DE CAUCHO	8
SOLDAURA Y ADAPTACION DE TERMOSTATO Y VALVULAS (SOLDADURA - EXTERNO)	8
TUBO DE COBRE DE MEDIA PULGADA	12 metros
UNIONES Y ACOPLES DE COBRE	16
TERMOSTATOS	8
VALVULA DE PRESION	8
VALVULA DE SEGURIDAD (REGISTRO) 1/2"	1
UNIFIX PARA TUBERIA DE GAS	
FOGON O COCINETA PEQUEÑA	1
BARÓMETRO	8

Figure 11: Required materials for the “Canecas” project

2.3.2 Project “Salchicha” (based on Herrero, 2008)

The second project we planned was the construction of a continuous, horizontal, low cost biodigester of a type called “Salchicha”. This simple system has been already installed in a lot of developing countries mainly on a family scale to support the producers with daily cooking gas which is sometimes hard to get (Botero and Preston, 1987; Bui Xuan An et al., 1997; Preston and Rodríguez, 2002).

The proposed design is shown below:

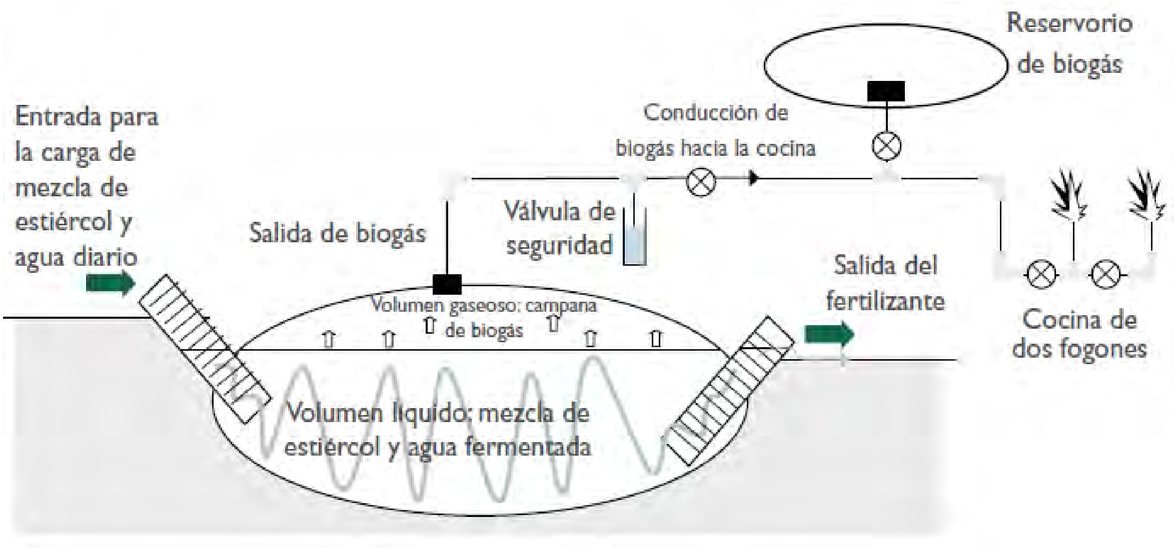


Figure 12: Scheme of the complete biodigester system with security valve and biogas reservoir (Herrero, 2008).

We requested an area in the southern campus of the U.D.C.A. just next to the water treatment plant to construct this system. The idea was to build up the "Canecas" project just next to it. Furthermore we planned to dig a pit with the length of the tubular reactor in order to stabilize and protect it. Our planned dimensions corresponded with the "valley-type" biodigestor proposed by Herrero (2008) given in the following table.

Biodigestor familiar modelo para Valle

Carga diaria: 20 kg de estiércol (de vaca) y 60 litros de agua mezclados
Producción de biogás diario: 700-750 litros (4-5 horas de cocina)
Producción de fertilizante diario: 80 litros
Tiempo de retención: 37.5 días
Tiempo medio de demora en empezar a funcionar: 1 mes
Temperatura de trabajo: 20°C
Temperatura ambiente: 15 a 20°C

	Valle
Volumen$_{\text{Líquido}}$	3000 lts
Volumen$_{\text{gaseoso}}$	1000 lts
Volumen$_{\text{Total}}$	4000 lts
Ancho de Rollo	1.5 m
Longitud de biodigestor y de la zanja (L/D)	5.6 m (5.7)
Longitud$_{\text{plástico}}$ por capa (se añade 1 m para amarre)	6.6 m
Plástico total (con reservorio) por biodigestor	16.2 m
Ancho inferior de zanja	0.5 m
Ancho superior de zanja	0.7 m
Profundidad de zanja	0.8 m

Figure 13: Dimensions of the planned „Valley-type“ biodigester

As the mean temperature in Bogotá is about 14.2° C we could use this model as a proposal for our own bioreactor. In order to receive an approximate production of 700 – 750 litres of biogas daily you have to load the digester with a load of manure mixed 1: 4 with water. This mixture is called daily load and consists in our case of 20 kg of manure and 60 kg of water. It is estimated that the bioreactor starts the production of the biogas with a delay of about a month due to the time consuming bacterial decomposition process. Once the bacterial population is established a daily production of 0.7m3 biogas and 60 liters of liquid fertilizer are formed.

