FUNCTIONING INDUSTRIAL SYMBIOSIS MODEL APPLICATION TO ORGANIC WASTE: A CASE STUDY OF A PAPER MILL COMPANY IN COCHABAMBA, BOLIVIA

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Master of Environmental Studies
Environmental Sustainability

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ABSTRACT

FUNCTIONING INDUSTRIAL SYMBIOSIS MODEL APPLICATION TO ORGANIC WASTE: A CASE STUDY OF A PAPER MILL INDUSTRY IN COCHABAMBA, BOLIVIA

Natalia Mendoza Abujder

Wastewater treatment plants across the world can transform themselves from energy consumers into energy producers and not only convert their operations into a circular economy, but also reduce their disposal and energy costs, ultimately benefitting their triple bottom line. This field study and research created a model specific to a paper mill company in Cochabamba, Bolivia, Copelme S.A., to investigate if its waste streams can be converted into a value stream and if its organic sludge waste can be transformed into energy. The model included an analysis of the application of an Up-Flow Anaerobic Sludge Blanket (UASB) reactor on the wastewater treatment plant to digest organic material and capture and burn gas to produce energy. Analysis of case studies, wastewater biometric sampling, and theoretical CO_2 discharge and reduction estimations were used to validate environmental and economic feasibility. This study found that for Copelme S.A., adopting a UASB reactor in the current aerobic treatment plant would result in a theoretical incurred investment of at least $USD 1.362.980, with savings of $USD 90 per day. In turn, the company's return of investment (ROI) would signify approximately 39 years. Using calculations taken from the Global Energy Interconnection Development and Cooperation Organization (GEIDCO), an estimate of 171,3 Mt CO_2/year would be expected. Although the ROI in years is high, the environmental impact that this signifies is enormous. This model could then be applied and used to power the company, resulting in an industrial symbiosis microcosm example with an additional financial and environmental benefit. The application of UASBs across other industries could take all of its waste streams and convert them into energy – benefiting the local communities, improving the health of the water systems and potentially sharing that energy generated through the creation of microgrids. By determining an initial model that works in transforming the company's waste to energy, the same can be implemented on a larger scale, starting with a company and ending by converting itself into an example for future applications of energy recovery and waste management facilities.

1. Introduction

There is a prophecy from indigenous people that says there is a black snake above ground and when it goes underground, it is going to be devastating to the Earth – this black snake is known as fossil fuels (Pauls, 2016). Different technologies have been on the rise to help reduce fuel consumption in the world and among these is recovering energy intrinsic in wastewater treatments. Energy recovery is one of the largest environmental, social, and economic challenges facing the world. To move towards a more circular economy, wastewater plants across the world need to transform themselves from energy consumers into energy producers. There is an enormous amount of energy available in treated wastewaters and these cannot operate merely as disposal facilities any longer (Umble, 2020).

This project will analyze the processes and steps required to transition from a conventional activated sludge-based wastewater treatment plant (CAS-WWTPs) to a water resource recovery facility (WRRF). Specifically, the research will focus on pulp & paper mill companies that have industrial wastewater treatment on-site. Several case studies will be reviewed and data gathered from experts on investing in digestor projects at water resource recovery facilities (WRRFs) in industries such as paper & pulp mill companies that have onsite wastewater treatment.

2. Background

Maintaining water efficiency, and reducing the gap between the available water resources and water demand is a very critical issue that the world faces since many countries suffer from water resources shortage. Wastewater treatments plants play a significant role in reducing the consumption of water. It is important to note that within wastewater treatment plants, CAS-WWTPs regarding the paper mill industry vary from municipal wastewater treatments plants as the municipal wastewater is usually from residential places. The industrial wastewater contains chemicals, organic and inorganic toxins, and substances that need high-end treatment (Water World International, 2020). Municipal and industrial wastewater contains a lot of harmful bacteria and contaminants that should be treated before disposing the water to the environment, or otherwise it can jeopardize human health as well as the environment. In the case of paper mill industries, its industrial wastewater treatment systems are similar to the municipal treatment that contains biodegradable matter, comparatively less harmful chemicals and sludge as their bi-product that can be utilized later. Nevertheless, the volume of industrial wastewater flow is comparatively lesser than municipal flow. The organic load contained in residential and animal waste is much higher than the organic load contained in the sludge residue that comes from paper and pulp. The processing of pulp and paper products yields a significant amount of waste in the form of sludge, collectively referred to as pulp and paper mill sludge, or PPMS. Historically, these pulp and paper residues have been landfilled or incinerated, but as disposal costs rise and sustainability becomes a requirement rather than an option, the industry is looking for a better way to manage them. With more companies turning to land application, processing the material into a premium fertilizer or soil alteration product is being explored (Carlson C., 2022). The management of this pulp and paper sludge is widely recognized by the industry as a substantial waste management challenge. Landfilling was long the primary method of disposal, but this approach has many downsides and is increasingly being discouraged. When landfilled, sludge poses environmental risks, with potentially significant impact to soil and water. Additionally, landfilling is expensive: the cost to transport sludge is already expensive due to its high moisture content, and with growing tipping fees, landfilling continues to become less economically feasible. The reuse of pulp and paper mill sludge would not only divert waste from landfills and incinerators, but it would also create a value-added product. This approach would give pulp and paper producers the opportunity to mitigate disposal costs while improving their environmental standing, and even potentially create an additional source of revenue. This is a viable alternative to reducing disposal costs and adding a revenue stream to sell this byproduct to agricultural providers or land owners.

Additionally, there are only a few technologies available for industries such as paper and pulp that can also convert their organic waste into energy in the form of biogas. As mentioned above, the nutrient load coming from paper and pulp wastewater is significantly smaller than the nutrient load coming from municipal or animal waste. Taking an example of pig farms in China, a large amount of digestate is generated which is regarded as a valuable soil amendment because it is rich in readily available macro- and micro- nutrients (Khoshnevisan et al., 2018, Vaneeckhaute et al., 2013). Comparing effluents from the production process of pig farms, the concentration increases with the size of the farm as follows: small farms with up to 2,500 pigs (COD varies between 3,478 and 9,300 mg/L); medium-sized farms with 2,500 to 7,999 pigs (COD varies between 19,344 and 38,544 mg/L); large farms with 8,000 or more pigs (COD varies between 34,310 and 40,498 mg/L) (Garzón-Zúñiga, M. A., & Buelna, G., 2013). For the purpose of this research, the COD levels will be used from the paper mill case study analyzed in Bolivia, Copelme S.A.

The optimal functioning of the effluents plant in industries is important to guarantee the stability of the production process and the reuse of water allows these plants to reduce the consumption of well water as well as increase awareness of it. Industrial wastewater treatment plants must become a cornerstone of facility operation, producing water fit for a purpose, recovering nutrients, and reducing fossil fuel consumption by recovering the energy inherent in wastewater (Rauch-Williams, et. al., 2018). Several studies have tested different methods of recovering resources and nutrients and transforming them into biogas energy as a cleaner alternative to fossil fuels. Of these, the anaerobic membrane method (AnMBR) and the Up-Flow Anaerobic Sludge Blanket (UASB) reactor are currently thought to be the most effective and popular (Muñoz, et. al., 2019). The application of anaerobic digestion (AD) to capture energy from the wastewater can be tested on pulp and paper mill companies that have onsite wastewater treatment. AD has brought advantages over conventional biological paper & pulp (P&P) waste treatments such as a significant reduction of the produced wastes and the production of biogas, mainly composed of methane. By adopting anaerobic membrane technologies, it is possible to achieve complete solid–liquid phase separation and, as a result, complete biomass retention (Kamali, et. al., 2016). Some studies have been carried out to investigate the efficiency of such systems for the treatment of paper and pulp mill wastewater (PPMW), and have shown 50–96% removal of chemical oxygen demand (COD) (Hall, et. al., 1995). COD is the amount of oxygen required to oxidize organic matter using a chemical oxidant. The COD test involves using chemical oxidants that oxidize both organic as well as inorganic matter in wastewater. Another important measure for wastewater treatment plants is the Biological Oxygen Demand (BOD_5). BOD_5 is the amount of oxygen required for the bacteria in a natural water body to decompose organic matter at a specific temperature. If the BOD_5 is higher, it means more of the dissolved oxygen in the rivers or lakes will go towards decomposing biological waste (INOVAR, 2021). For reference, the higher the BOD_5, the higher the pollutants present in water.

It is important to note that most of the development in the AD of P&P mill wastes have not been implemented in full-scale applications. In this regard, further work is required to evaluate and enhance the performance of these promising lab-scale technologies for large-scale operation in P&P mills (Kamali, et. al., 2016).

With regards to UASB reactors, this technology is the most widely approached system worldwide (Chong, et. al., 2012). A key feature of a UASB reactor is that it accepts the paper mill's granular sludge, which retains highly active biomass, and shows a very low sludge volume index (SVI). In turn, this leads an improvement of the sludge-effluent separation (Fig.1).

