Biogas Generation from Sugarcane Waste and Peanut Shell Waste

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***Abstract*—this study reviews the utilization of agricultural wastes, specifically peanut shells and sugarcane bagasse, for biogas production and heavy metal removal. The process involves feeding 30 kg each of powdered peanut shells and sugarcane bagasse, along with equal volumes of water and cow dung, into an 8 m³ anaerobic digester. The fermentation process, facilitated by bacteria, produces 0.57 m³ of biogas daily. Initial zinc concentrations of 7.056 ppm in peanut shells and 13.824 ppm in sugarcane bagasse were effectively reduced to 0.05 ppm and 0.1 ppm, respectively, rendering the treated liquid environmentally safe and suitable for use as fertilizer. Further purification of the biogas removes carbon dioxide and hydrogen sulfide, yielding methane-rich gas comparable to natural gas. The study highlights the simplicity and efficiency of this biogas production system, which is applicable for domestic, commercial, and industrial purposes, including electricity generation, heating, and cooking. The combined process also demonstrates significant advantages over traditional methods, with improved biodegradability, efficient heavy metal removal, and a notable reduction in sludge toxicity, positioning it as an effective alternative for treating agricultural and industrial wastes.**

***Index Terms*—Peanut shells, sugarcane bagasse, heavy metal, Anaerobic digestion**

I. INTRODUCTION

Due to scarcity of petroleum and coal it threatens supply of fuel throughout the world also problem of their combustion leads to research in different corners to get access the new sources of energy, like renewable energy resources. Solar energy, wind energy, different thermal and hydro sources of energy, biogas are all renewable energy resources. But, biogas is distinct from other renewable energies because of its characteristics of using, controlling and collecting organic wastes and at the same time producing fertilizer and water for use in agricultural irrigation. Biogas does not have any geographical limitations nor does it require advanced technology for producing energy, also it is very simple to use and apply.

Peanut shells are rich in nutrients, with good potential for development and utilization, but its use is mainly in feed development, food processing and other fields. It will be an efficient and rational way to realize the utilization of peanut shells to convert them into energy substances (i.e., methane) with microbial anaerobic fermentation technology. Feasibility of biomass energy conversion is done using peanuts shell to produce biogas.

Biogas production from sugarcane waste has large potential for energy generation. However, to enable the optimization of the anaerobic digestion (AD) process each substrate characteristic should be carefully evaluated. In this study, the kinetic challenges for biogas production from different types of sugarcane waste were assessed. Samples of bagasse were analyzed. Biochemical methane potential assays were performed to evaluate the energy potential of the substrates according to different types of sugarcane plants. Methane yields varied considerably (5 – 181 Nm^3.ton FM^{-1}), mainly due to the different substrate characteristics and ethanol production processes.

While some of these organic wastes are directly applied as organic fertilizers on the sugarcane fields for nutrient recycling without previous energetic utilization (i.e., vinasse and filter cake), the other part of the residues are mostly used as fuel in low-efficiency cogeneration systems (i.e., bagasse).

The AD of sugarcane waste can be considered a promising strategy, since the digest state could still be used to partially replace the mineral fertilizers on the sugarcane fields and the produced biogas could be upgraded to bio methane and sold as a new energy product by the sugarcane plants. However, before being implemented on a large-scale, the AD process should be carefully evaluated, especially regarding the substrates characteristics, as organic matter and nutritional value, macronutrients, trace elements, and specific biogas production. Those parameters directly influence some other important process parameters, such as the pH, accumulation of inhibitors, potential macronutrients and trace elements deficiencies, as well degradation rates. The toxic metal i.e., zinc present in sugarcane is 17.2 mg $Kgts^{-1}$ and standard deviation ± 10.2.

The sludge waste after the generation of biogas is tested for determining the toxic elements through Atomic Absorption Spectrophotometer method (AAS).

Thus, the toxic elements from remaining sludge waste are removed by coagulation process, which is widely used due to its simplicity and cost-effectiveness. Finally, the sludge used as the fertilizer.

A. Biogas

Biogas is a renewable gas generated by the anaerobic decomposition of organic materials in the absence of oxygen. Sources include plant and animal waste, kitchen scraps, manure, sewage, and biomass. This fuel is primarily composed of methane and carbon dioxide, suitable for energy applications.

