# STUDY AND ANALYSIS OF BIOGAS PRODUCTION FROM SEWAGE TREATMENT PLANT & DESIGN ANAEROBIC DIGESTER

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**Abstract:** *Climate change demands clean water and sustainable energy. Advances in wastewater treatment may allow for the recovery of valuable resources like biogas and fertilizers. Long-term sewage treatment is harder. This study looks on getting biogas from STPs. The technology's applicability for various applications is examined by comparing its performance to those applications. These systems' technical and environmental performance is also evaluated. The next step is to develop a framework for monitoring sustainability and include essential indicators. This is a STP in Greater Noida, Uttar Pradesh. Annually, 1.417*106 m3 biogas may be produced, greatly lowering CO2 emissions. Combining wastewater and sludge improves biogas recovery. STPs may help achieve the SDGs (SDGs). The multilateral and cross-cutting nature of resource recovery benefits is demonstrated by their linkages with SDGs. New water treatment methods and prospect.*

**Keywords:** climate change, wastewater treatment, sewage treatment, energy recovery

## 1. Introduction

Demand for coal, oil, and natural gas continues to rise. Biogas is currently one of the most promising renewable energy sources. Unlike wind or solar energy, biogas is not weather dependent. Concerns over fossil fuel use have raised interest in renewable energy sources. Dispose of biogas in a safe manner.

Anaerobic digestion converts organic waste into biogas. Biogas contains methane ($CH_4$) and $CO_2$ ($CO_2$). Other gases include sulphur dioxide ($H_2S$), nitrogen, ammonia, oxygen, and carbon monoxide (CO). Biodegradable byproducts of wastewater and sewage sludge treatment (WWSST). By closing the carbon and nutrient cycles, anaerobic digestion creates an important biofuel by-product (Maragkaki et al., 2018).

In recent years, anaerobic digestion has transformed wastewater treatment plant sludge into a renewable energy. The benefits of anaerobic digestion extend beyond energy and fuel. The use of manure as a fertilizer in agriculture has prompted concerns about pollution. Manure storage emits methane and $CO_2$. Anaerobic digestion decreases manure decomposition aromas. The USDA believes biogas digestate is as fertile as manure. Soil erosion is reduced, and methane emissions are eliminated.

### 1.1. Aim and objectives

1. To acknowledge the importance of Anaerobic Digester in Sewage Treatment Plant (STPs).
2. To provide information on the advantages and disadvantages of the programme.
3. To encourage the optimum utilisation of biogas produced and utilized.
4. Design an Anaerobic Digester for 137 MLD Kasna Sewage Treatment Plant, Greater Noida.
5. Estimation of the biogas production from Kasna Sewage Treatment plant, Greater Noida.

