Article Integration of Water and Energy Sustainable Program in Cluster Starch Industry

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ABSTRACT
The issue of water supply and sustainable energy is significant in dealing with clean water and energy crises in the long term. In addition, there has been a rise in water and air pollution caused by the community's activities. Conservation strategies should be implemented to lessen dependence on the supply of clean water and energy and promote self-reliance. The aim of this paper is the existence of a water and energy conservation program system. It is not separately built from the industrial unit, where pollution is a source of raw materials for water and energy to create a sustainable conservation system. The scope of the case report is on the tapioca and sago flour industries. The problem is solved by reusing the wastewater from the production line as raw material for biogas production. The residual water is reused for tapioca and sago starch production. The field data collection was conducted using a combination of primary and secondary data. The case study results are a consistent power supply of 900 kW from a 1.2 MW generator, the reuse of treated wastewater as raw water at a rate of 702 m^3 per day, and an idle capacity of 300 m^3 per day for biogas.

Keywords: *water, energy, sustainable, conservation, cost saving*

1. INTRODUCTION

Waste is considered residue from a business or human activity. It can be referred to as residual goods from an activity that is no longer useful or has economic value [1]. Furthermore, it can be categorized as liquid, solid, and gaseous waste [2]. Several countries are also faced with an energy crisis due to the depletion of fuel oil reserves, specifically from non-renewable fossil fuels. This has forced the world community to look for alternative sources of renewable fuels [3]. Dependence on petroleum can be reduced by developing alternative energy sources. Tapioca and sago flour waste can be converted into biogas to generate sustainable energy [4].

Wastewater released by the manufacturing industry contains many organic materials and can be decomposed biologically (biodegradable) to prevent environmental pollution problems [5]. Anaerobic biological treatment followed by facultative and aerobic systems is a wastewater treatment plant (WWTP) widely applied in tapioca [6]. As the primary unit of tapioca industrial wastewater treatment, the anaerobic biological system produces CH4 (methane), CO2, and other gases that can cause global warming [7]. Methane is a combustible gas from high organic industrial wastewater, serving as an alternative renewable energy source [8].

With increasing tariffs and demands for electrical energy, LPG (Liquefied Petroleum Gas), gasoline, diesel, kerosene, and other fuels, biogas can be an alternative energy source that is environmentally friendly and inexpensive. Biogas is one source of many other alternative energy sources, which are currently being developed in several countries [9].

Integration of water supply and sustainable energy independently is essential in many industries. The agroindustry is growing rapidly in Indonesia and other parts of the world. Cassava and sago are used in the tapioca flour and sago flour industries. The use of these raw materials often causes problems due to the direct disposal of wastewater and solids into the river without processing [10].

2. MATERIAL AND METHOD

This case study used a quantitative descriptive method to identify the estimated potential amount of

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biogas and water quality produced from tapioca and sago industrial wastewater. The sample consisted of wastewater produced by tapioca and sago, water from the final treatment in water pond, and biomethane gas used for power generation. Sampling wastewater uses a technique according to the Indonesian National Standard (SNI) regarding surface water. Furthermore, water and gas samples were taken using the grab sampling method and FIT (flow indicating totalizer) instrument unit. Primary and secondary data were collected over 3 months of factory operation with an in-depth literature study on the problems and objectives.

Data was collected in starch factory, PT Bangka Asindo Agri, Kenanga Village, Sungailiat District, Bangka Regency, Bangka Belitung Province, Indonesia. Real production capacity and wastewater flow rate were measured for three (3) months of tapioca factory operation. Meanwhile, wastewater sampling and laboratory analysis were conducted according to the Environment Ministry of Indonesia number 5/2014 to measure pH, COD (Chemical Oxygen Demand), BOD (Biological Oxygen Demand), TSS (Total Suspended Solid), and CN (Cyanide). Samples were collected at least 6 hours after the tapioca factory started operation. Parameters and measurement methods in this monitoring system are described in Table 1, while the schematic diagram of the sampling location is described in Figure 1.