B. History of Biogas

Biogas production was first observed in the 17th century by Van Helmont, who linked swamp gases to decaying matter. In 1776, Volta identified its flammable properties. By 1884, Gauon, a student of Pasteur, produced biogas by fermenting cattle manure, achieving 100 liters per cubic meter at 35°C.

C. Characteristics of Biogas:

The composition of biogas varies depending on the feed material. It is approximately 20% lighter than air and has an ignition temperature between 650-750°C. Biogas burns with a blue flame similar to LPG, with a calorific value of 20 Mega Joules (MJ) per cubic meter and a combustion efficiency of around 60% in conventional stoves. It can replace fuels like firewood, cow dung, LPG, and electricity depending on local conditions. The residue from biogas digesters contains ammonia and can be used as fertilizer.

D. Properties of Biogas:

1. Volume change with temperature and pressure.
2. Calorific value change due to temperature, pressure, and water vapor content.
3. Variation in water vapor with temperature and pressure.

E. Floating Dome Type Biogas Plant:

This plant features an underground brick masonry digester connected to an inlet and outlet, with a floating steel gas holder for gas collection. The gas holder rises and falls, guided by a central pipe, in response to gas accumulation and release. Made of mild steel, the gas holder accounts for around 40% of the total plant cost, making this design more expensive than fixed-dome types. A partition inside the digester promotes circulation, and the gas holder helps maintain constant pressure by adjusting to gas production as shown in Figure 1.

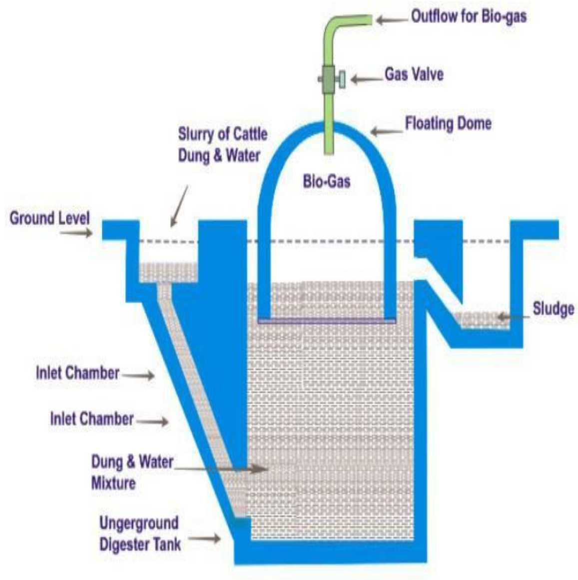


Figure 1 Floating dome bio-gas plant

F. Fixed Dome Type Biogas Plant:

In a fixed dome digester, the gas holder and digester are integrated, with gas stored in the upper part of the digester. The displaced slurry level creates the necessary pressure for gas release. This system is typically built underground, making it ideal for cold regions. Without the need for steel components, the plant can be constructed with local materials, reducing construction costs.

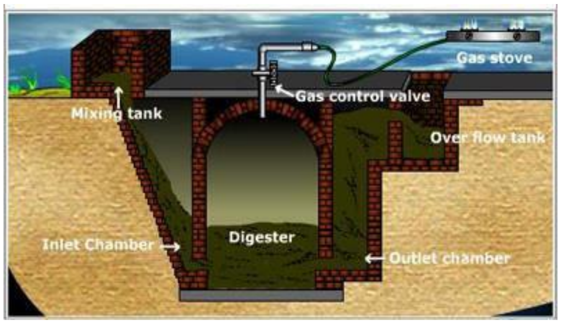


Figure 2. Fixed dome bio-gas plant

G. Floating Rotating Plant (FRP):

The FRP consists of a cylindrical or dome-shaped digester and a floating gas holder, which moves up and down based on gas production and consumption. The gas drum is guided by a frame and may float in a water jacket, preventing it from sticking even in high-solid substrates. Although popular in India for digesting animal and human waste in continuous-feed mode, FRP plants became less common due to high costs and design issues after the introduction of cheaper fixed-dome models. They are used primarily in small to medium-sized systems (5–100 m³).