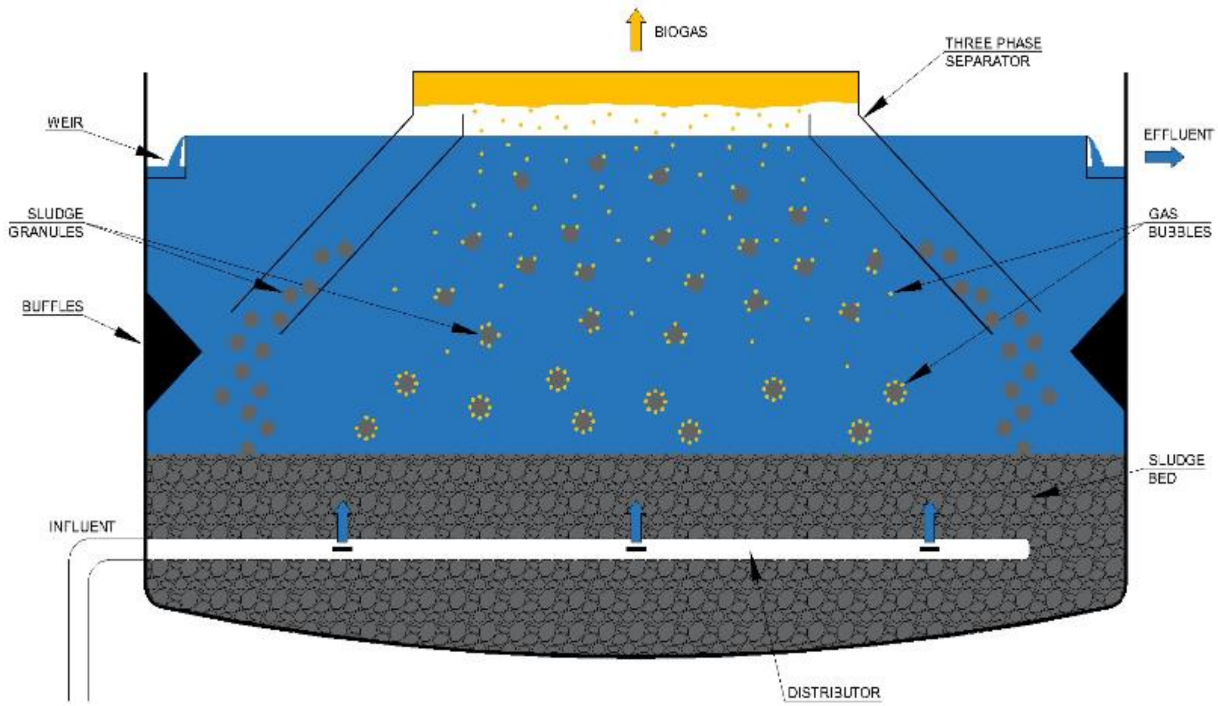

Figure1: Up-Flow anaerobic sludge blanket (UASB) reactor process theme (Mainardis, et. al., 2020)

Additionally, UASB treatment requires low energy consumption, is efficient at a higher loading rate and needs limited micro and macro-nutrients, producing a reduced amount of sludge, that is characterized by an improved dewaterability (Lim & Kim, 2014).

The most important aspects to be controlled when applying a UASB treatment are reactor start-up and granulation enhancement, coupling the anaerobic section with a post-treatment unit to efficiently abate organic matter, nutrients and pathogens (Chong, et. al., 2012). Biogas is a renewable and valuable source of energy. The biogas that is generated will be used to produce steam in a dedicated steam generator, which is another way to save energy. The biogas will be desulfurized in a two-stage reactor in which it is scrubbed with activated sludge from the aerobic treatment (GWE, 2019). After desulfurization, the biogas is dried before is it compressed and transferred to the steam generator. By using the biogas as a source of energy, a contribution is made to a circular economy. Thus, this leads to the original hypothesis: if we invest in digestor projects at water resource recovery facilities (WRRFs) in industries such as paper & pulp mill companies that have wastewater treatment onsite, we can produce sustainable energy from waste.

3. Global Case Studies on Paper & Pulp Mill Companies that have applied UASBs

3.1. Case study: an industrial paper mill in the state of São Paulo (Brazil)

This case study includes a paper mill located in the state of São Paulo, Brazil, which has invested USD 3.4 million in an advanced wastewater treatment system from 2004 to 2014. (Ferreira et al., 2019). The advanced wastewater treatment facility consists of three different parts. The primary treatment consists in an equalization tank and an effluent flotation system. The secondary treatment consists of UASB reactors (UASB 1 and 2). The first UASB reactor was incorporated into the existing effluent treatment system at the mill in 2004. In 2014, a second UASB reactor was incorporated. Finally, the tertiary treatment is performed in an aerobic polishing pond. This advanced wastewater treatment system includes different parts/streams involved (Fig. 2). More specifically, the first part is a conventional aerobic treatment system including primary settling and sludge digestion after treatment. The second part is a combined AD consisting of two UASB reactors, i.e., the beating heart of the developed biorefinery, where the generated biogas is directed to a boiler (to produce steam for heating) and a stationary engine (for electricity generation). The third part is an additional sludge digestion post-treatment including a polishing pond. At this stage, contaminants are removed in accordance with the environmental regulations, offering the possibility of using the treated effluent as reuse water in the paper and pulp production stage. Furthermore, the UASB reactor bottom sludge could be applied as soil fertilizer or could be further processed by pyrolysis to produce biochar which can be used as soil conditioner (Buller et al., 2014; Elkhalifa, 2019) and activated carbon (Alhashimi, 2017).

The integration of the processes presented below can be classified as a biorefinery. The use of biogas to generate heat and power could contribute to decreased consumption of natural gas (NG) in the plant while reducing the plant`s overall CO_2 emissions.

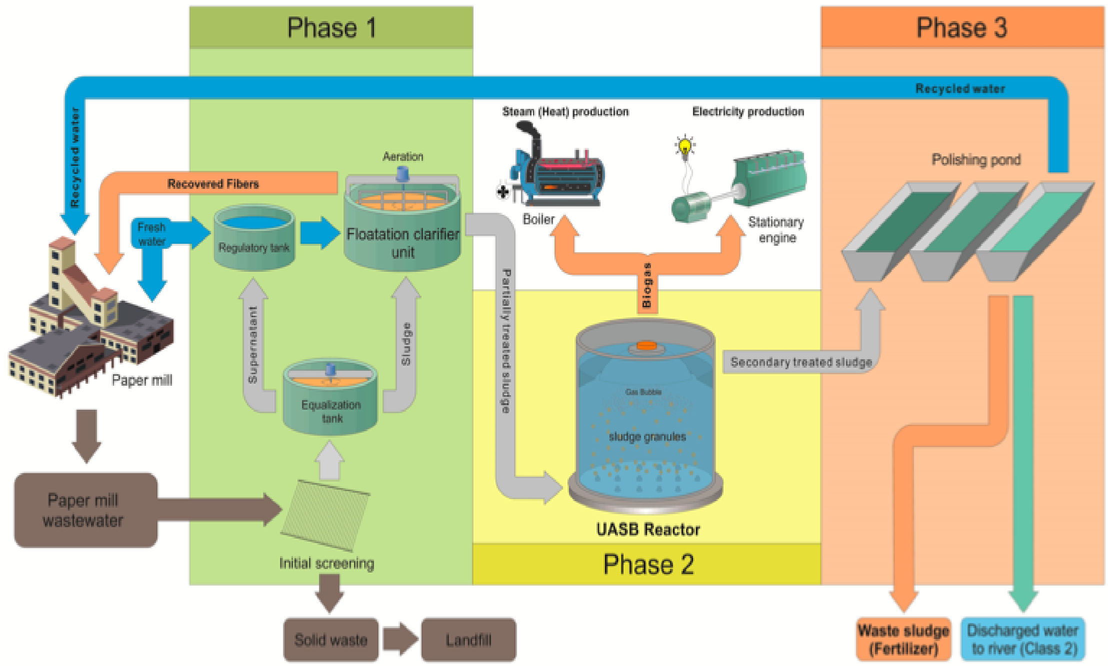

Figure2: A UASB schematic of a paper & pulp mill company for simultaneous wastewater treatment and bioenergy/biomaterial recovery (Ferreira et al., 2019)

3.2. Case study: an industrial paper mill in the province of Guayas (Ecuador)

Papelera Nacional (PANASA) is the main producer of medium corrugated paper and test liner for Ecuador. PANASA's plant has a liquid effluent treatment system consisting of a physical-chemical process using a Krofta clarification system, primarily to remove suspended solids from the wastewater. Sludge removed from the system is used for compost, as it is nontoxic and consists primarily of nonrecoverable fiber from the recycled paper. The compost is used to fertilize PANASA's garden. The wastewater is then routed to 4 natural aeration lagoons and then discharged during seven months of the year to an adjacent sugar cane plantation for irrigation (IDBInvest, 2021). These lagoons provided the secondary treatment of effluents, but did not allow the purification of their wastewater and discharge in accordance with the values defined in current environmental legislation. With the BOD_5 parameters of 100 mg/L and the COD of 250 mg/L, the company faced possible sanctions by local authorities and additionally, its discharges seriously impacted the Saraguayo estuary that receives these waters, causing the life of the river to be seriously affected (Fig.3).

Additionally, unforeseen spills due to activities exogenous to those of the company, caused these discharges to be evacuated without primary treatment to the lagoons, resulting in a distortion of the lagoons biological makeup and accumulating a greater contaminant load to be purified (Gonzalez, 2015).

Figure3: Previous PANASA Water Lagoons (Gonzalez, 2015)

In 2019, PANASA implemented a wastewater treatment plant tackling two of the biggest problems faced by the pulp and paper industry – efficient wastewater treatment and fossil fuel dependency. The organic contamination present in the PANASA's wastewater stream was converted to biogas through T Expanded Granular Sludge Bed (EGSB). T anaerobic reactors are designed with a focus on minimal maintenance and operational requirements. Their tower-like design also saves a significant amount of space compared with other wastewater treatment plant designs (GWE, 2019).

The high efficiency of the wastewater treatment system helped to reduce the environmental footprint of forward-thinking companies like PANASA. The savings produced by replacing fossil fuels will ultimately cover the entire cost of the wastewater treatment plant and then go on producing profit for the client. This is an example of a successful waste-to-energy technology incorporated into PANASA's existing aerobic wastewater treatment facilities as a turnkey project.

4. Methods: Analysis of applying UASB technology on a Paper & Pulp Mill

4.1 An industrial paper mill company in the city of Cochabamba and Santa Cruz (Bolivia)

After gathering the background information on different companies, a Life-Cycle Assessment (LCA) study was conducted on the selected paper mill company in Cochabamba, Bolivia, both before and after the implementation of the waste to energy conversion system to compare the magnitude of the environmental improvement that could be achieved.

4.2 Subject Background

The company COPELME S.A. is an enterprise dedicated to the production of tissue paper, and a major portion of its product lines are based on recycled paper. All its products are sold in Bolivia's 9 departments and it is the most important paper mill company nationwide. Due to the high demand of water that is used in the production process, an effluent treatment plant is required, so that recirculation of water into the production process is possible. Consequently, in 2012 the project of building a new effluent treatment plant was carried out. This was done in two stages; The first one consisted of a Dissolved Air Flotation system (DAF) and two screw presses. The second one was the implementation of two Anaerobic Biological Treatment plants, one in each of its facilities located in Cochabamba and Santa Cruz. Both consist of an activated sludge reactor, a lamella separator, and a pair of sand filters. The purpose of wastewater treatment plants is to mimic the natural process of self-purification of water. Removing most of the suspended solids (SS), also known as the primary treatment; BOD (secondary treatment); pathogens and less than half of the nitrogen and phosphorus (tertiary treatment).