3. RESULT AND DISCUSSION

3.1. Covered Lagoon Anaerobic Reactor

Covered Lagoon Anaerobic Reactor/CoLAR is an applied technology for producing biogas to treat industrial starch wastewater. The CoLAR system bioreactor aims to provide energy independence for electricity and heating in the form of biogas in the tapioca and sago industries of PT BAA. The CoLAR system bioreactor is made of geomembrane material with a capacity of 120,000 m^3 to accommodate wastewater with a flow rate of 3000 m^3 per day. The wastewater will undergo an anaerobic fermentation process with an HRT (hydraulic retention time) of 40 days in the digester. Figure 1 shows the CoLAR system's treatment process, producing 2 outputs of gas and treated wastewater.

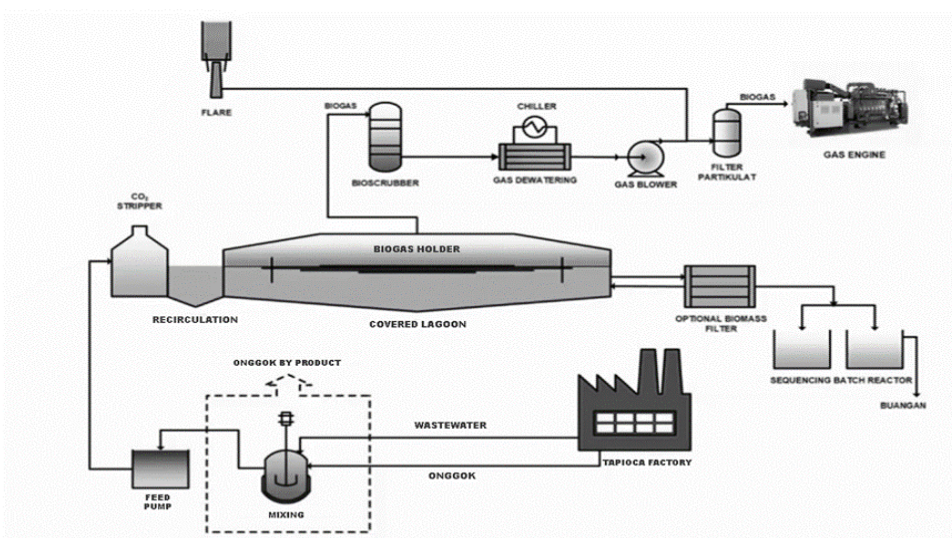

Figure 1 Process of Wastewater & Biomethane Treatment Plant

For this case study, the data collected are as listed in Table 1 as follows:

Table 1. Wastewater Flowrate & Production from observed tapioca factory

Period	Wastewater Generated (m3/day)	Inlet COD (mg/L)	Outlet COD (mg/L)	Processed Cassava (ton/day)	Processed Starch (ton/day)
First Month	V	V	V	V	V
Second Month	V	V	V	V	V
Third Month	V	V	V	V	V
Average	V	V	V	V	V

3.2. Tapioca and Sago Flour Industrial Wastewater

The production process of making tapioca flour requires much water to separate the starch from the fiber. Therefore, the liquid waste produced by the tapioca factory is quite large, namely 4-5 m^3 per ton of cassava [11]. This excess liquid waste requires further treatment because of its high COD content [12]. Meanwhile, sago wastewater is another crucial application in its use as an additional carbon in anaerobic digesters for biogas production [13], with a weight range of 1,000-1,200 kg per plant and production of 150-240 kg per stem. Sago flour from the production process ranges from 15-20% of the total wet weight [14].

Table 2 shows a wastewater parameter checked based on the regulation of PermenLH RI No.5/2014 Attachment V [15].