Figure 3 Floating rotating plant

H. Peanut Shell Wastes:

Peanut shells, a byproduct of groundnut milling, are rich in nutrients, including carbon (41.53%), nitrogen (2.13%), hydrogen (2.13%), and sulfur (0.24%). These shells, which make up 20-24% of the harvested crop, are primarily used in animal feed and food processing. However, a more efficient way to utilize them is through anaerobic digestion, which converts the shells into biogas (methane), offering a sustainable solution for waste management and energy production.

I. Sugarcane Waste:

As oil and fertilizer prices rise, biogas production becomes more economically viable. Biogas, composed mainly of methane and carbon dioxide, offers a decentralized energy and waste management solution, especially in rural areas of developing countries. Sugarcane waste, known for its high energy content, can be combined with cattle slurry to produce biogas. The digestate can then serve as a fertilizer.

Sugarcane Bagasse Composition:

- Carbon (C): 44.80%
- Hydrogen (H): 5.35%
- Nitrogen (N): 0.38%
- Oxygen (O): 39.55%
- Sulfur (S): 0.01%
- Ash: 11.27%

J. Uses and Benefits of Biogas:

Biogas addresses key environmental challenges, including reducing pollution, mitigating the greenhouse effect, and combating global warming. It helps lower reliance on fossil fuels, reduces waste volume, and diminishes the need for commercial fertilizers, cutting related costs. Biogas production also produces nutrient-rich manure, benefiting soil health, and significantly lowers odors and pathogen levels. By diverting waste from landfills and reducing deforestation, biogas contributes to a cleaner environment and offers financial benefits through energy sales.

K. Uses of Biogas Digesters:

Biogas digesters replace fossil fuels and non-renewable energy sources with cost-effective and readily available fuel. They improve the utilization of manure, eliminate water pollution, reduce burning, and contribute to saving money. Additionally, biogas digesters lower greenhouse gas emissions, offering environmental and economic advantages.

L. Need for Study:

Biogas produced from anaerobic digesters typically contains 50-70% methane (CH_4), which can be corrosive to pipes and is toxic. Since methane is the primary component of natural gas, it needs to be removed from biogas before use. Agricultural waste, rich in methane, is often collected in digesters for cooking, but it may also contain heavy metals, which can be reduced through various treatment processes. Proper treatment of these wastes is essential to minimize environmental pollution before their discharge.

M. Objectives of the Study:

1. To assess the feasibility of biogas production.
2. To examine the effective determination of heavy metals using the Atomic Absorption Spectroscopy (AAS) method.
3. To explore the removal of heavy metals through the Coagulation-Flocculation process.

II. LITERATURE REVIEW:

The production of biogas from kitchen and agricultural wastes aims to enhance methane yield with a base pH greater than 7.0, suitable for cooking and electricity generation. Biogas is produced from peanut shells, sugarcane bagasse, and cow dung to achieve the same biogas output in a shorter period. This chapter provides an overview of recent advancements in biogas production from various waste materials.

A. Biogas Production from Peanut Waste:

Yong *et al.* investigated the impact of NaOH pre-treatment on biogas production from peanut shells. The study compared two approaches: one with NaOH solutions (2%, 4%, 6%, 8%) at normal temperatures and one with distilled water at a pH of 7.2. Results showed that 4% NaOH pre-treatment produced a total gas volume of 28.083 mL.

Liu (2012) examined the biogas fermentation potential of peanut shells, using the Box-Behnken model to optimize pre-treatment parameters. The study showed a methane yield of 0.323 m^3/kg at a pH of 7.5 with added cow dung, chicken manure, and pig manure.

Liu *et al.* (2011) used peanut vines for biogas production, achieving a biogas yield of 0.349 m^3/kg at a pH of 7.3.

Kasakova *et al.* (2010) studied anaerobic co-fermentation of cattle slurry and peanut nibble waste, resulting in a biogas production of 0.78 m^3/kg and methane production of 0.46 m^3/kg.

B. Biogas Production from Sugarcane Bagasse:

Mohamed *et al.* (2006) investigated biogas production from sugarcane bagasse using anaerobic fermentation, examining the effects of adding poultry droppings. The study revealed a total biogas yield of 0.05 m^3/kg from sugarcane bagasse with the addition of poultry droppings.