4.3 Schematics

All urban or industrial wastewater depends on the same processes in general: primary, secondary and tertiary treatments, using only those that are of application to the concrete industrial process.

As it is the case of the plant in Santa Cruz, the schematic represents both primary and secondary treatments together (Fig.4).

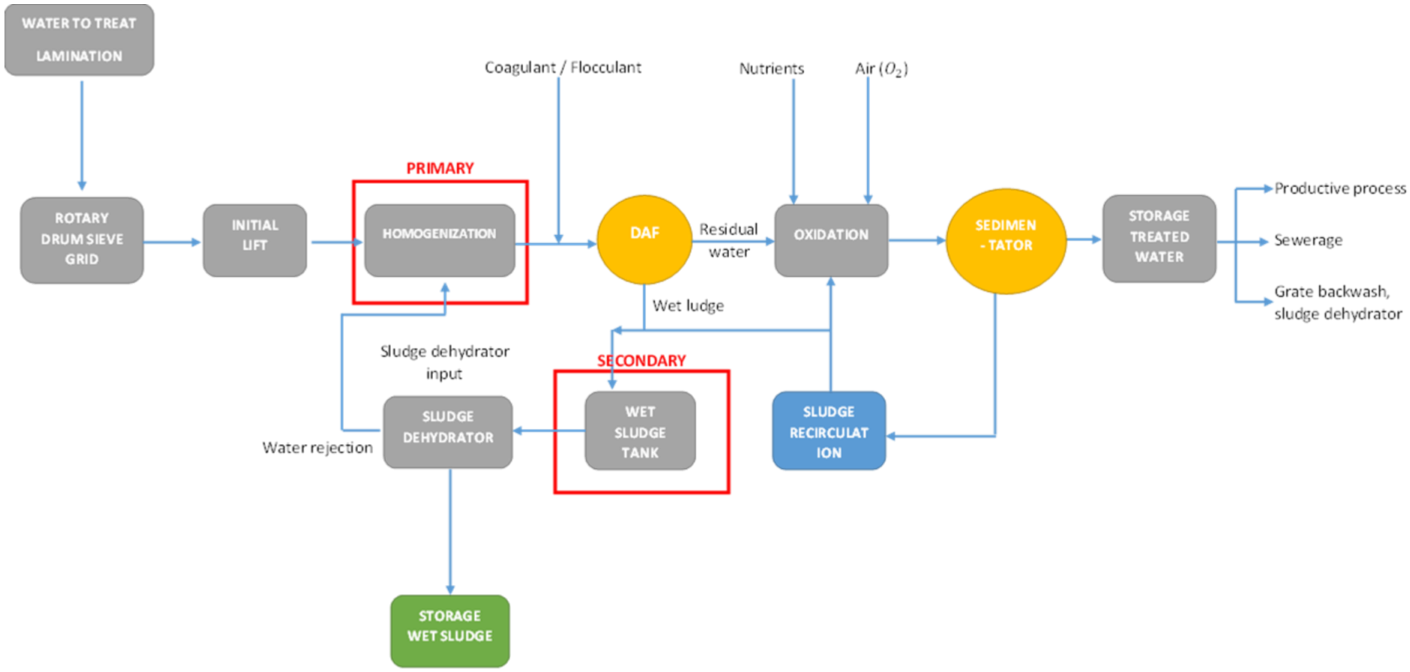

Figure4: Primary & Secondary treatment schematics of plant in Santa Cruz, Bolivia (Copelme S.A., 2021)

In the case of the plant in Cochabamba, the schematics are divided in two parts for both primary and secondary treatment processes (Fig.5).

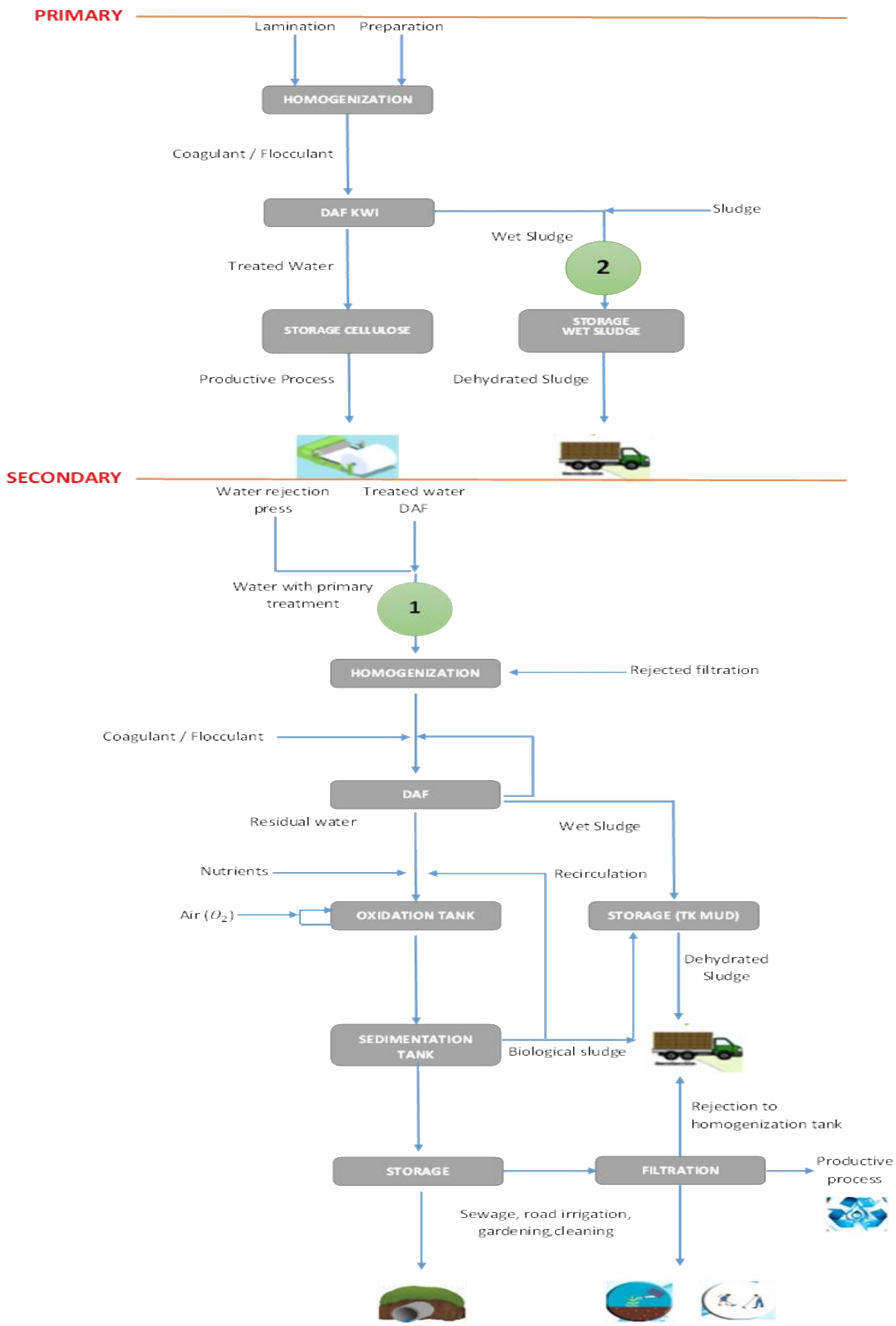

Figure5: Primary and secondary treatment schematic of the plant in Cochabamba, Bolivia (Copelme S.A., 2021)

The biological treatment of wastewater involves the removal of contaminants through biological activity, which is used to eliminate mainly organic substances that are biodegradable, colloidal, or dissolved, from wastewater, through its conversion of gases that escape into the atmosphere and through extractable biomass coming from the sedimentation.

The most important mechanism for the removal of organic matter present in the residual water, is the bacterial metabolism. The metabolism consists of the utilization by the bacteria of the organic matter as a source of energy and carbon to generate new biomass. When the organic matter is metabolized, part of it is transformed chemically into final products, in a process that is accompanied by the release of energy called “Catabolism”. Another process called "Anabolism or Synthesis" occurs simultaneously, where part of the organic matter is transformed into new cellular material (Ledesma, 2015).

4.4 Anaerobic Digestion Lab Analysis

In order to analyze if the implementation of UASB technology is feasible, anaerobic digestion factors have to be analyzed to see if the water and sludge of the company meet the standards needed to implement this technology (Fig.7).

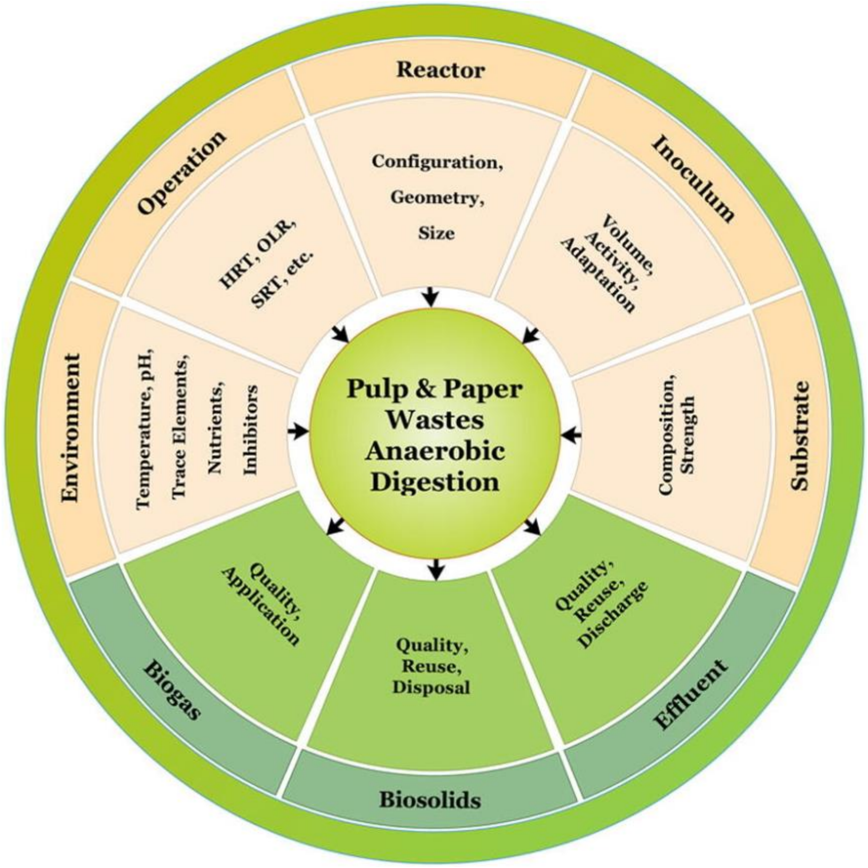

Figure7: Factors involved in the Anaerobic Digestion (AD) of P&P mill (Kamali et al., 2016)