Table 2. Wastewater Quality Standards for the Tapioca Industry

	Parameter				
	pH	Cyanide	TSS	COD	BOD
Value	6.0 -9.0	0.3	100	300	150
Flow Rate Max	30 m3 per starch production				

The wastewater quality (Table 2) does not meet the requirements for reuse. Therefore, it is processed in other treatment oxidation pond and filtration process before reuse, as shown in Figure 2 below:

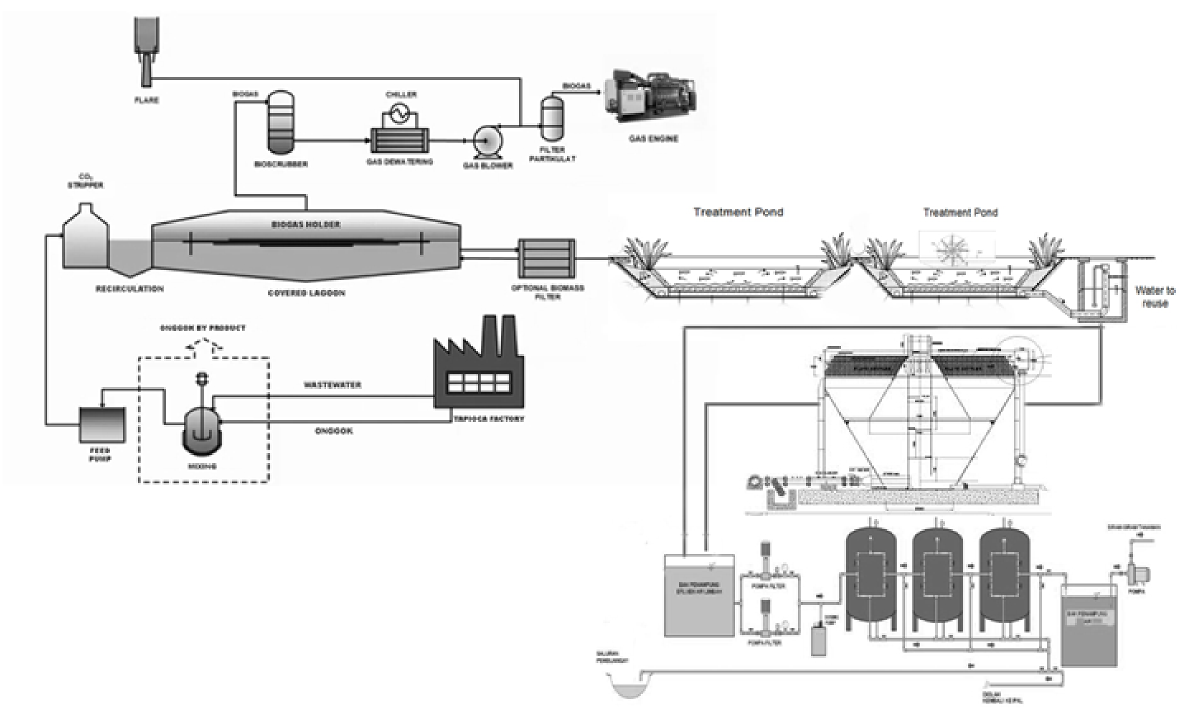

Figure 2 Wastewater Treatment and Recycle Plant Unit

The reuse of wastewater (recycling) from the CoLAR reactor refers to the regulation of the Minister of Health Permenkes No. 32/2017 [16]. Regarding Environmental Health Quality Standard and Water Health Requirements, as shown in Table 3 follows:

Table 3. Water Quality Standard for Hygiene and Sanitation

Parameter	Unit	Standard	Method
pH		6.5 – 8.5	SNI 06.6989.11.2009

Parameter	Unit	Standard	Method
Total Dissolved Solid	mg/L	1.000	Electrometri
Color	TCU	50	Electrometri
Temperature	^{o}C	Ambient +3	SNI 06.6989.23.2005
Taste	-	ND	Organoleptic
Odor	-	ND	Organoleptic
Cyanide (CN)	mg/L	0.1	Spektrofotometri
Nitrite	mg/L	1	SNI 06.6989.09.2004
Hardness	mg/L	500	SNI 06.6989.12.2004
Turbidity	mg/L	25	SNI 06.6989.25.2005
MBAS	mg/L	0.05	SNI 06.6989.51.2005
Fe	mg/L	1	SNI . 6989.84.2019
Mn	mg/L	0.5	SNI . 6989.84.2019
Zn	mg/L	15	SNI . 6989.84.2019
Pb	mg/L	0.05	SNI. 6989.84.2019
Cd	mg/L	0.005	SNI . 6989.84.2019
SO4	mg/L	400	SNI . 6989.84.2019
Escherichia Coli	MPN/100	0	SM 9221 B&C 23 rd 2017
Total Coliform	MPN/100	50	SM 9221 B&C 23 rd 2017

3.3. Energy generation from starch wastewater

The average production capacity of the observed starch factory was about 175 tons of starch per day and can be expanded to 350 tons, produced to 3000 m^3 of wastewater per day. The wastewater was treated in a biogas reactor as primary treatment to reduce the environmental load and produce biogas simultaneously. COD in and out average are 12,216 mg/L and 623 mg/L, respectively (Table 4).

Table 4. Wastewater Flowrate & Production from observed tapioca factory

Period	Inlet COD (mg/L)	Outlet COD CLAR (mg/L)	Outlet COD WWTP (mg/L)	Processed Starch (ton/day)
First Month	12.372	619	153	128
Second Month	11.651	599	135	121
Third Month	12.625	652	150	126
Average	12.216	623	146	125

Methane gas generated from the wastewater was estimated using equation 1 [17]:

$$CH4\,ww = \frac{\text{COD in} - \text{COD out}}{1000} \times Q \times 0.35 \qquad (1)$$

Where:

CH4ww = methane gas generated from the tapioca wastewater (m^3/day)

COD in = COD concentration in the inlet of biogas reactor (mg/l)

COD out = COD concentration in the outlet of biogas reactor (mg/l)

Q = Flow rate of wastewater (m^3/day)

0.35 = Potential of methane generated (m3/kg COD removal) [9]

Using the equation, the methane potential was estimated per day in the observed tapioca factory. Based on the potential of methane, the energy generated from the wastewater can be estimated to be 12.172 m^3 biomethane per day.
The heating value was used to calculate the energy generation using the following equation (equation 2) [17]:

$$P = \frac{CH4ww \times LHv \times 0.40}{24 \times 60 \times 60} \quad (2)$$

Where:

P = Power generation (MW)

LHv = Low Heating Value of methane (35.7 MJ/Nm^3)

0.40 = Conversion efficiency from biogas to electricity

The potential of methane production and power generated from tapioca wastewater during 3 (three) month research using equation (2) was 2,02 MW electricity. This will be a significant opportunity for expansion in the future.
From the observations, the incoming wastewater flow rate is 702 m^3 per day on average, while flour production is 175 tons per day. The amount of wastewater is 4.0 m^3 per ton below the statutory regulations of 30 m3 per ton of starch production. There is still an idle capacity of 75%, with an average load of 702 m^3 per day of wastewater. The measurement results show that the ready-to-use biomethane produced is 800 m^3 of gas per day. However, only 500 m^3 has been used to generate 900 kW of electricity from the 1.5 MW installed power generator. Therefore, the biomethane gas yield and the installed power capacity have an idle capacity of 300 m^3 and 600 kW of power generation, respectively.