Sathish *et al.* (2015) studied biogas production using sugarcane press mud in a floating drum anaerobic digester, with cow dung as inoculum. They found that the maximum biogas yield from dry press mud was 0.68 m^3 at pH 7.1.

Samuel *et al.* (2011) focused on biogas production from sugarcane vinasse waste, aiming to reduce contamination and use the biogas as fuel for vehicles. The study showed a theoretical yield of 0.14 m^3 of biogas per 1 m^3 of vinasse.

Pound *et al.* (2008) studied biogas production from sugarcane pressed stalk (PSC) mixed with cattle slurry, with and without urea addition. The results indicated that the addition of urea increased the pH and biogas production, yielding 0.37 m^3 of biogas with urea and 0.3 m^3 without.

C. Biogas Production from Other Wastes:

Dinesh Kumar *et al.* (2000) explored the use of microbial stimulants to enhance biogas production. They studied the effect of adding Aquasan, a microbial stimulant, to cow dung and a mixture of cattle dung and kitchen waste. The results showed a 55% increase in gas production, with the residue increasing by 15%.

Malakahmad *et al.* (2009) developed an anaerobic biogas reactor with a unique design, promoting the growth of diverse microbial communities. While small amounts of protozoa and fungi were present, bacteria made up 93% of the microbial population. The study concluded that methane content was higher in the anaerobic baffled reactor (ABR) compared to other methane-forming systems.

D. Summary of Literature Review

The literature review examines various techniques to enhance biogas production from organic waste, focusing on inoculums like cow dung, pig manure, and chicken manure. Methods such as NaOH pre-treatment, co-fermentation, microbial stimulants, and urea addition are used to optimize methane yield and improve biogas efficiency. Studies have demonstrated successful biogas production using materials like peanut shells, sugarcane bagasse, and kitchen waste. This research aims to use peanut shell and sugarcane bagasse in a floating rotating digester, with cow dung as an inoculum, to produce biogas for cooking, achieving a pH of 7.0–7.5.

III. MATERIALS REQUIRED:

A. Collection of Samples:

Peanut shell waste was collected from M/S Lathi Lakshmi Modern Rice Mill in Puzhal, GNT Road, Chennai, within two days. Sugarcane bagasse was gathered from roadside shops. Both materials were dried in sunlight at 37°C, then ground into powder and brought to room temperature before use in the experiments. Figures 4 and 5 show the powdered forms of peanut shell and sugarcane bagasse waste, respectively.

Figure 4 Peanut shell powders

Figure 5 Sugarcane bagasse

B. FRP Biogas Plant:

The FRP Biogas Plant is an efficient alternative to LPG for cooking, producing biogas from agricultural waste such as peanut shells and sugarcane bagasse. A daily production of 8 cubic meters of biogas is achieved from 4.8 kg of these wastes, equivalent to 0.43 kg of LPG. The plant is made from FRP with a two-cylinder water jacket system and includes PVC pipe inlets for feed and slurry/drain, as well as gas valves and safety stoppers.

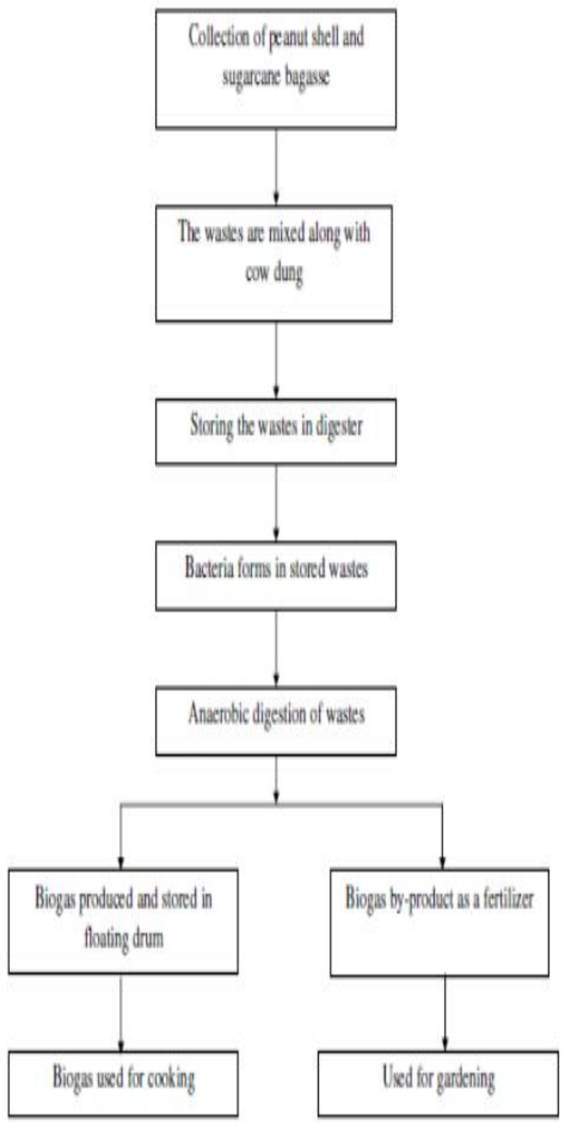
C. AAS-263 Device:

The AAS-263 device, based on a PC with a lamp turret, is a user-friendly tool equipped with graphics and printing options. It features high sensitivity HCL (Hollow Cathode Lamp) technology at a low cost without compromising quality or efficiency.

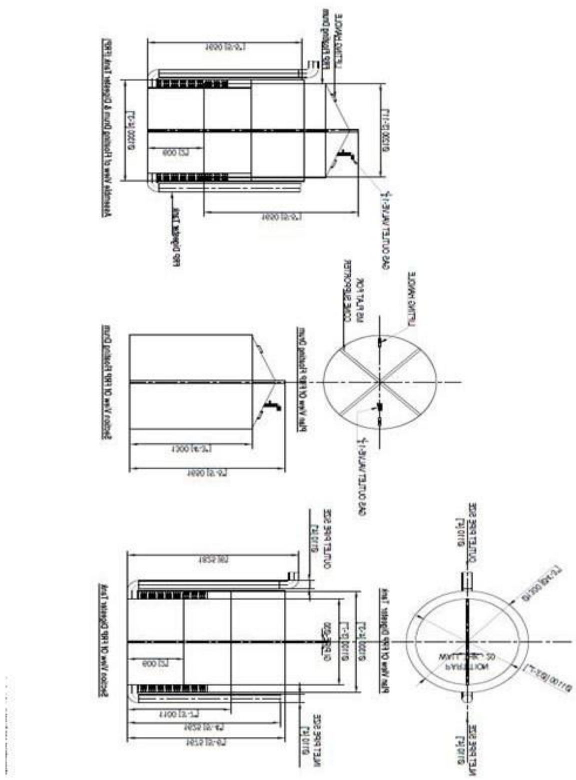
D. Chemicals Used:

Zinc oxide, an organic compound, is used in the AAS process for determining zinc levels, while Aluminum Sulphate (alum) is used in the coagulation process for separating heavy metals.

E. Methodology



F. Biogas plant plan



G. Method of Producing Biogas from Wastes:
General Procedure for Biogas Production:
Plant Capacity: 8 m³
Waste Load: 80 kg
Water-to-Waste Ratio: Equal amounts of water and waste
Conversion Factor: 10 kg of waste equals 0.5 unit
Biogas Calculation (for 8 m³ plant):

- Burning Time per Day: 8 hours
- Gas Output per Day: 5.7 kg
- Monthly Burning Time (30 days): 240 hours
- Monthly Gas Output: 78 kg
- Monthly Savings: Equivalent to 4 LPG cylinders

H. Process of Biogas from Peanut Shell:
The process begins by filling the digester with processed cow dung mixed with an equal amount of water. Over 10 to 15 days, the anaerobic bacteria grow, and biogas is produced. After this period, peanut shell waste is collected and introduced into the digester through the inlet chamber. Inside the digester, the anaerobic bacteria break down the waste, producing both biogas and manure. The generated gas is stored in the gas collector and is used for cooking purposes.

I. Process of Biogas from Sugarcane Bagasse:
In this study, the biogas production process from sugarcane bagasse begins with mixing cow dung in a 1:1 ratio to create the inoculum. The collected sugarcane bagasse is dried for one day and then ground into a fine powder. The powder is soaked in water for one day before being added to the digester for the anaerobic digestion process. After one week, the produced biogas is collected in a floating drum and utilized for cooking purposes.