We further adapted the list of required materials given by Herrero (2008):

Materiales y presupuesto estimado para biodigestores familiares modelo
(en bolivianos, dólares y euros al siguiente tipo de cambio
1$us=0.7 €; 1 € =11,6 Bs; 1$us=7,5 Bs)
(Costes en abril de 2008 en la ciudad de La Paz, Bolivia)

	Material	Unidades por biodigestor	Precio unidad (Bs)	Precio por biodigestor: Bolivianos (Bs)	Dólares ($)	Euros (€)
Conducción de biogás	Tubería de PCV de ½"	(+/-) 25m	5bs/m	25	16,67	9.09
	Llaves de bola ½" de plástico	4	35	140	18,67	8.73
	Flange ½" de plástico	2	20	40	5,33	5.09
	Codos PCV ½"	4	1,5	6	0,8	1.27
	Niple PCV ½"	2	2.50	5	0,67	0,43
	Tee PVC ½"	4	2,5	10	1,33	0,86
	Teflón	2	1,5	3	0,4	0.26
Cocina	Codo metálico ½"	2	3	6	0,8	0,52
	Tubos metálicos ½", 12cm	2	7	14	1,87	1.21
	Tubos metálicos ½", 7cm	2	5	10	1.33	0,86
Biodigestor	Tubería PVC 6"	2m	47,25 Bs/m	94,5	12,6	8,15
	Liga de neumático	60m	1,5 Bs/m	90	12	7,76
	Polietileno tubular (300 micrones color negro humo)	Trópico 15.6m	30,24 Bs/m (AR 1.25m)	480,82	64,11	41,45
		Valle 16.2 m	36,3 Bs/m (AR 1.50m)	588,06	78,41	50,69
		Altiplano 21.2 m	42,34 Bs/m (AR 1.75m)	897,61	119,68	77,38
	Carpa solar	Altiplano 9 m	25 Bs/m (AR 2m)	225	30	19,4
Total	Trópico			1024,32	136,58	88,3
	Valle			1131,56	150,87	97,55
	Altiplano			1666,11	222,15	143,63

ITEM	UNIDADES	CANTIDAD
FIBRA DE POLIETILENO DE ALTA DENSIDAD (PLASTICO DE INVERNADERO) TIPO MANGA x 1.50 mt	METROS	12
MAGUERA DE POLIPROPILENO DE 2"	METROS	2
EMBUDO GRANDE	UN	1
TUBERIA DE PVC PRESION DE 1/2"	METROS	10
ABRAZADERAS METALICAS DE 2"	UN	4
ABRAZADERAS METALICAS DE 1"	UN	2
TERMOSTATOS	UN	2
VALVULA DE PRESION	UN	2
VALVULA DE SEGURIDAD (REGISTRO) 1/2"	UN	2
PLASTICO DE INVERNADERO PELICULA DE 10m x 4m techado	UN	1
MADERA O ESTRUCTURA DE TECHO	UN	1
FOGON O COCINETA PEQUEÑA	UN	1
ADECUACION DE SITIO (MANO DE OBRA)	UN	1

Figure 14: Version of the required material list left by Herrero (2008) and adapted one for our project on the right

The idea was using the money the university earned by selling their recycling materials (1’983‘455$ COP ≈ 840 CHF) for my projects. With that money we could have realized both projects and still would have had enough reserves to deal with any problems if encountered.

We handed in our proposal with the required materials on Monday the 22nd of September and hoped we might receive them in the same week to somehow make up for the time already lost within the first weeks.

2.3.3 Project “pozones sépticos”

The third project was rather an idea to take advantage of the knowledge gained during the first 2 months in the other two projects too enlarge the scale and adapt the same techniques to an old, unused well at the campus. This well has an estimated volume of 25 m^3 and had the potential to use all organic waste produced at the university to transform it into combustible gas and fertilizer.

Figure 15: Old well with large volume that could be used as a bioreactor.

2.4 Projects realized

After handing in the project proposals and the material request we waited. In the first week unfortunately we did not receive anything so I used this time to do more research and to work out a more detailed experimental setup. This went on and I received every time a “toca que esperar” (you need to wait) answer by the office of the environmental science faculty, where I stopped several times a week. I asked whether I could support Mauricio and the “Sistema Integrado de Gestión Ambiental” (SIGA- the office where I worked) in other projects. As mentioned above although I already worked with Mauricio around the 3rd week of my internship I was still under the responsibilities of Marco Tulio. As a result they were not allowed to offer me tasks until Marco Tulio on the 8th of October finally confirmed the change of responsibilities.

The truth is that we never got an answer whether our proposal has been approved or not. Fortunately Mauricio could offer me some tasks in the laboratory during this time. However the environmental faculty kept us waiting for weeks and finally passed us on to Claudia

Uribe to ensure that the money for the project is available. Claudia gave us the confirmation which we forwarded to the environmental faculty. Another week passed and at the beginning of November Mauricio stated that it wouldn´t add up to still initiate my proposed projects now. I insisted to do at least one of. We decided to do a cheaper, simplified, improvised version of the Salchicha project and bought the materials in the same week ourselves (The money has been returned afterwards by the university).