Samples of the metrics were taken through including factors such as sedimentation, infiltration, Volatile Solids (VS), Total Suspended Solids (TSS), Total and Soluble COD, Total Nitrogen (TN), Soluble Nitrogen (SN), Ammonium (NH4-N), Nitrite (NO2-N), Nitrate (NO3-N), Total Phosphorus (TP), Soluble Phosphorus (SP), Sulphide (S2−), hardness concentrations, pH, salinity and chlorine concentrations. The technique used to collect this data was taken following an effluent analysis using the Standard Methods for the examination of water and wastewater through a laboratory to analyze these metrics and samples (Figs.8,9,10,11).

4.5 Lab Results: Plant in Santa Cruz, Bolivia

Quebracho
SERVICIOS DE PROTECCIÓN AMBIENTAL S.R.L.

LABORATORIO AMBIENTAL
Direccion: Av. Esmeralda # 209 paralela a
Doble Via a la Guardia entre 5to y 6to Anillo
Telf.: 3532403 - 3527122 / 721-00840 - 68937700
E-mail: quebracho@quebracho.com.bo
www.quebracho.com.bo

INFORME DE LABORATORIO

Empresa	: COPELME	**Solicitud**	: Q 496/21
Nº de Orden	: 4831/21	**Código de Laboratorio**	: 1515A
Lugar	: PILAT	**Código del Cliente**	: RS-01
Punto de muestreo	: TANQUE DE HOMOGENIZACION	**Volumen**	: 1000 ml
Fecha de muestreo	: 2021-08-10	**Hora de muestreo**	: 10:35
Fecha de recepción	: 2021-08-10	**Hora de recepción**	: 18:00
Fecha de análisis	: 2021-08-11	**Fecha de entrega**	: 2021-08-26
Muestreado por	: QUEBRACHO S.R.L.-D.S.V.		

ANÁLISIS FISICOQUÍMICO DE AGUA RESIDUAL

Ítem	Parámetro	Unidad	Método	Limite de Cuantificación	ANEXO A-2	Resultado
1	Aceites y Grasas	mg/l	Infrarrojo EPA 413.2***	0.1	20	<0.1
2	Amonio-N	mg/l	Method (8038)**	0.02	4	0.88
3	Cadmio	mg/l	ASTM D 3557-02A(*)	0.005	0.3	<0.005
4	DBO5	mg/l	Cálculo	1	80	301
5	DQO	mg/l	Method (8000)**	3	300	1203
6	Nitratos	mg/l	Method (8039)**	0.3	45	6.5
7	Nitritos	mg/l	Method (8507)**	0.002	NV	0.005
8	Plomo	mg/l	ASTM D 3559-03A(*)	0.03	NV	<0.03
9	Potencial Redox	mv	Electrométrico (4500-H+B)*^	-	6-9	8.70
10	Sólidos Disueltos Totales	mg/l	Electrométrico (2540-C)*	-	NV	299.00
11	Sólidos Suspendidos Totales	mg/l	Gravimetrico*	1	60	798
12	Solidos Totales a 103°C	mg/l	Gravimetrico (2540-B)*	1	NV	1354

ENSAYOS MEDIDOS IN SITU

*^ Métodos normalizados para análisis de aguas potables y residuales : APHA, AWWA y WPCF - Edición 22
** Métodos HACH para el espectrofotómetro DR 3900 con certificación ISO 9001
*** Métodos normalizados por Horiba para el equipo OCMA-350 con certificación ISO 9001
(*) Subcontratado.

Información Adicional:

ANEXO A-2: Limites permisibles para descargas líquidas según el Reglamento en Materia de contaminación Hídrica, Ley 1333 del Medio Ambiente.

Ing. Silviana Guzman Justiniano
R.N.I. 18.013
Jefe de Laboratorio

QUEBRACHO S.R.L.
SERVICIO DE PROTECCION AMBIENTAL
NIT: 1012577027
LABORATORIO

Ing. Lizeth Carballo Choque
Analista de Laboratorio

Código: RLB/ 002 V:004

c/c/ Laboratorio

Figure8: Homogenization tank lab results of plant in Santa Cruz, Bolivia (Quebracho Labs, 2021)

LABORATORIO AMBIENTAL
Direccion: Av. Esmeralda # 209 paralela a Doble Via a la Guardia entre 5to y 6to Anillo
Telf.: 3532403 - 3527122 / 721-00840 - 68937700
E-mail: quebracho@quebracho.com.bo
www.quebracho.com.bo

INFORME DE LABORATORIO

Empresa	: COPELME	**Solicitud**	: Q 496/21
Nº de Orden	: 4831/21	**Código de Laboratorio**	: 1516A
Lugar	: PILAT	**Código del Cliente**	: RS-02
Punto de muestreo	: TANQUE DE LODOS	**Volumen**	: 1000 ml
Fecha de muestreo	: 2021-08-10	**Hora de muestreo**	: 10:45
Fecha de recepción	: 2021-08-10	**Hora de recepción**	: 18:00
Fecha de análisis	: 2021-08-11	**Fecha de entrega**	: 2021-08-26
Muestreado por	: QUEBRACHO S.R.L.-D.S.V.		

ANÁLISIS FISICOQUÍMICO DE AGUA RESIDUAL

Ítem	Parámetro	Unidad	Método	Limite de Cuantificación	ANEXO A-2	Resultado
1	Aceites y Grasas	mg/l	Infrarrojo EPA 413.2***	0.1	20	81.2
2	Amonio-N	mg/l	Method (8038)**	0.02	4	8.05
3	Cadmio	mg/l	ASTM D 3557-02A(*)	0.005	0.3	<0.005
4	DBO5	mg/l	Cálculo	1	80	8562
5	DQO	mg/l	Method (8000)**	3	300	34250
6	Nitratos	mg/l	Method (8039)**	0.3	45	50.6
7	Nitritos	mg/l	Method (8507)**	0.002	NV	0.095
8	Plomo	mg/l	ASTM D 3559-03A(*)	0.03	NV	<0.03
9	Potencial Redox	mv	Electrométrico (4500-H+B)*^	-	6-9	135.10
10	Sólidos Disueltos Totales	mg/l	Electrométrico (2540-C)*	-	NV	343.0
11	Sólidos Suspendidos Totales	mg/l	Gravimetrico*	1	60	20500
12	Solidos Totales a 103°C	mg/l	Gravimetrico (2540-B)*	1	NV	21732

ENSAYOS MEDIDOS IN SITU

*^ Métodos normalizados para análisis de aguas potables y residuales : APHA, AWWA y WPCF - Edición 22
** Métodos HACH para el espectrofotómetro DR 3900 con certificación ISO 9001
*** Metodos normalizados por Horiba para el equipo OCMA-350 con certificacion ISO 9001
(*) Subcontratado.

Información Adicional:
ANEXO A-2: Limites permisibles para descargas liquidas según el Reglamento en Materia de contaminación Hidrica, Ley 1333 del Medio Ambiente

Ing. Silviana Guzman Justiniano
R.N.I. 18.013
Jefe de Laboratorio

QUEBRACHO S.R.L.
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LABORATORIO

Ing. Lizeth Carballo Choque
Analista de Laboratorio

Código: RLB/ 002 V:004

c/c/ Laboratorio

Figure9: Sludge tank lab results of plant in Santa Cruz, Bolivia (Quebracho Labs, 2021)

Table 1: Summary of lab results of plant in Santa Cruz, Bolivia (Copelme S.A., 2021)

Parameters		**Option 1**	**Option 2**
	Units	**Before Aerobic Treatment**	**Humid Sludge**
COD	mg/L	787	N/A
BOD_5	mg/L	200	N/A
Suspended Solids	mg/L	268	5968
pH	n/a	7,4	7,6
Conductivity	mS/cm	458	388
Temperature	ºC	25	19,37
Water Flow	m^3/h	20 - 40	4

It is important to note that these water samples were taken before the water was treated. The reason for this is to compare the current aerobic wastewater treatment plant that the company has and how much it reduces its COD and BOD_5 parameters once the water is treated. Based on an evaluation of the current water treatment in Santa Cruz, it was considered as a first option to implement the anaerobic treatment only in Cochabamba before the current aerobic treatment. The treatment to the wet sludge - the byproduct of the DAF system, has higher concentrations in the Cochabamba plant as it used both recycled and cellulose materials. This option takes into account the paper fiber load at that point, and can lead to the recovery of as much energy or biogas as possible.