IV. RESULTS AND DISCUSSION

A. Production Of Biogas From Peanut Shell
The peanut shell waste used in this study was sourced from M/S Lathi Lakshmi Modern Rice Mill, located at Puzhal, Chennai. The peanut shells had a pH value of 7.2, and the total solids content was measured at 20%. The biogas production from the peanut shells is detailed in Table 4.1.

Table 4.1-Results of biogas from peanut shell removal of heavy metals

ITEM	VALUES
pH	7.2
Total solids	20 %

B. Production of Biogas From Sugarcane Bagasse:
The sugarcane bagasse waste was sourced from a roadside shop near the biogas plant site. The pH of the sugarcane bagasse was measured at 7.4, with a total solids content of 15%. The amount of biogas produced from the sugarcane bagasse is presented in Table 4.2.

Table 4.2 Results of biogas from sugarcane bagasse removal of heavy metals

ITEM	VALUES
pH	7.4
Total solids	15 %

C. Biogas Calculation For Peanut Shell And Sugarcane Bagasse
Mass (Kg)= Volume (m3) * Density of methane gas (Kg / m3) Mass = 8 * 0.717 = 5.7 Kg
Bio culture= 20 Kg = 2 m3

Peanut shell= 30 Kg= 3 m3 Sugarcane bagasse= 30 Kg= 3 m3
Amount of biogas produced per day:
For Bio culture= 2 * 0.717= 1.4 Kg
For peanut shell= 3 * 0.717= 2.151 Kg
For Sugarcane bagasse= 3 * 0.717 = 2.151 Kg
Total amount of biogas per day for both wastes = 5.7 Kg of biogas per day. In m3, total amount of biogas produced per day for peanut shell and sugarcane bagasse wastes = (5.7 / 10) = 0.57 m3.

D. Determination Of Heavy Metals From Peanut Shell Before Coagulation Process:
After the biogas production, the byproduct from the digester was analyzed using an Atomic Absorption Spectrophotometer to determine the concentration of heavy metals (Zn). The absorbance and concentration values for the peanut shell sample are shown in Figure 6.

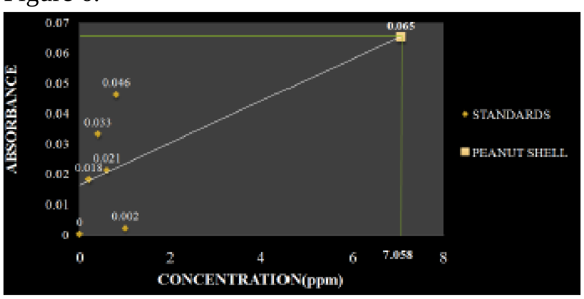


Figure 6 Concentration and absorbance for peanut shell (Zn) before coagulation

E. Determination Of Heavy Metals From Sugarcane Bagasse Before Coagulation Process:
After the biogas production, the byproduct from the digester was analyzed using an Atomic Absorption Spectrophotometer to determine the concentration of heavy metals. The absorbance and concentration values for sugarcane bagasse are presented in Figure7.

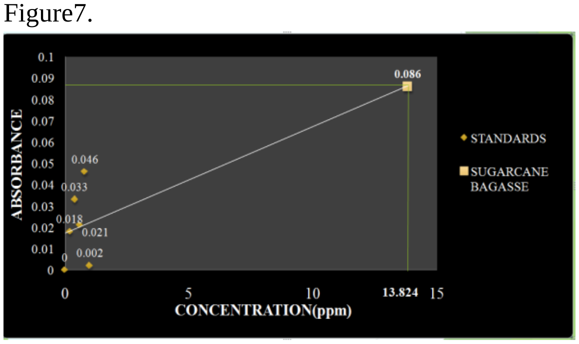


Figure 7 Concentration and absorbance for sugarcane bagasse before coagulation

F. Determination Of Heavy Metals From Peanut Shell After Coagulation Process
After the coagulation process, the treated sludge was analyzed using an Atomic Absorption Spectrophotometer to assess the reduction of heavy metals. The absorbance and concentration values for peanut shell are presented in Figure 8.