## 2. Related work

Akash Deep Singh, et al. (2020). Has carried out the research "Life-cycle assessment of sewage sludge-based large-scale biogas plant." To determine the environmental impact of the plant's basic biogas production systems, as well as the impact of using biogas as an alternative fuel using the ReCiPe and midpoint methods, this study was conducted at the Wastewater Treatment Plant (WWTP), Delawas, Jaipur – Rajasthan, India, with a capacity of 6000 m3. There was no significant impact of plant development on the entire cycle, according to the results. A biogas plant's digestate could be used in place of chemical fertilizer, which has lower GHG emissions than coal-fired power plants (-0.2385 kg CO2 eq/m3). The favorable results that can be connected to biogas production and agricultural spreading (-3.059E-08 kg CFC-11 eq/m3) may have been improved by avoiding energy and chemical fertilizers. Environmental benefits were found to accompany the use of a biogas plant that generated power from treated municipal solid waste, according to the study's findings. Akash Som Gupta et al. (2020). Studies the “Feasibility study for the production of biogas from Wastewater and Sewage Sludge–Development and application framework.” As a technique of recovering energy, this dissertation investigates wastewater and sewage treatment facility (WWTP) biogas recovery options. The viability and relative efficacy of several biogas recovery technologies are examined and analyzed. Afterwards, a framework for measuring sustainability performance is developed, complete with relevant sustainability indicators. Tbilisi, Georgia's WWTP serves as a case study in this framework's use. Using this case study as an example, combined heat and power recovery (CHP recovery) has the potential to generate 130 GWh of yearly energy, while biogas recovery from wastewater alone has the ability to reduce CO2 emissions by 28,200 tCO2 Eq annually. B. Bharathiraja, et al. (2014). “Biofuels from Sewage Sludge: A Review” describes the process by which sludge can be turned into biofuels. In this study, biofuels are made from municipal wastewater treatment plant sludge. Water used for irrigation, forestry, and agriculture can be derived from sludge and wastewater, respectively. Now that we have so much advanced technology, we can turn our wastewater into an environmentally friendly, renewable biofuel. A few examples of this sort of biofuel are: biodiesel, ethanol, CNG, and LNG (bio-H2), as well as biosolids. T.Z.D. de Mes, et al. (2010). “Methane production by anaerobic digestion of wastewater and solid wastes” has been studied. Waste and wastewater can be effectively treated via Anaerobic Digestion according to the study. For heating, upgrading to natural gas quality, or cogeneration of power and heat, biogas produces a mixture of methane (55-75 vol percent) and carbon dioxide (25-45 vol percent). According to the research, biogas yields range from 80 to 200 cubic metres (m3) per tonne for municipal solid waste and animal manure. Anaerobic digestion plants in Europe now have a combined capacity of 1500 MW, but by 2010, that number is predicted to expand to 5300-6300 MW. Nicolae Scarlat, et al. (2018). “Biogas: Developments and Prospects in Europe” is the title of this presentation. In accordance with the findings, biogas may be utilized to generate electricity, heat houses, and power cars in the European Union and its member countries, among other applications. EU biogas production has increased in recent years as a result of renewable energy legislation and the related economic, environmental, and climate benefits. In 2015, EU biogas production reached 654PJ, accounting for half of the world's total biogas production. European Union (EU) biogas capacity exceeds 10GW, with over 17,400 biogas plants in operation, according to the International Energy Agency (IEA).

**3. Biogas production technology**

Detailed information about anaerobic digestion of household trash and sewage sludge follows. Throughout this piece, we'll examine the many high-end systems available today and weigh their benefits and drawbacks. With the right mechanism, the hydraulic retention time (HRT) of high rate anaerobic digestion systems can be drastically lowered while the solids retention time (SRT) remains much longer (SRT). For large volumes of wastewater, high-rate systems are the most effective treatment technology available today.

The EPA says anaerobic digestion can help clean wastewater and stabilise sludge (AD). Large-scale deployments and continuous research and development are making sustainable wastewater management a desirable treatment technique. AD can help you recover energy and valuable organic resources like biogas and stabilised sludge. AD improves effluent stream quality by removing pathogens and reducing methane emissions.

WWTPs can boost their energy independence by creating biogas and recovering it from waste by using AD plants to create heat and electricity. They can cut prices while increasing environmental performance by moving from fossil fuel production to renewable energy generation. Anaerobic digestion generated significant advances in nutrition and illness prevention as early as the 1800s. Initially, AD was thought to be most suited to industrial effluent and temperatures of 20-25°C, but further research found this to be false. This led to the first anaerobic reactors, which largely handled industrial waste, being erected in tropical locales. But anaerobic digestion systems began treating low-strength waste streams at low temperatures in the 1980s, leading to further advancements in efficiency and process design. Currently, most anaerobic digestion operations use high-rate anaerobic reactors, which are bioreactors equipped with mixing, heating, and all necessary monitoring and control equipment.