4.6 Lab Results: Plant in Cochabamba, Bolivia

spectrolab

Servicios Analíticos - Laboratorio Químico
Unidad Descentralizada - Universidad Técnica de Oruro

FOR - INFORME DE ENSAYO - 01
Revisión:00
Emisión 2015 - 06 - 20

INFORME DE ENSAYO

Nº.: 47546

NOMBRE DEL CLIENTE	**COPELME S.A.**		
DIRECCIÓN DEL CLIENTE	**Av. Rafael Mendoza S/N, Zona Challacollo**		
CARACTERÍSTICAS	**Lodo**		
PROCEDENCIA	**		
RESPONSABLE MUESTREO	**	*FECHA DE MUESTREO*	**
FECHA RECEPCIÓN	**2021-07-30**	*FECHA DE ENSAYO*	**Según detalle**
PÁGINA	**3/4**	*FECHA DE ENTREGA*	**2021-08-30**

RESULTADOS:

Parámetros		Unidades	Fecha de Ensayo	Método	L.D.	Código Cliente: Lodo / Código Laboratorio: 3974
Sólidos Disueltos		mg/l	2021-08-09	STM 2540 C	5	6024
Sólidos Suspendidos		mg/l	2021-08-09	DIN 38409 T2	1	73209
Sólidos Totales		mg/l	2021-08-09	DIN 38409 H1	1	79233
Cadmio	Cd	mg/l	2021-08-03	ASTM-3557-12 A	0,012	<0,012
Plomo	Pb	mg/l	2021-08-03	ASTM-3559-15 A	0,109	<0,109
Amonio	NH_4^+	mg/l	2021-08-05	ASTM D 1426-03	0,05	16,18
Nitratos	NO_3^-	mg/l	2021-08-02	DIN 38405 T10 mod.	0,01	22,44
DBO_5		mg/l	2021-08-06	DIN 38409 T 51 mod.	5	11553
DQO		mg/l	2021-08-09	ASTM D 1252-00	2	17773
Potencial Rédox		mV	2021-07-30	Potenciometría		226

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FOR - INFORME DE ENSAYO - 01
Revisión:00
Emisión 2015 - 06 - 20

INFORME DE ENSAYO

Nº.: 47546

NOMBRE DEL CLIENTE	**COPELME S.A.**		
DIRECCIÓN DEL CLIENTE	**Av. Rafael Mendoza S/N, Zona Challacollo**		
CARACTERÍSTICAS	**Lodo**		
PROCEDENCIA	**		
RESPONSABLE MUESTREO	**	*FECHA DE MUESTREO*	**
FECHA RECEPCIÓN	**2021-07-30**	*FECHA DE ENSAYO*	**Según detalle**
PÁGINA	**4/4**	*FECHA DE ENTREGA*	**2021-08-30**

RESULTADOS:

Parámetros	Unidades	Fecha de Ensayo	Método	L.D.	Código Cliente: Lodo / Código Laboratorio: 3974
Aceites y grasas	mg/kg	2021-08-09	EPA 1664 A	0,3	645,6

REFERENCIAS

****Responsabilidad del Cliente**

LD/ppm = Límite de determinación en partes por millón .

Valor con símbolo "<" implica por debajo del límite de determinación.

Figure10: Sludge tank lab results of plant in Cochabamba, Bolivia (SpectroLab, 2021)

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Revisión:00
Emisión 2015 - 06 - 20

INFORME DE ENSAYO

Nº.: 47546

NOMBRE DEL CLIENTE	**COPELME S.A.**		
DIRECCIÓN DEL CLIENTE	**Av. Rafael Mendoza S/N, Zona Challacollo**		
CARACTERÍSTICAS	**Agua**		
PROCEDENCIA	**		
RESPONSABLE MUESTREO	**	*FECHA DE MUESTREO*	**
FECHA RECEPCIÓN	**2021-07-30**	*FECHA DE ENSAYO*	**Según detalle**
PÁGINA	**1/4**	*FECHA DE ENTREGA*	**2021-08-30**

RESULTADOS:

					Código Cliente	Agua
					Código Laboratorio	3973
Parámetros		**Unidades**	**Fecha de Ensayo**	**Método**	**L.D.**	
Sólidos Disueltos		mg/l	2021-08-09	STM 2540 C	5	3786
Sólidos Suspendidos		mg/l	2021-08-09	DIN 38409 T2	1	256
Sólidos Totales		mg/l	2021-08-09	DIN 38409 H1	1	4042
Amonio	NH_4^+	mg/l	2021-08-05	ASTM D 1426-03	0,05	15,19
Nitratos	NO_3^-	mg/l	2021-08-02	DIN 38405 T10 mod.	0,01	17,52
DBO_5		mg/l	2021-08-05	DIN 38409 T 51 mod.	5	1821
DQO		mg/l	2021-08-09	ASTM D 1252-00	2	2601
Potencial Rédox		mV	2021-07-30	Potenciometría		304

REFERENCIAS
**Responsabilidad del Cliente
LD/ppm = Límite de determinación en partes por millón .
Valor con símbolo "<" implica por debajo del límite de determinación.
DBO_5 = Demanda Bioquímica de Oxígeno en 5 días
DQO = Demanda Química de Oxígeno

Laboratorio de ensayo acreditado IBMETRO DTA-CET-032

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Emisión 2016 - 01 - 25

INFORME DE ENSAYO

Nº.: 47546

NOMBRE DEL CLIENTE	**COPELME S.A.**		
DIRECCIÓN DEL CLIENTE	**Av. Rafael Mendoza S/N, Zona Challacollo**		
CARACTERÍSTICAS	**Agua**		
PROCEDENCIA	**		
RESPONSABLE MUESTREO	**	*FECHA DE MUESTREO*	**
FECHA RECEPCIÓN	**2021-07-30**	*FECHA DE ENSAYO*	**Según detalle**
PÁGINA	**2/4**	*FECHA DE ENTREGA*	**2021-08-30**

RESULTADOS:

					Código Cliente	Agua
					Código Laboratorio	3973
Parámetros		**Unidades**	**Fecha de Ensayo**	**Método**	**L.D.**	
Cadmio	Cd	mg/l	2021-08-05	ASTM-3557-12 A	0,012	<0,012
Plomo	Pb	mg/l	2021-08-05	ASTM-3559-15 A	0,109	<0,109

REFERENCIAS
**Responsabilidad del Cliente
LD/ppm = Límite de determinación en partes por millón .
Valor con símbolo "<" implica por debajo del límite de determinación.

Figure11: Water tank lab results of plant in Cochabamba, Bolivia (SpectroLab, 2021)

Table 2: Summary of lab results of plant in Cochabamba, Bolivia (Copelme S.A., 2021)

Parameters		Option 1	Option 2
	Units	**Before Aerobic Treatment**	**Humid Sludge**
COD	mg/L	3900	N/A
BOD_5	mg/L	2560	N/A
Suspended Solids	mg/L	390	9,6
Turbidity	NTU	860	ND
pH	n/a	7,8	7,8
Conductivity	mS/cm	2,85	2,7
Temperature	ºC	28	28
Water Flow	m^3/h	25 - 60	6

The technique used to collect this data was taken following an effluent analysis using the Standard Methods for the examination of water and wastewater through a laboratory to analyze these metrics and samples. This sample analysis was sent to two UASB supplier companies and an analysis on each was made to see if a digester project can be applied to the company or additional steps will be required to fully become a WRRF.

5. Analysis: UASB Supplier Company Proposals on Copelme S.A.

An internal evaluation was made on the challenges faced when implementing a UASB from two different supplier companies including the costs associated with this technology, how well it will accept the consistency of the organic sludge waste, and the time needed for application.

5.1 Case study: Empresa de Enghenaria Ambiental (EEA) located in Rio Claro, Brazil

Environmental Engineering Company (EEA) is a company of projects and execution of Sanitary Waste Treatment Stations and Industrial Effluents, and has been in the market since 1999. In its 23 years of history, EEA carried out works throughout their national territory in Brazil as well as internationally, standing out for the quality of its equipment and its engineering (EEA, 2022).

EEA's proposal was to install a Sanitary Sewage Treatment Station with average efficiency of removal of 70% BOD (without physical chemical nutrient removal). Their proposal included the application of UASB model of 250 m^3/day with a guarantee of 5 years (Fig.12).

Orçamento 6 x UASB 250 m^3/dia – Modelo D2				
Item	Descrição	Qtd.	Vlr. Unit.	Subtotal
1	Reator UASB PRFV	1	-	-
2	Escada marinheiro padrão para reator vertical com 6m de altura – aço carbono	1	-	-
3	Passarela para interligação - Aço Carbono	5	-	-
4	Guarda corpo padrão UASB - Aço Carbono	6	-	-
	VALOR GLOBAL – EQUIPAMENTOS *			**R$ 2.016.000,00**

Figure12: EEA proposal on UASB reactor for Copelme S.A. (EEA, 2022)

In this proposal, a table was made to include the internal costs such as construction work and electrical installations, elevator pump, energy generator and other. The total cost of the investment equals $1,362,980 (Table 3).

Table 3: Summary of total investment cost from UASB proposal (Copelme S.A., 2021)

Description	**Cost $USD**
UASB Equipment	631.980
Electrical Installation	63.000
Civil Work Execution	63.000
Elevator Pump	80.000
Energy Generator	500.000
Other Expenses	25.000
Total ($USD)	**1.362.980**

According to the EEA plant data collected from a paper mill client in Louisiana, there would be an estimated energy generation of 0.457m^3 of biogas per Kg of COD. With regards to the production of recycled paper, a load of 1,536 Kg COD/day is generated. The generation power is approximately 702m^3 of biogas per day. Assuming a heat capacity of biogas of 5,500 Kcal/m^3, there would be a generation of 3,861,943 Kcal/day.

Copelme S.A. currently consumes around 450 MCF (Mille Cubic Feet) of natural gas per day with a heat capacity of 10,301 Kcal/m^3. The generated volume of biogas could cover the energy consumed of 13.2 MCF of natural gas per day, equal to approximately 2.9%.

With regards to the cost, currently the company pays 14.6 Bs/MCF, which in turn by applying this UASB, it is estimated that the company would save 193.5 Bs/day. These saving do not consider the UASB operating cost.

Although theoretically, by lowering the power load to 30% of the current load by the application of this UASB, a saving in that same proportion is considered, and it is important to note that currently, with the equipment it has, to obtain the theoretical savings, new investments must be made on behalf of the company to adapt to the hydraulic design capacity. With the reduction of the load, a saving of approximately 467.7 Bs/day could be generated.

Looking at this data, an analysis of the return of investment was made which shows the company would get its investment back in approximately 39.3 years (Table 4).

Table 4: Return of investment of the UASB proposal from EEA (Copelme S.A., 2021)

Description	Quantity	Units
Biogas Savings	193,5	Bs/day
Aerobic Charge Savings	467,7	Bs/day
Total Savings in Bolivianos/day	661,2	Bs/day
Total Savings in US dollars/day	95	$USD/day
Total Investment	1.362.980	$USD
Time of Return of Investment	**39,3**	**Years**

5.2 Case study: Global Water & Energy

GLOBAL WATER & ENERGY (GWE), a member of the Global Water Engineering Group of Companies, is a Belgian solutions provider to the global marketplace for industrial wastewater treatment, water reuse and green energy production. To that end, GWE offers state-of-the-art technologies to assist industries and private owners in their efforts to grow, while reducing their operational costs (GWE, 2022).