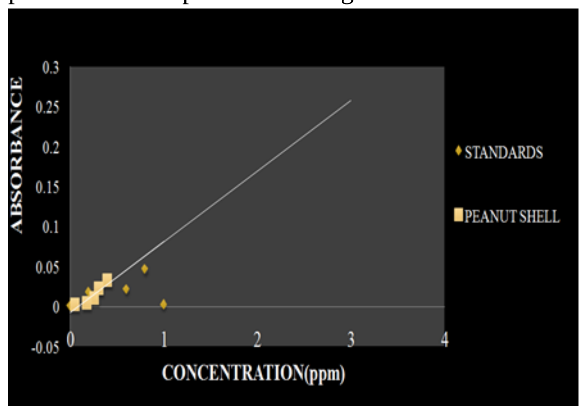


Figure 8 Concentration and absorbance for peanut shell (Zn) after coagulation process

G. Determination of Heavy Metals in Sugarcane Bagasse After the Coagulation Process:
After the coagulation process, the treated sludge is analyzed using an Atomic Absorption Spectrophotometer to measure the reduction in heavy metal content. The absorbance and concentration values for the sugarcane bagasse are provided in Figure 9 .

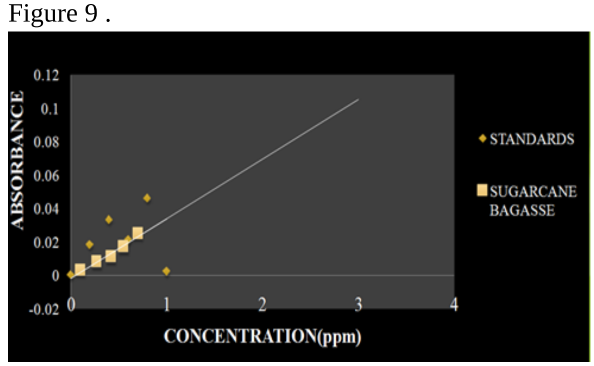


Figure 9 Concentration and absorbance for sugarcane bagasse (Zn) after coagulation process

V. SUMMARY

The current review examines the utilization of agricultural wastes, specifically peanut shells and sugarcane bagasse, for biogas production. The preceding chapters summarize the processes involved in biogas generation from these waste materials, as well as the detection and removal of toxic elements, including heavy metals, from the resulting sludge.

The research describes the overall process of the experiment, which includes biogas production and the removal of heavy metals. In the biogas production system, 30 kg each of powdered peanut shells and sugarcane bagasse, along with an equal volume of water and cow dung, are fed into a digester. An anaerobic fermentation process, facilitated by bacteria, occurs within the digester, leading to the production of 0.57 m^3 of biogas from both the peanut shell and sugarcane bagasse wastes. The non-digestible residual material, known as sludge, is collected for further analysis.

The initial concentrations of zinc in the peanut shell and sugarcane bagasse wastes were found to be 7.056 ppm and 13.824 ppm, respectively. After the elimination process, these concentrations were significantly reduced to 0.05 ppm and 0.1 ppm. This treatment ensures that the resulting liquid from the waste treatment process is rendered environmentally safe and can be repurposed as a fertilizer.

The biogas produced is then further processed to remove carbon dioxide and hydrogen sulfide gases, resulting in a methane-rich gas that closely resembles natural gas extracted from oil and gas fields.

VI. CONCLUSION

The experiment demonstrated that the biogas production process is suitable for domestic, commercial, and industrial applications, such as generating electricity, providing heat, and serving as cooking fuel. This is achieved by enhancing the biodegradability of agricultural waste. Observations from the Atomic Absorption Spectroscopy (AAS) method and the coagulation treatment process were key to achieving the project's objectives. A notable reduction in zinc concentration was observed in the final treatment process. The acclimation phase significantly improved the degradation rate during the biological process. Additionally, the simplicity of the reactor design and the advantages of the combined treatment process highlighted its potential as a superior alternative to existing methods for treating textile dye effluents.

The study further concluded that biogas production from peanut shell and sugarcane bagasse waste yielded 0.57 m^3 of gas per day using an 8 m^3 reactor (digester). The process successfully reduced zinc concentrations to permissible levels, and the remaining sludge was free of heavy metals.

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