Anaerobic digestion may treat both wastewater and sludge in wastewater treatment plants. The anaerobic digestion of the sludge doubled the amount of methane recovered compared to the typical activated sludge system. Thanks to a successful energy recovery operation, the institution got all the power it needed for free. Using this treatment method instead of aerobic treatment can save energy and money by minimising the amount of digested sludge produced. So, in some cases, wastewater and other pollutants can be used to generate electricity.

In addition to improving energy security, sludge and wastewater energy can help cut greenhouse gas emissions and reduce reliance on fossil fuels. Evaluation of pre-treatment procedures must assess additional biogas produced, total sludge produced, overall energy balance, and overall expenses. According to study, using recovered methane energy might pay nearly half of the treatment plant's operational costs (Mention in reference, Tyagi and Lo, 2016)

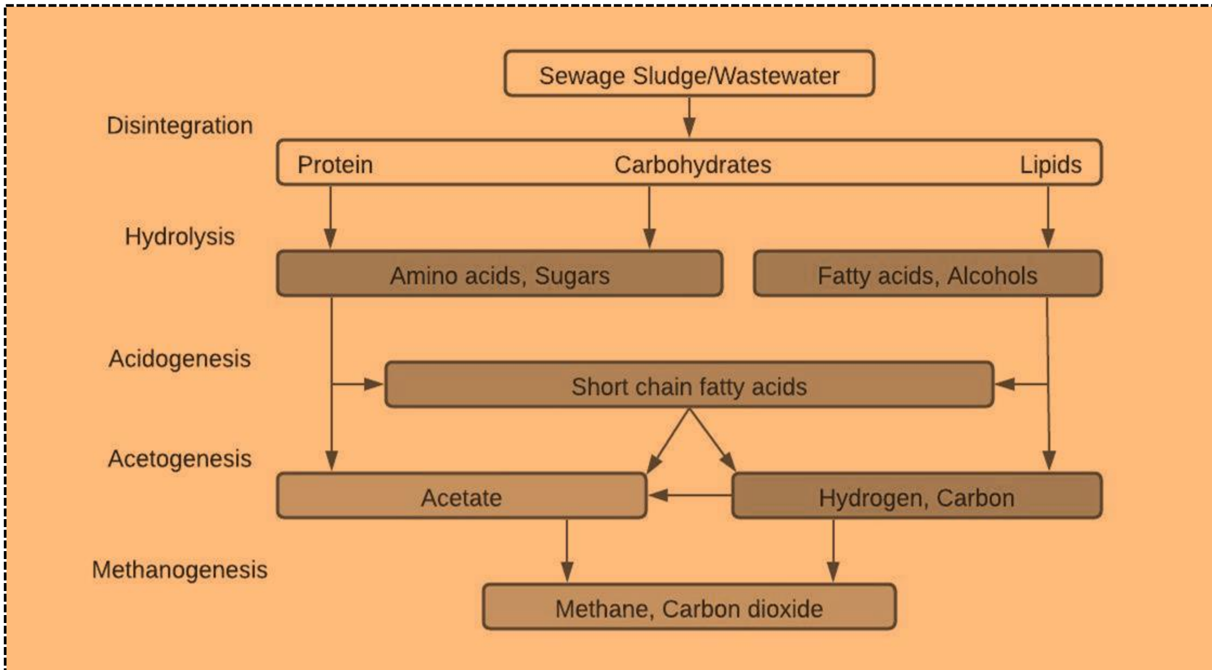


**Figure.1. Anaerobic digestion microbial process stages**

They can construct anaerobic digestion systems for treating sludge if they understand the microbiological and process factors acquired from research into municipal wastewater treatment procedures (Tezel et al., 2011). This short review covers the process of anaerobic sludge stabilisation in detail, including the microbial activities involved and the control settings used. The regulatory framework that oversees these procedures also addresses applications for disposal and reuse.

Untreated landfill sludge generates methane, a significant contributor to global warming. A wastewater treatment facility can generate power from methane retained during aerobic digestion to reduce CO2 emissions. Thus, methane produced by wastewater treatment and other processes can be used to generate sustainable energy.