In the following there is description of the adapted Salchicha project and the different task I did while waiting for the money and the material for our initial project.

2.4.1 Biodigestor type "Salchicha"

In the beginning of November I went with Mauricio to the center of Bogotá to buy the minimal material needed to construct a functioning bioreactor. All in all we spent about 120’000$ COP (≈50 CHF). With the help of two students from Mauricio’s class we dug a pit of 5 meter lengths, 90 centimeters width and about 50 centimeter depth. We started to do this widthwise as they did not allow us to us that much space. We furthermore applied posts that supplied further stability and protection, and that at the same time, we could use as pillars for the planned roof later. The posts are actually PVC tubes that were laying around next to the water treatment plant.

Figure 16: Location of the bioreactor just next to the water treatment plant

Work halfway done however they changed their mind and we started over again to dig the pit and place the tubes lengthwise as we could take advantage of the green-orange pillars that were already there. Our pit had rather a parabolic shape than a trapezoid shown as “Corte B” below.

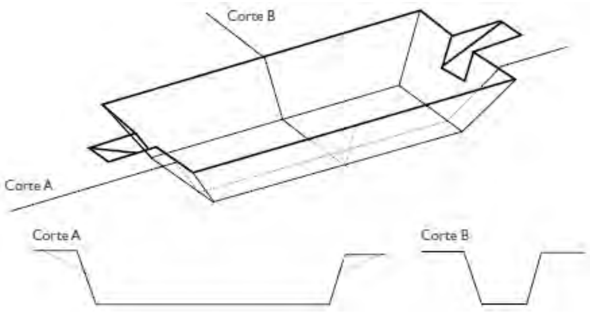


Figure 17: Scheme of pit.

We then covered the surface with two layers of plastic to ensure that no rocks and no roots damaged the plastic shell of the bioreactor. Once completed, we folded the 12 meters of black tubular plastic to a 6 meter double layered tube again for safety reason. We entered the plastic to the pit and first made a hole in the middle to connect the gas outlet and the valve. We then closed the reactor at one side as we applied the outlet tube. From the other side we started to fill the “Salchicha” with 1:3 mitxture of manure and water. As the filling process began to get difficult we closed also the second end as we applied the inlet tube. As the tubular plastic has a width of 1.5 m and a length of 5.2 m the potential volume can be easily calculated using:


Figure 18: Two alumni and I preparing the pit for the bioreactor.


Figure 19: Adding the plastic for further protection.

$V = R^2 \pi L$.

In our case $V = (0.477m)^2 * \pi * 5.2m = 3.724m3$

As the perfect cylindrical shape will not be achieved due to the shape of the pit I estimated the volume of the bioreactor about 3600 liters. As 1/3 of the volume should be space for the biogas to be produced we filled the digester with about 1800 liters of water and 0.6m3 of the freshest manure that is collected on a huge piles near the veterinary clinic. The water and the dung then combine for 2400 liters of volume. However as the dung mixes quite well with the water the final volume was not that high. I therefore added some 20 % more of the mixture despite the fact that I couldn´t find any similar approaches in the literature.

Further we added a plastic roof to protect the bioreactor from the harsh weather in Bogotá. In general we had to improvise on each working step. As we didn´t get the money to buy the actual material required we used substitutes that were laying around on the campus and which had no further use. For example the roof is a combination of a rusty wire, an old plastic we found in the northern campus, some heavy iron pegs we actually found digging the pit, some stones and tape.

Figure 20: Improvised roof construction.

In the literature they always inflate the bioreactor first. We also tried to do this with the exhaust of the car of Mauricio. We encountered some difficulties however as the hose was very old and apparently not airtight. We decided then to let the bioreactor inflate itself which actually makes more sense.

Our digester is operative since the 10th of November. Literature however suggests that the gas building process will start with a delay of a month. As my internship already ended on the 5th of December I was not able to get any results out of this project.

I had many ideas to treat and store the biogas afterwards to get a methane enriched compressed fuel. But as all these ideas would imply investments that the university is obviously far from ready to make, ideas they remained.

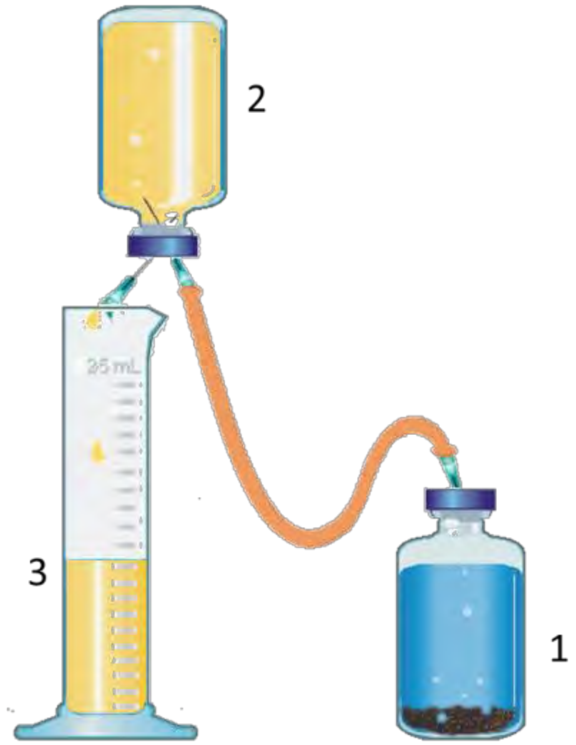


Figure 21: Schematic representation of how the methane content of the biogas could be enriched. methane measuring displacement of a solution of 3% NaOH. 1) representation of a bioreactor, 2) serological bottle with aqueaous solution of $Ca(OH)_2$ 3) tube to colllect the displaced solution

As the biogas passes the aqueous solution the CO_2 which accounts roughly for 50% of the biogas reacts with the Ca^{2+} ions to form $CaCO_3$ which precipitates.