3.4. Recycled water from tapioca wastewater

Effluent COD after CoLAR, which is still high, will continue to be decreased in the sequent pond, as shown in Figure 2. The relationship between time and COD removal can be described in Graphic 1 [18] as under:

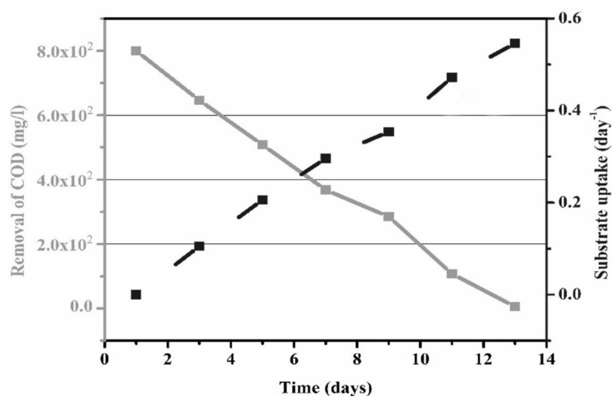

Figure 3 Relationship Time and COD Removal

Table 5 shows a quality report of wastewater after treatment in an aerated constructed wetland because the quality of effluent needs further treatment, as shown in Table 4, needs further treatment.

Table 5. Effluent quality report of wastewater after treatment

Quality	Value				
Parameter	pH	Cyanide	TSS	COD	BOD
Pond 12	7.2	0.0080	38	92.8	33.8
Pond 13	6.89	0.001	5.0	30.3	11.6
Regulation	6.0-9.0	03	100	300	150

The wastewater in large quantities can be recycled and reused for processing. In the tapioca industry, it has a high BOD, COD, TSS, cyanide, and low pH. Therefore, it should be treated in the wastewater treatment plant (WWTP) before reusing. The wastewater recycling scheme for the tapioca industry can be seen in Figure 2, and the quality and quantity of treated water recycled can be seen in Table 6.

Table 6. Treated Water Recycle Quality

Parameter	Unit	Standard	Result			Average
			1st Month	2nd Month	3rd Month	
pH		6.5 – 8.5	6.5	5.30	5.48	5.76
Total Dissolved Solid	mg/L	1.000	32.6	33.1	34.8	33.5
Color	TCU	50	26	24	25	<25
Temperature	ºC	Ambient +3	27.5	29.2	28.2	28.3
Taste	-	ND	ND	ND	ND	ND

Parameter	Unit	Standard	Result			Average
Odor	-	ND	ND	ND	ND	ND
Cyanide (CN)	mg/L	0.1	0.002	0.002	0.002	0.002
Nitrite	mg/L	1	<0.00632	<0.00632	<0.00632	<0.00632
Hardness	mg/L	500	49.8	51.0	51.6	50.8
Turbidity	mg/L	25	1.01	1.20	1.30	1.17
MBAS	mg/L	0.05	<0.0342	<0.0342	<0.0342	<0.0342
Fe	mg/L	1	<0.0478	<0.0478	<0.0478	<0.0478
Mn	mg/L	0.5	<0.0150	<0.0150	<0.0150	<0.0150
Zn	mg/L	15	<0.0203	<0.0203	<0.0203	<0.0203
Pb	mg/L	0.05	<0.0250	<0.0250	<0.0250	<0.0250
Cd	mg/L	0.005	<0.00456	<0.00456	<0.00456	<0.00456
SO4	mg/L	400	5.10	4.98	6.51	5.53
Escherichia Coli	MPN/100	0	0	0	0	0
Total Coliform	MPN/100	50	< 1.80	< 1.80	< 1.80	< 1.80
Flow Rate			690	711	705	702

4. CONCLUSION

The tapioca production process comprises peeling, washing, grating, extraction, settling, drying, and packaging. These various processes are designed to produce 350-ton starch a day and handle 3000 m^3 of wastewater. Furthermore, wastewater from the biogas process as primary treatment can be reused during production. The liquid waste contains an average of 12.216 mg/L COD with a CoLAR efficiency of 94.9%, converting to 12.172 m3 methane (CH4) and potential electricity of 2.0 MW. By recycling wastewater from the production process, the industry can save 702 m3 of clean water per day below the capacity of the installed recycle unit. The excess gas of about 300 m^3 a day that has not been utilized can be distributed to the general public when there is a supply shortage.

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