A preliminary study for the anaerobic pretreatment of the company's effluents was made. GWE provided a 'Flow Chart' document (Fig.13) which opted to propose their ACTIVOX^{TM}-B technology, a UASB-type anaerobic reactor. This reactor takes medium to high loading rates and is highly effective on a large variety of wastewaters. Handles concentrated wastewaters that take up to 30,000 mg/L COD and requires low suspended solids content: TSS/COD < 0.1 (GWE, 2022).

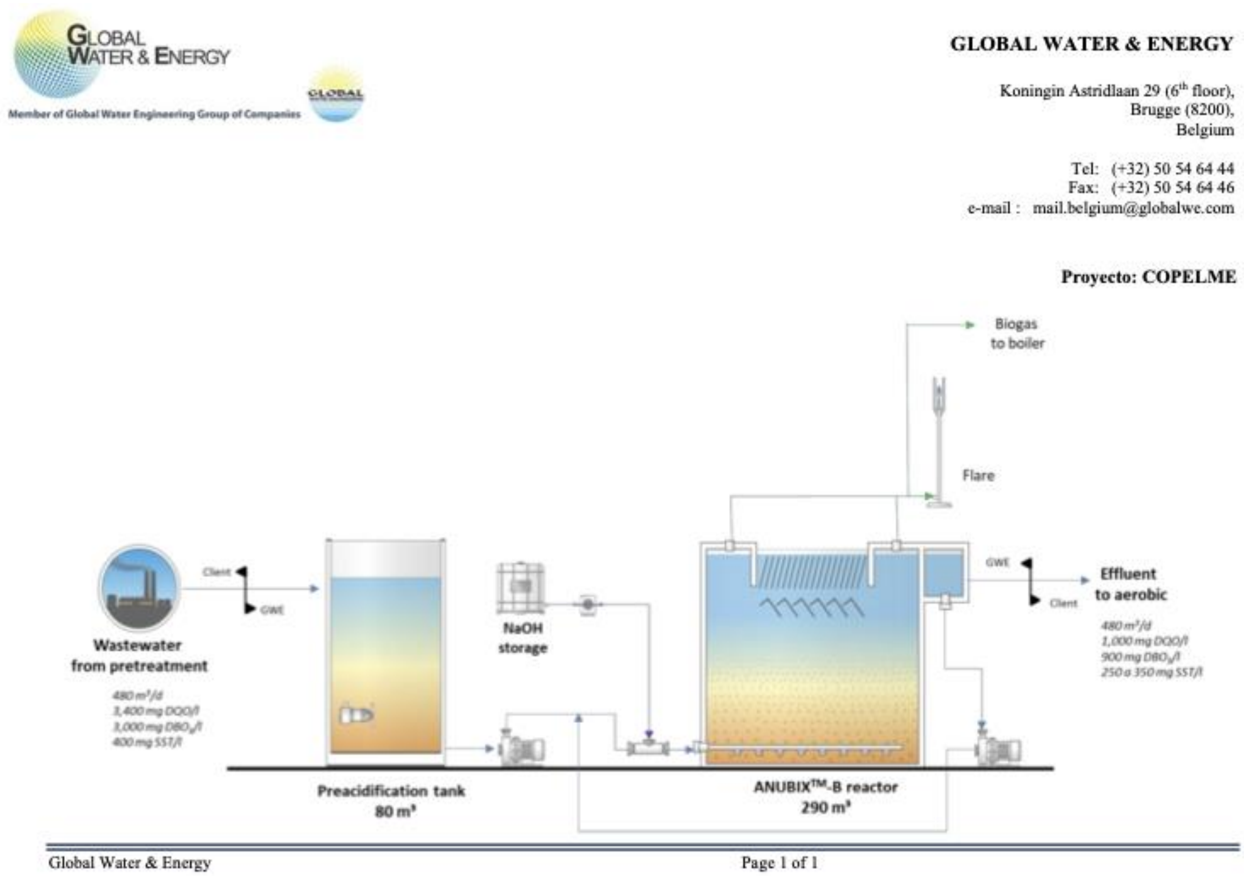

Figure13: GWE proposal on UASB reactor for Copelme S.A. (GWE, 2022)

The plant would be built in concrete and will not have the appearance of a WWTP). The space required would be 14m L x 5.5m W = 77 m2.

Considering the unit costs provided by the Copelme S.A., they would be generating savings of 100€ euro/day due to the reduction in energy consumption, natural gas consumption (they would burn the biogas in the company's boiler) and less sludge production. These savings are contained since Copelme's prices for electricity and sludge disposal are very low (normally, in Latin America, the price of electric kWh ranges between 0.08 eur/kWh and 0.2 eur/kWh and sludge disposal between 30 eur/m^3 and 50 euros/m^3) (GWE, 2022).

As for the investment, they would be talking about 600,000 euros ±10% (considering the modification of their boiler to accept biogas), to which they would add the electromechanical assembly and civil works. Therefore, with the savings generated, it would be difficult to justify the investment, unless Copelme S.A. expands the treatment capacity of their current WWTP. The estimated investment cost was summarized (Table 5).

Table 5: Summary of total investment cost from UASB proposal (Copelme S.A., 2021)

Description	Cost in $US
UASB Equipment & Gas Installation	949.200
Electric Installation	33.000
Civil Work	105.000
Mechanical Installation	30.000
Other Expenses	25.000
Total ($us)	**1.142.200**

Based on a similar analysis made for EEA, the total return of investment time calculated for GWE would be 28,8 years.

The estimate of how much CO_2 would be reduced was also calculated for GWE using the methodology of the UN Climate Change News (UNFCCC) following pre-established formulas taken from the IDB (Inter-American Development Bank). These were specifically acquired for projects applying the clean development mechanism under the Kyoto Protocol regarding the treatment of residual waters to determine the impact of the application of this wastewater resource recovery on the facility.

The first step consisted on calculating the emissions of the Global Energy Interconnection Development and Cooperation Organization (GEIDCO) taking the base scenario, in which the following equation was used (Table 6):

$$BE = \left(Q * COD_d * MCF * B_0 + S * DOC * MCF_s * DOC_f * F * \frac{4}{3}\right) * GWP_{CH4} * UF + EC * EF$$

In which:

Table 6: GEIDCO base scenario equation to calculate Co^2 emissions **(**BID & Nolasco, D. A., 2010)

BE: Baseline Emissions (tCO_2/year)
Q: Flow rate entering the treatment plant (m^3/year)
COD_d: COD degraded by the system (t/m^3)
MCF: Methane Correction Factor (according to table B of Annex II, lowest value)
B_o: maximum methane production capacity ($kgCH_4$/kgCOD)
S: Amount of Sludge generated in dry weight (t/year)
DOC: Organic matter content in the generated sludge (in dry weight)
MCF_S: Methane correction factor for the sludge treatment system (according to table B, lowest value)
DOC_F: Fraction of the DOC that transforms into biogas
F: Fraction of methane in biogas
GWP_{CH4}: Global Warming potential of methane ($kgCO_2e/kgCH_4$)
UF: factor uncertainty correction
EC: Energy Consumed
EF: Emission Factor of the Electrical Network (tCO_2e/MWh)

Additionally, the below equation to calculate the emissions the project would create was used (Table 7):

$$PE = Q * COD_d * B_o * GWP_{CH4}\, x\, L - EG * EF$$

In which:

Table 7: GEIDCO equation to calculate project's emissions (BID & Nolasco, D.A., 2010)

PE: Project Emissions (tCO_2e/year)
Q: Inlet Flow to the treatment plant (m^3/year)
COD_d: COD degraded by the system (t/m^3)
B_o: maximum methane production capacity ($kgCH_4$/kgCOD)
GWP_{CH4}: Global Warming potential of methane ($kgCO_2e/kgCH_4$)
L: Fraction of the biogas generated that is lost in the capture, routing and utilization system or burned
EG: Surplus amount of generated energy (= generation – project consumption) that displaces the use of fossil fuels or electricity (in this case MWh/year)
EF: Emission Factor of the Electrical Network (tCO_2e/MWh)

Considering the efficiencies of the anaerobic treatment, a discharge of COD of 1020 mg/L is reached, so it is necessary to complete the treatment by implementing the aerobic treatment with a lower load. The biogas generated is consumed in the boiler.

After this analysis, the expected total CO_2 reduction would be of 171.7 megatons (Mt) of CO_2 per year (Table 8) (Annex1).

Table 8: Summary of total CO_2 emission reductions from GWE proposal (Copelme S.A., 2021)

Current emissions of the aerobic treatment	**365 (Mt CO_2/year)**
Emissions of the anaerobic treatment project	81,7 (Mt CO_2/year)
Combination with aerobic treatment	112 (Mt CO_2/year
Expected Total CO_2 Reductions	**171,3 (Mt CO_2/year).**

The calculations resulted in a significant of CO_2 reduction, particularly when combining both an anaerobic and an aerobic treatment on the plant.

6. Result Analysis

6.1 Performing a LCA both before and after the implementation of the UASB reactor was challenging but very interesting once results where attained. In the results, a detailed examination was made of the advantages that can be gained when implementing UASB technology including cost savings in the long-term, energy created, as well as CO_2 reduced.

Without actual implementation of the reactor, it was difficult to be precise on the quantitative parts of the analysis but a close approximation was considered.

The advantages of having an existing aerobic treatment is that there is a stability in the load and flow variations and the current COD levels of Copelme S.A equal 140 mg/L after solid removal, falling wihtin the national limit of 250 mg/L. On the other hand, the main disadvantage that this current treatment has is its high energy consumption, hence the reason to look for alternative sources. Regarding anaerobic treatment, the advantage is that energy can be recovered, unlike an aerobic treatment. Nevetheless, aerobic treatments are highly unstable to load variations (typical in paper mills) and with this treatment alone, the COD levels calculated on both EEA’s and GWE’s proposal would equal approximately 1.020 mg/L after removal, surpassing the national limit of 250 mg/L (Fig.14).