Figure 22: Handling of the gas

Figure 23: Inlet (left) and outlet (right) of the bioreactor

Figure 24: Horses at the U.D.C.A. which produce the substrate used

Figure 25: Fresh dung and manure pile

2.4.2 Sludge as a substrate for the digester

Figure 26: Sludge drying zone

The university hired an external firm to collect the sludge which accumulates in the water treatment plant. As this service is quite expansive the idea came up to treat the sludge ourselves and use it as a substrate for the digester which was still in planning at this point. Adding the sludge to the digester could have two positive effects. First we could transform the high organic content of the sludge into combustible gas, second we could save the money spent for the disposal. However we had some concerns that the sludge may contain significant concentrations of antibiotics and other chemicals and pharmaceutics which may kill the methanogenic bacterial population and inhibit any microbial process within the bioreactor. As the veterinary clinic accounts for a significant part of the wastewater we expected the concentrations of the pharmaceuticals to be very high.

I therefore took some samples of the sludge and went to the microbiology laboratory. There they proposed a standard method and we diluted the probes with a factor of 1000. I applied the samples on Petri dishes with different media and incubated them for 72 hours in order to see whether there is microbial growth visible and if how many colonies can be counted. The complete results have been sent to Mauricio Romero and Marco Tulio. However in general they all show the same that in fact there is microbial growth (Aerobes, pseudomonas, fungi and yeast) visible and in some cases uncountable suggesting that the concentrations of the pharmaceuticals must have been low enough to not result in a inhibition of microbial growth.

Tipo de medio	Microorganismos	Cultura después de 72 horas	Existencia en prueba	Existencia promedia cada ml agua de lodos
A.N.	Aerobios mesófilos		Incontables	**>8* 10^4**
Cetrimide	Pseudomonas		Cápsula de Petri: 1) 74 2) 55	**3.2*10^3**
PDA	Hongos y levaduras		Cápsula de Petri: 1) 476 2) 454 3) 242 4) 576 (Levaduras no visible)	**2.2*10^4**

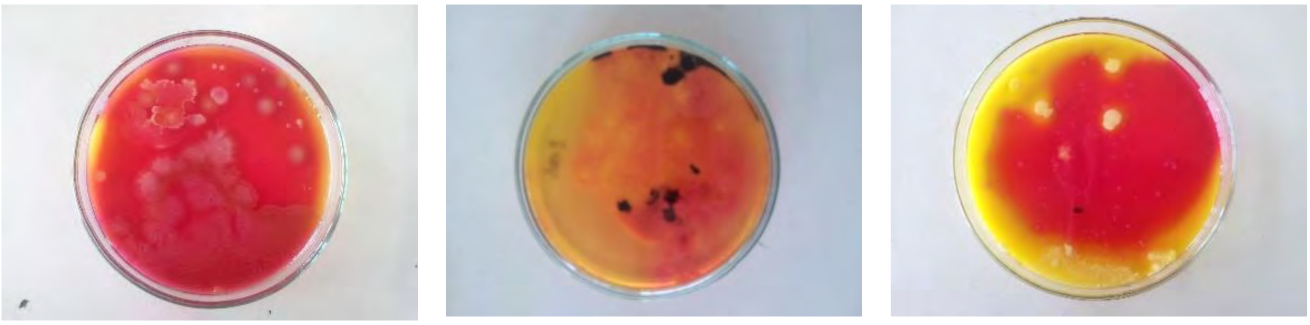
Figure 27: Part of the results obtained from the investigations of the sludge samples in the microbiological laboratory

We also used XLD agar as a medium to see whether there are any pathogens in the sample. This medium has originally a red color. Coliforms will ferment the lactose and sucrose present in the medium by decarboxylation which lowers the pH of the medium which results in a yellow color. *Salmonella* species can be deteceted by colonies with a black center and *shigella* species by pale red ones.

Figure 28: XLD agar in its initial condition

All of these possible pathogens I could detect in the samples. First we thought that the sludge will not serve as a substrate due to this presence. But further research showed (Wagner et al., 2008) that anaerobic digestion is actually able to remove pathogens.

This could mean that we could actually kill three birds with one stone: take advantage of the high organic content of the sludge; save the money to treat them externally; remove



Shigella Salmonella Coliforms

Figure 29: Presence of different Pathogens in the sludge samples

pathogens within the sludge.