### 3.1. Study area

Four sewage treatment plants (STPs) have been constructed and are set to begin operations at Kasna, Ecotech 2, Ecotech 3, and Badalpur's Sadopur, with a combined wastewater treatment capacity of 175 million litres per day (MLD). Kasna alone has a sewage treatment plant with a capacity of 137 million litres per day, which serves the entire municipality (MLD). It is an aerobic process, and it is now being used as a secondary treatment process at the Kasna STP. The SBR (Sequencing Batch Reactors) technology is being used in this process. In the Activated Sludge Process, SBR is a cutting-edge technology that was designed specifically for this purpose. This plant is unable to create bio-energy as a result of the absence of Anaerobic Digestion procedures in this facility. Following the completion of the study, we will be able to approach GNIDA to arrange for a demonstration of a pilot biofuel producing plant to be held at their location.

**Figure.2. Sewage Treatment Plant Kasna, Greater Noida**

We conducted a series of experiments to compute physical and chemical parameters of the sewage so as to further compute the amount of biogas.

### 3.2. Anaerobic digester design

#### 3.2.1. Design Consideration

Anaerobic digestion tanks have cylindrical shapes and can range in size from 3 to 12 metres in diameter (i.e. circular in plan). The bottom hopper floor of the tank features slopes ranging from 1:1 to 1:3. (i.e. 1H: 3V). If sludge from outflow is removed by mechanical means, a flat bottom slope is feasible on the bottom slope of the tank. It is customary to have a digesting tank that is 6 metres deep. Deeper tanks are more effective than shallower tanks, despite the fact that they are more expensive. With the exception of really large plants, it is extremely rare to observe more than two units in a single plant. The amount of sludge produced, the length of time the sludge is digested, the degree of digestion, the amount of moisture lost, and the amount of organic matter converted all have an impact on the capacity of the digestion tank. If the sludge digestion process is considered to be linear, the following formula can be used to compute the capacity of the digestion tank (V):

$$\mathbf{V} = \left(\frac{\mathbf{V_1+V_2}}{\mathbf{2}}\right)\mathbf{t} \qquad (3.1)$$

Where $V$ = Vol. of the digester, $m^3$

$V_1$ = Raw sludge added per day, $m^3$/day

$V_2$= Equivalent digested sludge produced per day on completion of digestion, $m^3$/day ≈ $V_1/3$

$t$ = Digestion period, d

I. Design Flow, Kasna Greater Noida = 137 MLD
II. total solids in untreated raw sewage (TSS) = 300 mg/l

In 137 million litres of sewage every day, the weight in solids = $\frac{137 \times 10^6 \times 300}{10^6}$

= 4100 kg/day

60 percent solids are removed from primary settling tanks; therefore we have a mass of solids removed from the primary settling tank, for example.

$$= 60\% \times 4100 \text{ kg/day}$$

$$= 24660 \text{ kg/day}$$

Using the assumption that the fresh sludge is 95% water, we have 5 kilogrammes of dry solids that will yield 100 kilogrammes of wet sludge.

24660 kg of dry solids will make = $\frac{100}{5} \times 24660$ kg of wet sludge/day

= 493200 kg of wet sludge/day

Assuming the specific gravity of wet sludge as 1.02 (i.e. Density = 1020 kg/m3)