Additionally, the investment that the company would have to incur to transform itself into a hybrid combination of both aerobic and anaerobic treatment plants was taken into consideration and both result in an approximate ROI of 29 -39 years. This is a huge disadvantage for the company, but on the other hand, combined, both their COD and BOD_5 have the lowest levels and as seen previously, the CO_2 emissions are reduced significantly. As the company is currently functioning through aerobic treatment plant, there is a higher adaptation to implement an anaerobic treatment plant as this is the only solution it would have to fully generate biogas as an alternative energy source.

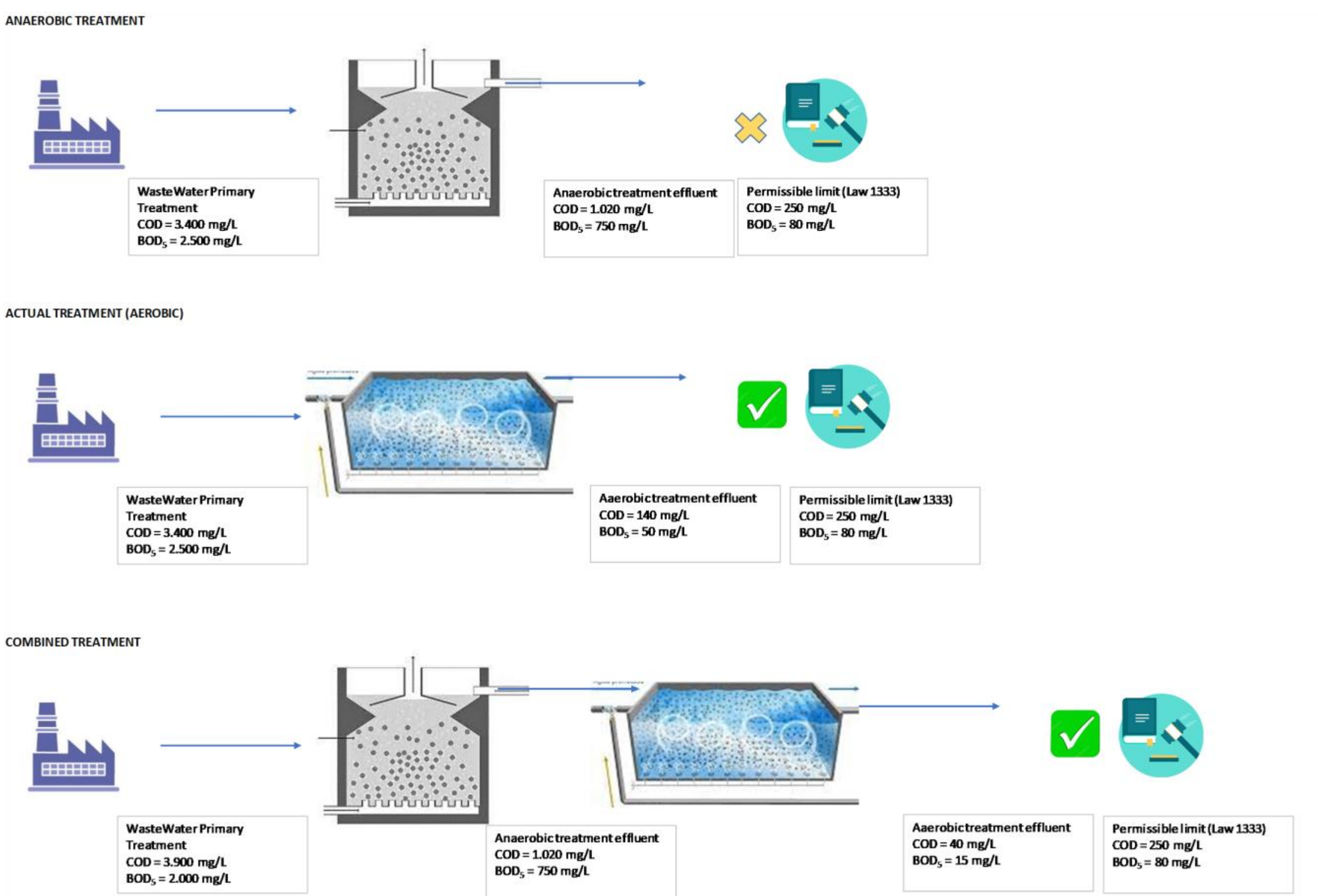

Figure14: Flow Chart comparing Anaerobic vs Aerobic treatments (Copelme S.A., 2021)

7. Permits & Regulations

According to the Bolivian Department of Environment on Law 1333, there are specific sections that have to be considered regarding the permits and limitations individuals and companies have on natural resource consumption and discharge to the environment.

7.1 Law on Natural Renewable Resources

Regarding the law on natural renewable resources, there are two explicit clauses that address a company's or individual's actions towards this resource.

ARTICLE 33.- The right of use of individuals over renewable natural resources is guaranteed, as long as the activity established on them is not detrimental to the collective interest and ensures their sustainable use and in accordance with the article of the present Law.

ARTICLE 34.- The special laws that are enacted for each natural resource must establish the rules that regulate the different modes, conditions and priorities for acquiring the right to use renewable natural resources in the public domain, according to the characteristics of the natural resources themselves, regional potentialities, and social, economic and cultural aspects.

7.2 Law on Air and Atmospheric Pollution

In order to regulate the activities of industries that can pollute the air and atmosphere, the following polluting sources are considered priority attention and control:

a) Combustion processes;

b) Processes that emit gases, particulate material and vapors;

c) Those that use, generate or emit volatile substances;

d) Those that emit noise and vibrations;

e) Those that emit ionizing and/or thermal radiation;

f) Those that emit polluting odors;

g) Those that emit ozone depleting substances.

The efforts of the industry must be reflected in the Environmental Management Plans, Annual Environmental Reports, renewal of the Industrial Environmental Registration form (RAI). The efforts of the industry are evaluated through the Information Evaluation and Disclosure System (SERI).

7.3 Law on Water Resources

Regarding the law on water resources, there are four explicit clauses that address a company's or individual's actions towards this resource.

ARTICLE 36.- The waters in all its states are the original domain of the State and constitute a basic natural resource for all vital processes. Its use is related to and has an impact on all sectors linked to development, so its protection and conservation is a fundamental task of the State and society.

ARTICLE 37.- The planning, protection and conservation of waters in all its states and the integral management and control of the basins where they are born or are found constitute a national priority.

ARTICLE 38.- The State will promote the planning, use and integral exploitation of waters, for the benefit of the national community, with the purpose of assuring its permanent availability; prioritizing actions in order to guarantee drinking water for the entire population.

ARTICLE 39.- The State will regulate and control the discharge of any substance or liquid, solid and gaseous residue that causes or may cause water pollution or the degradation of its environment. The corresponding organisms will regulate the integral exploitation, rational use, protection and conservation of the waters.

7.3 Law on Energy Resources

Lastly, regarding the law on energy resources, there are three explicit clauses that address a company's or individual's actions towards this resource (Congreso Nacional de Bolivia, 1992).

ARTICLE 74.- The Ministry of Energy and Hydrocarbons, in coordination with the National Secretariat of the Environment, will prepare the pertinent specific regulations. Likewise, it will promote research, application and use of non-polluting alternative energies.

ARTICLE 85.- Corresponds to the State and the specialized technical institutions:

85a) Promote and encourage scientific and technological research and development in environmental matter.

85b) Support the recovery, use and improvement of appropriate traditional technologies.

85c) Control the introduction or generation of technologies that threaten the environment.

85d) Promote the training of human resources and scientific activity in children and youth.

85e) Manage and control the transfer of technology of benefit to the country.

ARTICLE 86.- The State will give priority and will execute scientific and technological research actions in the fields of biotechnology, agroecology, conservation of genetic resources, use of energy, control of environmental quality and knowledge of the country's ecosystems.

Additionally, the revision of the Reglamento Ambiental para el Sector Industrial Manufactureo (RASIM), or the Environmental Regulation of the Manufacturing Industrial Sector (ERMIS), was made to further examine and compare if the company met the standard limits, particularly with COD and BOD_5 parameters. ERMIS regulates the activities of industries to protect and conserve the environment (RASIM, 2022). The objectives of the regulation are to reduce the generation of pollutants and the use of dangerous substances as well as optimize the use of natural resources and energy to protect and conserve the environment resulting in advancement of sustainable development.

In this examination, the water pollution clauses were specifically analyzed in which two of these stood out as most relevant to the future application of UASB technology stating the following:

ARTICLE 74 (Permissible limits).- The industry must comply with the permissible limits for discharges into bodies of water through the mixture parameter established in Annex 13-C.

ARTICLE 75 (Self-monitoring).- The industry must carry out self-monitoring of all the parameters that may be generated by its activities such as discharges. The industries contemplated, must carry out self-monitoring of the specified parameters in their discharges, according to standard methods available while the Bolivian Standard is established, and must maintain a record of sources and discharges for inspection by the authorities. Self-monitoring must be carried out at least once a year for each discharge point.

Regarding self-monitoring, Copelme S.A. uses accredited laboratories in Bolivia. Based on Annex 13-C of ERMIS, the permissible limits for liquid discharges regarding the main measurements with reference to the wastewater treatment plant are 80 mg/L for BOD_5 (DBO_5) and 250 mg/L for COD (DQO) (Table 9).

Table 9: Permissible limits for liquid discharges (RASIM, 2022).

NORMA - PARÁMETROS	Diaria	Mensual
Sólidos disueltos totales		500.0
Sólidos suspendidos totales	60.0	
Colifecales (NMP/100ml)	1000.0	
Aceites y grasas	10.0	
DB05	80.0	
DQ0	250.0	
Amonio como Nitrógeno	4.0	2.0
Sulfuros	2.0	1.0
Nitratos como Nitrógeno		10
Endrín		0.0002
Lindano		0.004
Metoxicloro		0.1
Toxafeno		0.005
Trihalometanos totales		0.1
Plata		0.1
Selenio		0.01

Looking at these low limits, a comparison was found between COD and BOD_5 in Bolivia rivalled to the parameters in other countries (Figs.15,16).