2.4.3 Analysis of water from different points at the U.D.C.A.

Another task Mauricio asked me to do was the analysis of wastewater, a task for which I was well educated through my time at ETH. With the help of Edilberto Cubillo Penagos I took samples from every wastewater collector of the campus. Unfortunately dark glass bottles were not available, neither were taps. So I used a variety of different glass container I found in the laboratory and tried to close them with parafilm. However I started then to test the samples on different parameters using the instruments available that were in working order. Some parameters as conductivity for example were obtained for all samples within minutes others like sulfate or nitrite required a time-consuming process of creating calibration curves to get reliable results from the spectrophotometer.

Figure 30: Location of the different sample points

Sample 1: Domestic wastewater — Sample 3: Industrial wastewater (Kitchen) — Sample 4: Industrial wastewater (Milk and meat products)

Figure 31: Wastewater collectors on the campus of the U.D.C.A.

The results which serve Mauricio Romero to adapt different treatment and collecting steps of the wastewater are shown in the figure below. We also wanted to test the concentrations of heavy metals using ion chromatography with UV-Vis detector. However neither a suitable column was available nor did the instrument work.

Parametro	Unidad	Promedio	Domestico 1	Domestico 2	Cafeteria	Lácteos y cárnicos	Clinica Veterinaria	PTAR entrada	PTAR salida
pH		6,8	8,5	8,4	4,7	4,7	6,3	7,6	7,6
Turbidad	NTU	161,3	89,9	100,0	267,0	252,0	81,2	330,0	9,2
Conductividad	mS/cm	1,6	2,6	2,6	0,8	0,7	0,8	1,8	1,9
O2	mg/L	1,8	0,6	0,5	0,5	0,6	4,9	0,5	4,7
Saturación de O2	10,8mg/L ≈ 100%	16,2	5,1	4,3	4,8	5,6	45,7	4,9	43,2
NO2	mg/L	3,8	<0.1	<0.1	<0.1	<0.1	3,8	<0.1	<0.1
NO3	mg/L	-	pendiente	pendiente	pendiente	pendiente	pendiente	pendiente	pendiente
SO4	mg/L	54,3	62,8	47,7	89,8	47,4	18,7	30,9	82,7
Hg	ng/L	-	pendiente	pendiente	pendiente	pendiente	pendiente	pendiente	pendiente

Figure 32: Results of the different parameters for each water sample

Figure 33: Experimental setup for the nitrite analyses of the samples (the increasing intensity of the reddish tone on the 6 tubes on the left indicate increasing concentrations of nitrite used to construct the calibration curve)

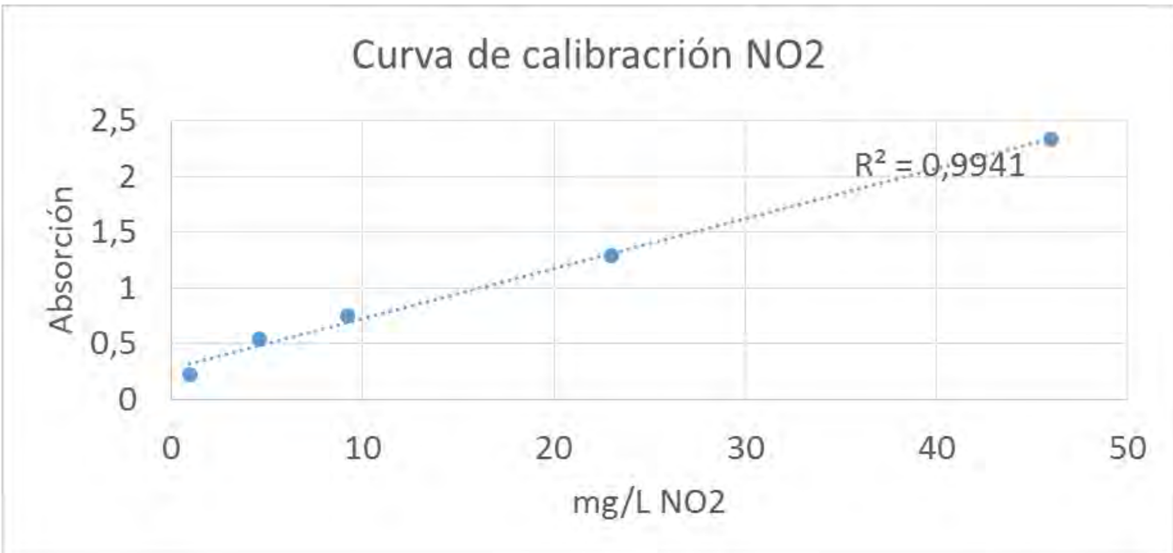


Figure 34: Calibration curve of nitrite needed to reference the absorption value obtained by the spectrophotometer to the concentrations of nitrite in each sample

2.4.4 The use of rain water at the "Remanso"

In Bogotá there is an annual precipitation of about 1000mm. At the moment the rainwater only gets collected in the building of the SIGA. Meanwhile however in the agricultural part of the university (Remanso) an annual 1400m^3 of tap water is used to water different plants. My task was to calculate how much water could be collected using the plastic roof of the greenhouse located there and to figure out how it could be stored.