We have,

The volume of raw sludge produced/ day

$$V_1 = \frac{493200}{1020}$$

$$V_1 = 483.53 m^3/day$$

The digested sludge volume (V 2) at a moisture content of 85% can be calculated using the formula

$$V_2 = V_1 \left[\frac{100-p_1}{100-p_2}\right] \quad (3.2)$$

$$V_2 = 483.53 \left[\frac{100-95}{100-85}\right]$$

$$V_2 = 161.18 \text{ m}^3/\text{day}$$

The digested sludge volume (V 2) at a moisture content of 85% can be calculated using the formula

$$\text{Capacity} = \left[V_1 - \frac{2}{3}(V_1 - V_2)\right] \times t \quad (3.3)$$

$$Q = 8058.9 \text{ m}^3$$

### 3.3. Estimated biogas production

Analyzing the wastewater and analyzing the sludge's characteristics can help determine its gas production capacity. Estimates of gas production during digestion can be made using the following values. Sixty-five percent of the sewage's suspended particles are removed by sedimentation, seventy-five percent are removed through chemical coagulation and settling, and ninety percent are removed with comprehensive treatment, such as activated sludge or trickling filters. Sludge reduces the volatile content of sewage suspended particles by approximately 65 percent. Gas is generated during digestion by approximately 0.6 m3/day of volatile matter in the sludge, or approximately 0.9 m3/kg of volatile matter decreased. A typical mixture of 65 percent methane and 30 percent CO2 includes trace amounts of other gases. The calorific value of methane is approximately 36000 kJ/m$^3$ (8800 kC/m$^3$). .

Design Flow = 137 MLD

sewage's total amount of suspended particles = 300 mg/l

Assuming that the primary settling tank removes 60% of the suspended particles, we have

Removed as sludge are the suspended solids

= 60% × 300 mg/l

= 180 mg/l

Now, if we assume that the volatile solids present constitute 70% of the suspended solids,

We have

I.e. the volatile solids eliminated

= 70% × 180 mg/l

= 126 mg/l

For the sake of argument, we assume that the volatile content in the digested sludge is reduced by 65 percent.

Decrease in the concentration of flammable substances = 65% × 126 mg/l

= 81.9 mg/l

Because of this, volatile matter was reduced by approximately 137 million litres per day (MLD).

$$= 81.9 \times \frac{137 \times 10^6}{10^6} \text{kg}$$

= 11220.3 kg

If 0.9 m3 of gas is produced per kilogram me of volatile stuff eliminated, then this is correct. We've got a lot of experience.

The total volume of gas that was produced = 0.9× 11220.3 kg

= 10098.27 $m^3$

In this example, we'll assume that the produced gas contains 65% methane and 30% carbon dioxide.
Methane produced = 0.65 × 10098.27 = 6563.87 $m^3$

## 4. Result and discussion

### 4.1. Experimentation result

| DATE | COD (mg/l) | TSS (mg/l) | BOD (mg/l) | pH |
|---|---|---|---|---|
| 01-04-2021 | 365 | 278 | 265 | 7.3 |
| 02-04-2021 | 373 | 265 | 278 | 72 |
| 03-04-2021 | 351 | 311 | 235 | 7.3 |
| 04-04-2021 | 400 | 304 | 281 | 7.4 |
| 05-04-2021 | 402 | 306 | 265 | 7.5 |
| 06-04-2021 | 394 | 315 | 245 | 7.3 |
| 07-04-2021 | 385 | 296 | 198 | 7.2 |
| 08-04-2021 | 393 | 294 | 216 | 7.4 |

| | | | | |
|---|---|---|---|---|
| 09-04-2021 | 387 | 291 | 232 | 7.3 |
| 10-04-2021 | 382 | 302 | 245 | 7.4 |

**4.2. Anaerobic digester design**

| **Capacity of Anaerobic Digester** | | | |
|---|---|---|---|
| Sr. No. | Design Parameter | Unit | Quantity |
| 1 | Design Flow (Included Recycle Flow) | MLD | 137 |
| 2 | Inlet Sewage TSS | mg/l | 300 |
| 3 | Inlet Sewage COD | mg/l | 400 |
| 4 | Inlet Sewage BOD | mg/l | 280 |
| 5 | Total TSS | kg/day | 41100 |
| 6 | 60% TSS are Removed in Primary Settling Tanks | kg/day | 24660 |
| 7 | Moisture Content of Fresh Sludge | % | 95 |
| 8 | Wet Sludge per Day | kg | 493200 |
| 9 | Density of wet sludge | kg/m$^3$ | 1020 |
| 10 | Volume of raw sludge | m$^3$/day | 484 |
| 11 | Volume of digested sludge @ 85% moisture content | m$^3$/day | 161 |
| 12 | Digestion period | day | 30 |
| 13 | Capacity of Anaerobic Digester | m$^3$ | 8059 |