PARÁMETROS FISICOQUÍMICOS EFLUENTES INDUSTRIALES							
PARÁMETRO	UNIDAD	PERÚ	ARGENTINA	VENEZUELA	ECUADOR	CHILE	BOLIVIA*
DQO	[mg/l]	1.000,00	375,00	900,00	240,00	600,00	250,00
DBO_5	[mg/l]	500,00	300,00	350,00	120,00	250,00	80,00
pH	Unidades de pH	6-9	6,5-8,5	6-9	5-9	6-9	6-9
SST	[mg/l]	500,00	500,00	400,00	95,00	250,00	60,00
TEMPERATURA	[ºC]	<35	<45		<40	<40	<40
ACEITES Y GRASAS	[mg/l]	100,00	200,00	20,00	50,00	50,00	10,00

*Anexo 13-C RASIM

Figure15: Physiochemical parameters in by country of industrial effluents (RASIM, 2022).

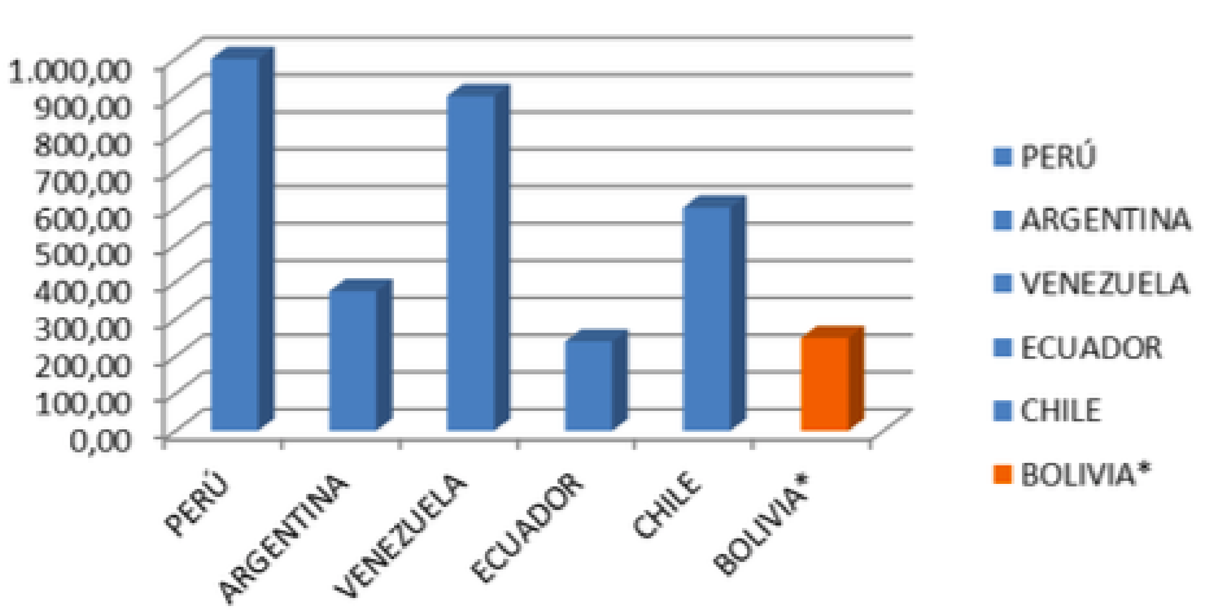

Figure16: Permissible limits of COD in mg/L by country (Hanna Instruments, & Arias Cárdenas, A. S., n.d.)

Through these comparisons, Bolivia ranks as one of the countries with the lowest limit for DBO and BOD_5 concentrations in South America, which in turn makes it one of the countries with the highest restrictions for disposing water concentrations with high contaminant concentrations. Looking back at the results, the company's current aerobic treatment after solid removal is self-sufficient and falls within the limits for both DBO and BOD_5 concentrations pertaining to Bolivian law. On the contrary, having just the anaerobic treatment, the COD and BOD_5 parameters do not fall under the Bolivian law limits. Lastly, from a carbon-footprint perspective, combining both anaerobic and the current aerobic treatment plant, would not only fall under the limits placed by RASIM, but also reduce CO_2 emissions by more than half to its current levels.

7.4 Community Effect

The industry is responsible for the prevention and control of pollution generated by its emissions, and must make efforts to:

a) Substitute fuels for others that minimize the generation of emissions of particulate matter and sulfur dioxide (SO2);

b) Optimize its operations and processes in addition to the proper maintenance of its equipment;

c) Capture and manage fugitive emissions;

d) Isolate sources of noise and radiation, and treatment of odors;

e) Exhaust cleaner production measures before incorporating corrective pollution systems.

To improve impact that industries have in the surrounding communities, it is of outmost urgency that employers and employees involved in the manufacturing industry comply with the regulations and apply the established instruments, implement solutions to their environmental problems and be open to dialogue with society and the authorities, and be more aware of the effects of their activity on the environment. It is also important for authorities to develop and apply flexible regulation instruments and incentives consistent with environmental, technological, social, economic and political changes. Additionally, authorities need to provide adequate and timely information to publicize the environmental problems of the manufacturing industry and facilitate the incorporation of the best available technologies. In this regard, society needs to be duly informed of any environmental problems and actively participate in their solutions as these populations are the most affected and need to be involved first handedly. Finally, consumers need to be taken into consideration and be informed of the manufacturing procedures to become more aware of the effect and benefit of their support for the development of an environmentally clean industry.

8. Conclusions

If sustainable energy from waste can be produced by applying an UASB in a paper & pulp mill company in Cochabamba that has a wastewater treatment plant onsite, it may be feasible for any industry that has a wastewater treatment plant, particularly in South America, to do the same over the next 25 years and imitate this model and have a functioning industrial symbiosis around organic waste. This would not only recover power and nutrients but also result in a reduced methane production in landfills and a creation of micr227 grids to power entire facilities. One of the main advantages of anaerobic treatments is the generation of energy or biogas. Under this criterion, the evaluation of this type of projects was carried out for Copelme S.A. company in Bolivia. However, due to the low energy costs in the country and the relatively small production compared to bigger companies, these projects are not economically feasible, obtaining return times averaging 30 years. The organic load of the effluent from the Cochabamba plant production process is close to the minimum acceptable concentrations for the application of anaerobic treatment. In the case of the Santa Cruz plant, due to the low concentration of organic load, it is not possible to apply this type of treatment. Compared to the pig farmers in China, it is feasible for them to install simple anaerobic systems on their farms to utilize the waste from their pigs in an economical way and generate methane/energy that can be beneficially and cost effectively utilized. The reason for this, is because their organic loads can reach up to 40,000 COD, which generates a significant amount of energy that can be recovered. Similarly, their flow rates are very low, reaching approximately 2 m^3/h, which in turn allows for a smaller plant and higher retention times. In which case, a paper and pulp mill plant such as COPELME S.A, contains low organic load, and high flow rates, making the anaerobic treatment installation more costly. Nevetheless, just looking at the environmental impact of the implementation of the anaerobic treatment in carbon emissions we see a reduction of 171.5 (MT CO_2/year). It is proven that the application of UASB in wastewater treatment plant helps reduce the company's CO_2 emissions and therefore, reduces its overall carbon footprint significantly, while at the same time converts its waste into biogas. However, in order for the company to validate this investment, it would have to also increase its paper production significantly to have a higher nutrient load, thus shortening the time to recover the costs of this investment. Likewise, applying a hybrid production process of both anaerobic and aerobic treatments with the current production volumes would not legally comply with the permissible limits for liquid discharge set by RASIM regarding their COD and BOD_5 concentrations, unless again, these production volumes are increased. Consequently, it can be inferred that the larger the company's production process is, the higher the possibility to implement UASB technology and achieve an overall triple-bottom line result.

Overall, if more companies on the field who produce enough organic load decided to implement this technology, it would lead to more company incentives to tackle the environmental impact that waste has on the planet and the economy. If society and culture work on these microcosms of economy, and growth begins to happen at that scale, humans can be completely decoupled from the impacts of environment that we create.

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Annexes

Annex 1: Approximate Carbon Calculations

			Carbon Footprint			
Datos						
Caudal	24000	m3/día	Eficiencia	2.5	KWh/m3CH4	
	8760000	m3/año				
DQO	500	g/m3				
DQO	0.0005	TM/m3				
Remocion anaerobio	60%	%				
	0.000300	TM_{DQO}/m3				
A Variables						
Emisiones Base						
BE	8715	TM CO2/año		el tratamiento anerobio		
Actual tratamiento Aerobio						
Caudal	131400	m3/año				
DQO	3400	g/m3				
	0.0034	TM/m3				
Eficiencia aerobio	96	%	DQO descarga	136	ppm	
Remocion DQO	0.003264	TM/m3				
S, Cantidad lodo generado	112	Tn/año				
DOC, contenido mat org	0.5					
MCFs, Factor de correcion metan	0.8					
Bo capacidad maxima de producc	0.3	CH4/COD				
EC, Energía consumida	120	MWh/año				
Facto emision bolivia	0.581	TMCO2/MWh				
BE	365	TnCO2/año	Emisones de tratamiento aerobio			
Proyecto Anerobio						
Eficiencia	0.7	%		Caudal	131400	m3/año
DQO degradada	0.00238	TM/m3		DQO	1020	g/m3
L	0.1	Fraccion de biogas q se pierde			0.00102	TM/m3
GM, generacion de metano -energ	88218.4	m3CH4/año		Eficiencia aerobio	90	%
GM, generacion energía	220.5	MWh/año		Remocion DQO	0.000918	TM/m3
Consumo energía	22.0	MWh/año		S, Cantidad lodo ger	34	Tn/año
EG, energía excedente	198.5	MWh/año		DOC, contenido mat	0.5	
				MCFs, Factor de corr	0.8	
PE (Emisiones Proyecto Anaerobic	81.7	TnCO2/año		Bo capacidad maxim	0.3	CH4/COD
				EC, Energía consumi	40	MWh/año
DQO	1020	ppm		Facto emision	0.581	TM CO2/MWh
				PE (Emisiones Proye	112	Tn CO2/año
PE total	**193.5**			DQO	102	ppm
Reducción de emisiones						
RE=BE-PE						
RE	**171.5**	Tn CO2/año				
Equivalente a	109.3					