Figure 35: Greenhouse at the Remanso

The roof of the greenhouse has already an inclination pointing towards west (left in the figure). I therefore proposed a simple gutter system (indicated in yellow in figure 36) which would collect the water at the western end of greenhouse, transport it around it to finally fill a reservoir of several thousand liters of volume. The total distance of the gutter system would be about 105 meters with an inclination of not more than 1% to ensure to pass the last section without hindering the daily routine of the workers there.

Figure 36: Proposed route of the gutter system

In the following chart the monthly total of the rainwater that falls on the roof of the greenhouse is given in blue, the consumption of tap water at the "Remanso" in orange and two collecting scenarios (50% and 90% of the total) in grey and yellow respectively. It is unlikely to collect all the water that falls on the roof due to the fact that a gutter system on minimum costs won´t be able to collect and transport the rainwater without any losses. This is especially true for heavy rainfalls which are typical for Bogotá during rainy season.

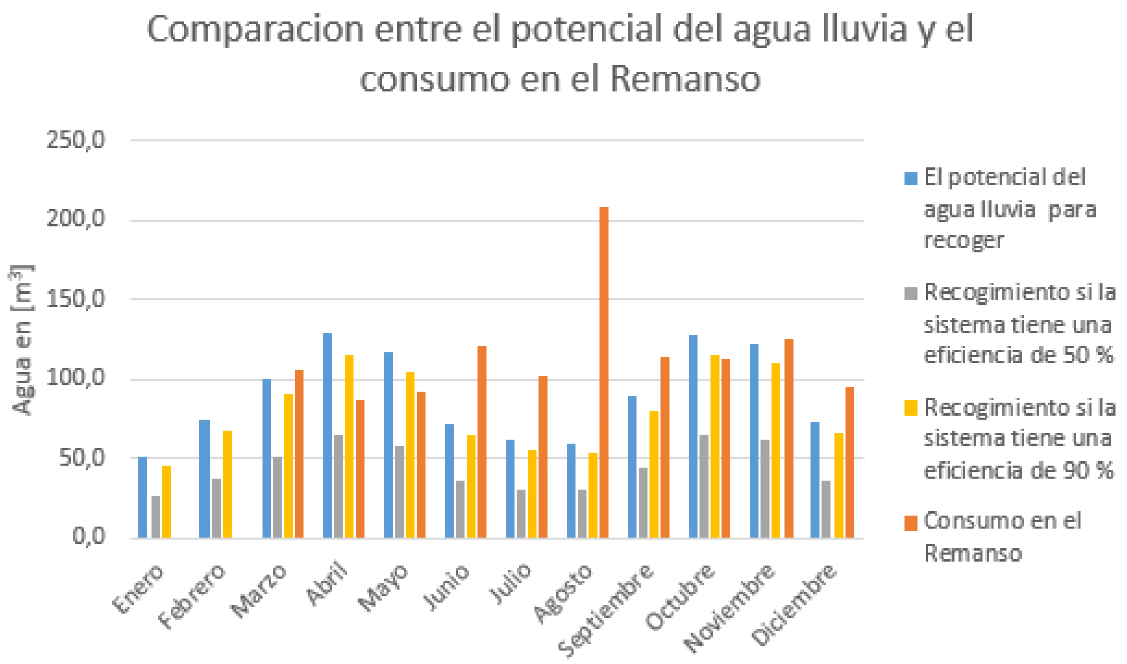


Figure 37: Comparison between the potential of collecting rainwater and the consumption at the Remanso

The use of rainwater at the Remanso could result in an interesting economic benefit for the university. In a realistic scenario annual savings of about 700 CHF could be achieved.

Scenario	**Pesimistic**	**Realistic**	**Optimistic**
Coverage of the consumption with rainwater	38 % (540/1400m^3)	57% (800/1400m^3)	70% (970/1400m^3)
Price of tap water	2100 COP/m^3		
Annual savings in COP	1'134'000	1'680'000	2'037'000
Maximum costs for a construction in COP assuming a 5 year working period	5'670'000	8'400'000	10'185'000

Figure 38: Profitability of different rainwater capturing scenarios

This would be just a small project as the "Remanso" is only a tiny part of the campus. However the experience gained in this pilot could be used to adapt similar systems to the other parts of the U.D.C.A. The potential at the university to feed for example the sanitary system with rainwater is actually significant as the roofs make up for a large total area. The rainwater there gets already collected but seeps then unused into a creek.

2.5 Conclusion of the projects and future handling

In the following I will conclude the projects starting in reverse order.

The results of the rainwater collecting project at the “Remanso” suggest that there is a significant unused, unexploited potential witch may be transformed not only into an environmental but also in a remarkable economic benefit. This is especially true expanding the area of interest over the whole campus. As the tab water at the university does not have drinking water quality it might be substituted with rainwater without any further concern especially in the sanitary system (e.g. toilet flush).

As mentioned above the results of the analysis of the wastewater served Mauricio to adjust certain treatment, mixing and transportation steps. However the credibility of the results is questionable, as some methods seemed rudimentary and results lacked of statistical significance. To improve this I would suggest to analyze at least triplicates of each sample and to use dark bottles to store the samples with taps to minimize further chemical reactions (one could even add a strong base or acid to kill the microorganisms to inhibit any further biochemical reactions). In order to get results with high reliability, however, it is probably the best to hire an external laboratory to do the analysis.