**4.3. Construction detail of anaerobic digester**

| **Construction Detail of Anaerobic Digester (AD)** | | | |
|---|---|---|---|
| Sr. No. | Item | Unit | Quantity |
| 1 | Radius of AD | M | 24 |
| 2 | Depth of AD | M | 453 |
| 3 | Area of AD | m$^2$ | 6 |
| 4 | Volume of AD | m$^3$ | 2715 |
| 5 | Required AD | Nos. | 3 |
| 6 | Total Volume of AD | m$^3$ | 8146 |

**4.4. Biogas estimation**

| **Estimated Biogas Production** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Sr. No.** | **Design Parameter** | **Unit** | GREATER NOIDA @ KASNA | | | | |
| **1** | **Design Flow (Including Recycle Flow)** | **MLD** | **137** | **137** | **137** | **137** | **137** |
| 2 | Inlet Sewage TSS | mg/l | 300 | 250 | 200 | 175 | 150 |
| 3 | Inlet Sewage COD | mg/l | 400 | 360 | 320 | 280 | 250 |
| 4 | Inlet Sewage BOD | mg/l | 280 | 230 | 190 | 175 | 150 |
| 5 | Removal of 30% Sewage BOD After Primary Sedimentation Tank | mg/l | 196 | 161 | 133 | 122.5 | 105 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 6 | % Removal of TSS in Primary Sedimentation Tank | % | 60 | 60 | 60 | 60 | 60 |
| 7 | Sludge Generated After Primary Treatment | kg/day | 24660 | 20550 | 16440 | 14385 | 12330 |
| 8 | Total Sludge Feed to Anaerobic Digester | kg/day | 24660 | 20550 | 16440 | 14385 | 12330 |
| 9 | Considering VSS/TSS Ratio | | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| 10 | VSS Available for Digestion | kg/day | 17262 | 14385 | 11508 | 10069.5 | 8631 |
| 11 | 65% VSS Destroyed As per Tender | kg/day | 11220.3 | 9350.25 | 7480.2 | 6545.175 | 5610.15 |
| 12 | Biogas Generation @ 0.9 m3 per Kg of VSS Destroyed | m3/day | 10098.27 | 8415.225 | 6732.18 | 5890.658 | 5049.135 |

## 5. Conclusion and future scopes

The addition of anaerobic digesters in sewage Treatment Plant has further improved the net yield obtained from it. The added benefit aside from treated water is the biogas which can be further used for multiple applications, like:

1. For combined heat and power (CHP) generation; biogas further negates the $CO_2$
2. Can be used as fuel for transportation
3. Can be used as fuel for cooking food in rural areas
4. Yielded biogas can be used in large scale hydrogen cell production

Benefits of using an anaerobic digester:

1. Non polluting in nature
2. Undigested sludge releases methane in the atmosphere which is further detrimental towards climate, where methane being 20 times more harmful than $CO_2$; using AD converts this $CH_4$ in $CO_2$.
3. The digested sludge can be used
4. AD usage can help us in achieving our sustainable development goals

Future consideration of output

1. The analysis will feed into my M.Tech thesis preparation titled "Feasibility study for bio energy and resources recovery from sewage treatment plant".

2. The report will build capacity in the field of bio-fuel production from the sewage sludge as feedstock. The benefits from the conducted analysis can be proposed to municipal corporations to upscale the sewage treatment sludge for generating bio-fuels.

3. The established economics can be used to attract bio-fuel production activities through devising business models.

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