The results of the sludge experiments actually don´t allow a final conclusion in regard to the initial question whether or not they are suitable as a substrate for the biodigester. The fact that there is microbial growth, however, shows that there is no inhibition suggesting that the methanogenic bacterial population might be not affected. My suggestion is to wait until the bioreactor (fed with manure and water only) produces a stable daily amount of biogas (might be the case in the beginning of January). Continuing to monitor the daily gas production one then can slowly switch to a mixture of sludge and water as a substrate. If the negative effects of the substrate change on the gas production are significant one might change back to the initial mixture. However if the loss is negligible or if there is even an increase in the gas production one might stick to the sludge-water mixture as this process has further benefits mentioned above. A further investigation then might do a comparison of the pathogens concentrations in the inlet and the outlet streams. This analysis could show the efficiency of the bioreactor to remove pathogens and might lead to further adaptions to the digester (e.g. additional heat supply).

A fact sheet of the constructed digester is given in the figure below:

	Unity
Liquid volume	2700 l
Gaseous volume	900 l
Total volume	3600 l
Diameter of the digester	0.95 m
Length of the digester	5.2 m
Total length of plastic bought	12 m
Daily load	18 kg of horse manure mixed with 54 l of water
Daily production of liquid fertilizer (biol)	72 l
Daily biogas production	630 – 680 l (equivalent to 0.5 l of gasoline)
Retention time	38 days
Average time delay to start working	1 month
Working temperature	≈ 20°C
Ambient temperature	≈ 15°C
Total expenses	≈ 120’000$ COP (≈52 CHF)

Figure 39: Fact sheet of the realized bioreactor project

As this project was started with a huge delay it is actually not finished yet. Questions or ideas that remain open are:

- Where and for which purpose the gas will be used

- How to store the gas (another large plastic bag as reservoir or compress it?)
- Whether to add CO_2 cleaning steps to improve the quality of the gas
- Improvements of the roof construction to collect rainwater which then can be used to apply the daily load.
- Where and for which purpose the liquid fertilizer will be used
- Whether the sludge of the water treatment plant is suitable as a substrate
- Whether this biodigester system can be applied to the old well in the Northern Campus

As my opinion to all this open questions might be useful I will surely keep in touch with Mauricio Romero which will together with Edilberto Cubillo Penagos take over this project. Also I would account myself fortunate if I received any news, results or problems encountered with regard to this project.

3 Personal experience

3.1 Living in Bogotá

The daily life in the 8 million city of Bogota was an adventure in and of itself. Fortunately I had my apartment quite close to the university where I was working. However, some days it took me more than 2 hours to get there by bus. The public transport systems still lacks efficiency and cannot keep up with the growing size and number of inhabitants of Bogota. As the university is only accessible by bus or private car I was forced to spend several hours each day standing in the bus. At the beginning this was actually very interesting and perfect to pick up some dialect vocabulary. Over time however it hampered the efficiency at work a lot as you never knew when you and your co-workers will arrive. Therefore there were no official working hours as nobody could stick to them unless you actually lived on the campus.

3.2 Work climate and work ethic

Work climate and work ethic are both very different to the ones in Switzerland. First it has to be stated that the university paid me for work there. The amount is relatively comparable to the one you obtain as an intern in Switzerland. However, in general there were no expectations or requirements for my work. There was this vague working plan at the beginning mentioned above but with no concrete goals. In fact, although I was paid during this time, I really had to insist to get some tasks.

When I finally could change my tutor and the situation improved I was finally given some tasks. However, none of them was given to me with a deadline or some time pressure. I neither received an introduction, an approach or any goals; they were rather ideas in which topics one could invest some time. I therefore was totally autonomous and independent. On the one hand this allowed me to work very efficiently on the other I would have preferred to have some goals to achieve as motivation. In this efficient period I worked out the three projects mentioned above and presented them. That was when the period ended. The following weeks we spent waiting for the cash and the materials to finally start the setup. I used this time to support my co-workers in different small tasks (e.g. giving French classes, replaning the draining system, translating various documents etc.). This allowed me to broaden my experience at the university a lot. However I would have preferred to advance further with my project.

As we decided to progress without any materials or cash given, I made one of my best experience to work with limited sources. “Necessity is the mother of invention”. With only 50 CHF we bought the plastic we needed and managed to construct a working biodigestor using a set of the simplest instruments and material that was thought to be trash.

Another interesting aspect was the communication. As shown in figure 2 there was only an English level of “fair” or “good” requested. However, no one was able to speak English there and they totally relied on my Spanish which was actually not a criterion in the solicitation. Fortunately my Spanish degree was already around B1-B2, so in the end I could profit a lot from this situation as I my language skills really improved. Though in the beginning a few misunderstandings occurred which hindered a proper start.

As I lived in an apartment with en elderly widow who only spoke Spanish and the other exchange students and interns came from Mexico, Argentina and Bolivia I only spoke Spanish during the whole time of my internship.

From an academic point of view I could not extend my knowledge very much. Neither was I able to apply a lot of the things I learned at ETH before. I expanded however my skills and knowledge in a more practical, engineering field. I not only planned the project, proposed the setup and knew about all the theory behind the project but I also went into the field to construct it, which is in my opinion a very valuable and recommendable experience.

As mentioned above there has been some difficulties with my former tutor. Reviewing my time there I am very glad that I insisted on changing supervision. It was really worth it to stay persistent because afterwards the situation really improved. I probably would not have achieved anything if I kept working on his supervision.

4 Conclusion and recommendations

Although much did not work out as planned and much patience was needed I still benefited a lot of this internship. The gains may not be academic but of a personal, cultural and linguistic manner. During my internship I met dozen of new people and many of them are good friends now. I changed habits, opinions and diet. I experienced the life in a metropolis. I learned plenty about the country, its nature and history. I experienced the extreme differences to the Swiss meritocracy and I improved my linguistic skills and broadened my horizons.

I really recommend trying to benefit from the opportunity to do the obligatory internship abroad. As mentioned above you might not make huge progress academically but the experience is character molding. However I advise to concrete the work in advance to save the trouble I experienced shortly after my arrival. Therefore it might be useful to contact the person responsible as soon as possible. I even suggest conversations on Skype to get an impression of the person you are going to work with.

Furthermore I think it is very helpful for the future to know how certain situations are beyond Switzerland. Work ethic, laboratory equipment and expectations in general are just a few examples. Thus the experiments I was running in the laboratory there must appear ridiculous if you are used to the standards at the ETH.

5 Literature

Aguirre, S. P. (2004). Granja integral autosuficiente: manual (Vol. 1). Editorial San Pablo.

Benner, Ronald (1989). "Book Review: Biology of anaerobic microorganisms". Limnology and Oceanography 34 (3): 647.

Botero, B. M., & Thomas, R. P. (1987). Biodigestor de bajo costo para la producción de combustible y fertilizante a partir de excretas. Manual para su instalación, operación y utilización. Centro Internacional de Agricultura Tropical. Cali, Colombia, 353-362.

Chen, Y., Cheng, J. J., & Creamer, K. S. (2008). Inhibition of anaerobic digestion process: a review. Bioresource technology, 99(10), 4044-4064.

Gujer, W., & Zehnder, A. J. B. (1983). Conversion processes in anaerobic digestion. Water Science & Technology, 15(8-9), 127-167.

Herman, S. (2012). Biogas digester. Retrieved, 14.10.2014 from www.shaunsbackyard.com website. URL: http://shaunsbackyard.com/746/biogas-digester/#more-746

Herrero, J. M. (2007). Experiencia de transferencia tecnológica de biodigestores familiares en Bolivia. Livestock Research for Rural Development,19.

Herrero, J. M. (2008). Biodigestores familiares: Guía de diseño y manual de instalación. Jaime Marti Herrero.

Holm-Nielsen, J. B., Al Seadi, T., & Oleskowicz-Popiel, P. (2009). The future of anaerobic digestion and biogas utilization. Bioresource technology, 100(22), 5478-5484.

Koyama, Tadashiro (1963). "Gaseous metabolism in lake sediments and paddy soils and the production of atmospheric methane and hydrogen". Journal of Geophysical Research 68 (13): 3971–3973

Lettinga, G. (1995). Anaerobic digestion and wastewater treatment systems. Antonie van leeuwenhoek, 67(1), 3-28.

MacGregor, A. N., and Keeney, D. R. (1973). "Methane formation by lake sediments during in vitro incubations". Journal of the American Water Resources Association (JAWRA) 9 (6): 1153–1158.

Martin, A. D. (2010). Understanding Anaerobic Digestion, Presentation to Environmental Services Association, 16.10. 07.

Nallathambi Gunaseelan, V. (1997). Anaerobic digestion of biomass for methane production: a review. Biomass and bioenergy, 13(1), 83-114.

Oparaku, N. F., Ofomatah, A. C., & Okoroigwe, E. C. (2013). Biodigestion of cassava peels blended with pig dung for methane generation. Afr. J. Biotechnol, 12(40), 5956-5961.

Preston, T. R., & Rodríguez, L. (2002). Low-cost biodigesters as the epicenter of ecological farming systems. In Proceedings biodigester workshop.

Song, Y. C., Kwon, S. J., & Woo, J. H. (2004). Mesophilic and thermophilic temperature co-phase anaerobic digestion compared with single-stage mesophilic-and thermophilic digestion of sewage sludge. Water Research,38(7), 1653-1662.

Wagner, A. O., Gstraunthaler, G., & Illmer, P. (2008). Survival of bacterial pathogens during the thermophilic anaerobic digestion of biowaste: Laboratory experiments and< i> in situ</i> validation. Anaerobe, 14(3), 181-183.

Wang X, Yang G, Feng Y, Ren G, Han X (2012) Optimizing feeding composition and carbon-nitrogen ratios for improved methane yield during anaerobic co-digestion of dairy, chicken manure and wheat straw. Bioresour. Technol. 120:78-83

Weiland, P. (2010). Biogas production: current state and perspectives. Applied microbiology and biotechnology, 85(4), 849-860.

Yadvika, Santosh, Sreekrishnan TR, Kohli S, Rana V (2004). Enhancement of biogas production from solid substrates using different techniques -a review. Bioresour. Technol. 95:(1)1-10